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Assessment of

Los Angeles Department of Water and Power

Cool Schools Tree Planting Program

Prepared for:

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Urban Ecosystem Analysis
Cool Schools

Executive Summary

The University of Southern California Sustainable Cities Program conducted an Urban Ecosystem Analysis of five schools that were part of the Cool Schools Program funded by the Los Angeles Department of Water and Power. The analysis was completed using CITYgreen software developed by American Forests to quantify the value of nature's services.

The Cool Schools Program was initiated in 1998 as a citywide greening program sponsored by the Los Angeles Department of Water and Power. During the first phase of the program, over 4,200 trees were planted at 40 schools in the Los Angeles Unified School District by four contracted non-profit partners: the Hollywood Beautification Team, Los Angeles Conservation Corps, North East Trees and TreePeople. Two schools with additional sustainable design features were included to increase the total number of schools in Phase I to 42.

To evaluate the progress of the Cool Schools Program, we used a Geographic Information Systems (GIS) software analysis program called CITYgreen by AMERICAN FORESTS. CITYgreen implements a set of models that allow for the production of quantified 'environmental services' associated with trees, shrubs, grass, and permeable surfaces. The services calculated by CITYgreen are CO_2 storage and sequestration, SO_2 removal, NO_2 removal, energy savings, and runoff reduction.

Research Findings

School Canopy Cover: The sample schools sites had an average tree canopy cover before project implementation of 9%. Following project implementation the percent cover increased to 12%, with 20% cover expected in 10 years.

Stormwater Runoff Reduction: Prior to project implementation, tree cover and permeable surfaces at sample schools reduced stormwater runoff by an average of 378 cubic feet per acre. The tree planting and expanded permeable surfaces increased the avoided runoff to 432 cubic feet (14% improvement), with 745 cubic feet (97% improvement) predicted in ten years.

Carbon: Increased tree cover reduces atmospheric carbon by transforming it to wood and by shading structures so that less fossil fuel is burned to power air conditioning. The sample schools stored approximately 2-5 tons of carbon per acre before planting, with a sequestration rate averaging 0.04 tons/year-acre. The rate of storage increased to 0.06 tons/year-acre following tree planting. This reduces the overall pollution produced by the city, and contributes to the reduction of greenhouse gases in the atmosphere.

Air Pollutant Removal: The sample school sites averaged the removal of 9 pounds of air pollutants per acre prior to tree planting, which was increased to 11 lb/acre with new trees, and is expected to double again in 10 years. This will result in cleaner air on school campuses, with all forty schools providing over $10,000/year in pollution reduction services.

Energy Savings: Direct energy savings through shading of buildings and air-conditioners was calculated for five sample schools. In unimproved conditions, trees provide an average 12% savings in energy costs. The Cool Schools plantings increased these savings by 2% immediately, and should result in 5% additional savings in 10 years. The benefit of these reductions in power usage should be most significant during the hottest months of the summer when statewide power demand is highest.

In addition to model results, it was noted that tree care on school campuses must be better than current practices if the benefits of the Cools Schools program are to be realized.

CITYgreen Analysis

Cool Schools Assessment

The Cool Schools program aims to achieve the following benefits:

- Reduce air conditioner use and electricity costs for schools,
- Lessen air pollution from the generation of electricity,
- Absorb carbon dioxide to help lower the rate of global warming, and
- Reduce stormwater runoff and schools' dependence on pumped water for irrigation.

In addition, the program expects associated benefits such as increased property values around schools, improved scenic values, and improved human health and well-being.

The CITYgreen urban ecosystem analysis program developed by American Forests is ideal to assess the success of Cool Schools and predict its performance into the future. CITYgreen is an extension to ArcView GIS that has been developed specifically to determine the benefits of urban forests. Using georeferenced data on trees, structures, permeable and impermeable surfaces, the program calculates:

- Carbon storage (tons)
- Carbon sequestration (tons/year)
- Energy savings (%)
- Ozone removal (lbs)
- SO_2 removal (lbs)
- NO_2 removal (lbs)
- PM 10 removal (lbs)
- CO removal (lbs)
- Runoff reduction (%)
- Peak runoff flow reduction (%)
- Total avoided runoff storage (cubic ft)

These values can be converted into dollar cost savings, and different scenarios (e.g., before and after tree planting) can be compared to calculate the total economic benefit of a project. The values calculated correspond well with the stated objectives of Cool Schools, making the program a logical choice for program assessment.

CITYgreen Methodology

The partner tree groups decided that among the 40 schools planted as part of Phase I of the Cool Schools program, five would be analyzed by USC. The schools were chosen so that one school planted by each tree group would be included, and one additional school with further sustainable design features such as cisterns would be analyzed. The schools were spread geographically across the City of Los Angeles. The schools included in the analysis were:

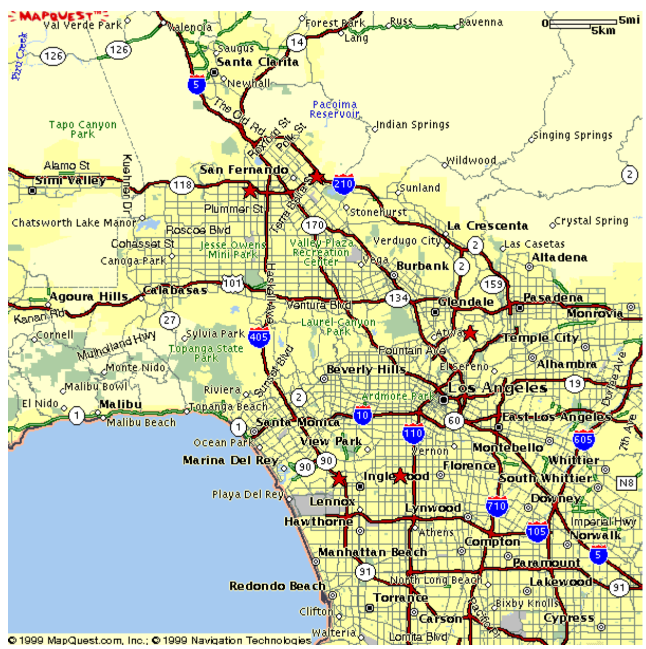
Buchanan Elementary School (North East Trees)

Open Charter Elementary School (TreePeople)

Tulsa Elementary School (Hollywood Beautification Team)

Raymond Elementary School (Los Angeles Conservation Corps)

Broadous Elementary School (Sustainable School; TreePeople and LACC)



Location of Cools Schools Included in CITYgreen Assessment.

Planting was completed on all schools except Broadous, where CITYgreen was used to evaluate the proposed plan. Results from Broadous are not included in averages because the additional sustainable design distinguish it from the other schools.

To complete the CITYgreen analysis, one must document the geographic distribution of site features (buildings, trees, grassy and other permeable surfaces, and impermeable surfaces). These can be obtained from an aerial photograph or architectural drawings. For this analysis, we used architectural drawings for the base map. Once digitized into the CITYgreen program, a field survey was made of each site to verify the accuracy of the drawings and to collect additional information about trees and buildings. The species, trunk diameter at breast height (DBH), height, health, and canopy size of each tree was recorded. Because measurement of canopy size in the field is estimated, we rounded canopy diameter up to the nearest five feet for the analysis. We recorded the roof color, number of floors, and location of windows and air conditioners for each building.

While CITYgreen provides a database of several hundred tree species, not all species found at Cool School sites were included in the database. For these additional species, we added records to the species database based on the characteristics of the trees (crown shape, leaf density, growth form, growth rate), based on our observations, published literature, and taxonomic relationships. We additionally estimated a parameter that relates tree trunk growth to crown growth over time based on taxonomic relationships.

To calculate the amount of energy saved from tree shading, CITYgreen requires specific knowledge of cooling costs. Lacking these data for school sites, we instead used CITYgreen to calculate energy savings as a percentage. While this does not provide total kilowatt hours, it does provide the basis for evaluating the relative value of shading to energy consumption.

Stormwater analysis is based on the TR-55 model created by the Natural Resource Conservation Service. The model provides simplified procedures to calculate storm runoff volume, peak rate of discharge, and storage volumes required for floodwater reservoirs and is applicable to small urban watersheds (Natural Resources Conservation Service 1986). We analyzed stormwater reduction provided by trees and permeable surfaces during a 2-inch, 24-hour storm event.

For each of the schools, the landscape environmental benefits were calculated for four time periods: 1) before the project was implemented, 2) after implementation as observed in field work, 3) projected 10 years into the future, and 4) projected 20 years into the future. These projections assume that the plantings are well maintained and that trees are allowed to grow to their full potential. The design for Broadous Elementary School was not modeled for future growth because it depends on the size of trees that are planted. While assumptions could be made about this variable, the results would not be comparable to those for other schools.

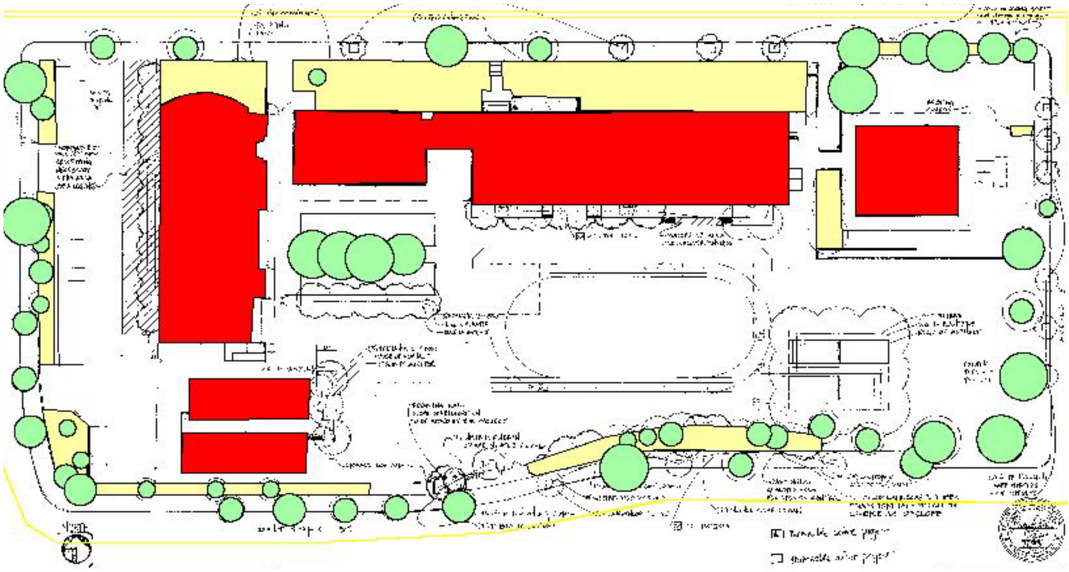
Analysis Results

All model results are reported in tables on the pages that follow. Average values are provided for the four schools for which tree planting and associated permeable surface increases were completed. The results from the more extensive planned improvements from the “sustainable” school are presented separately.

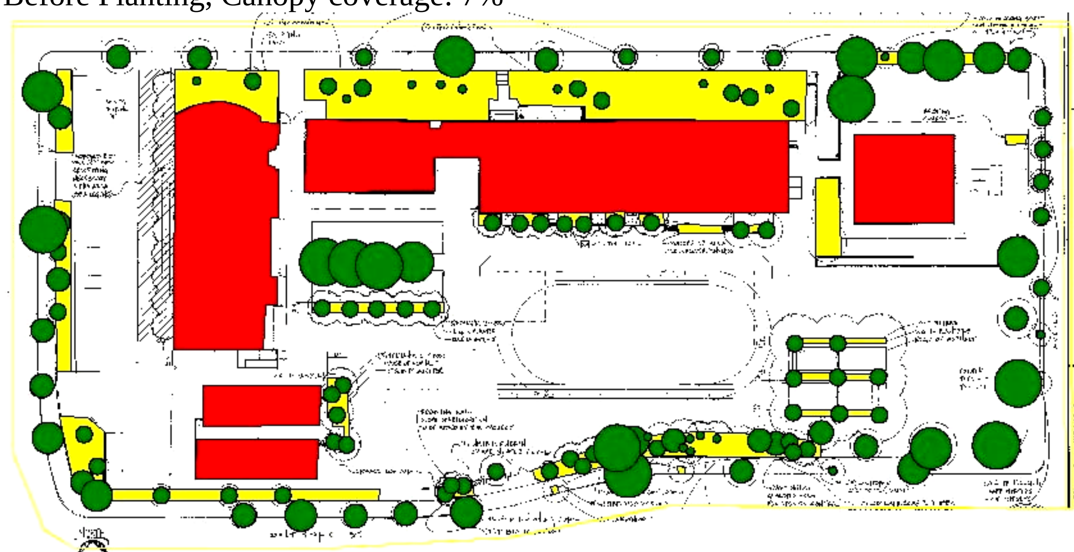
Site Morphology

The four elementary schools analyzed were on average 6 acres, ranging from 4.4 to 7.8 acres. Buildings constituted on average 11% of the school area. Prior to Cool Schools improvements, permeable surfaces (grasslands and other non-paved surfaces) only made up 7.5% of the area. Project implementation doubled permeable area to 15.5%. Extrapolation of this result means that the Cool Schools program has increased permeable surfaces by 19 acres across the forty schools of Phase I. This increase in permeable surface provides the environmental benefit of reducing stormwater runoff.

Buchanan Street Elementary School



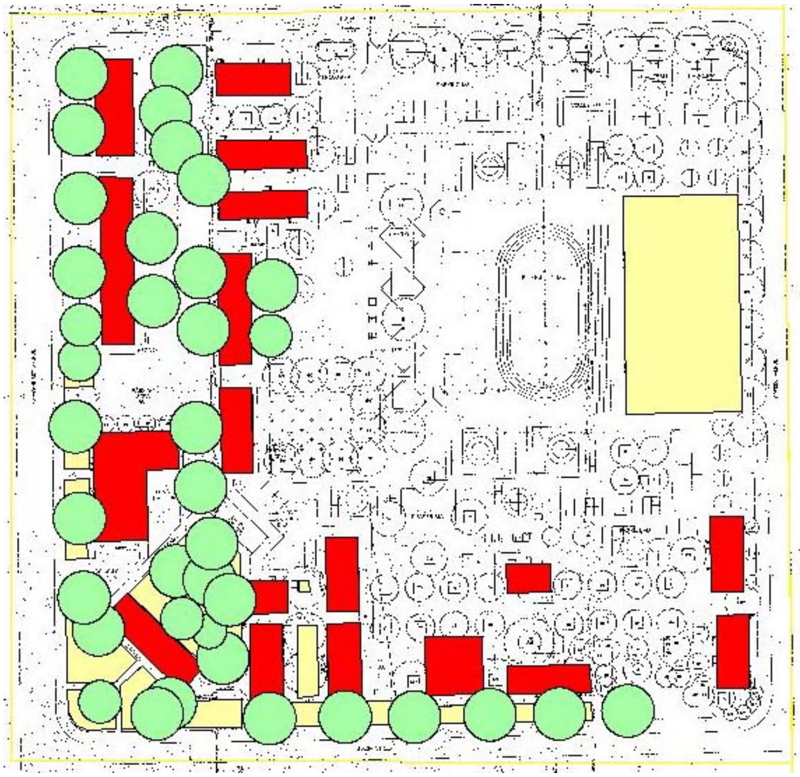
Before Planting, Canopy coverage: 7%



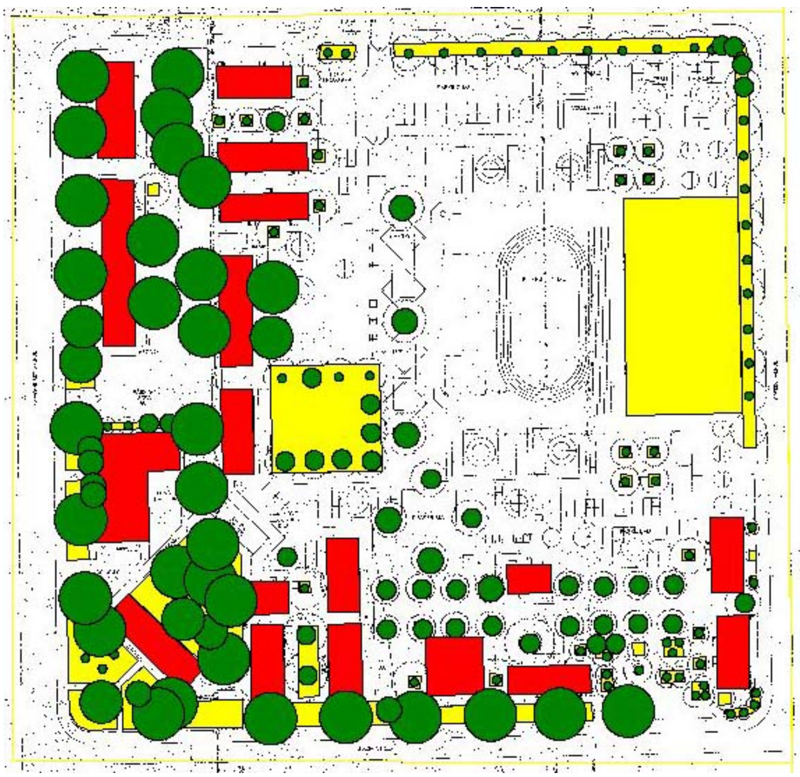
After Planting (2000), Canopy coverage: 10%

North is toward the top of the page. Trees are green, buildings are red, and grass is yellow.

Tulsa Elementary School



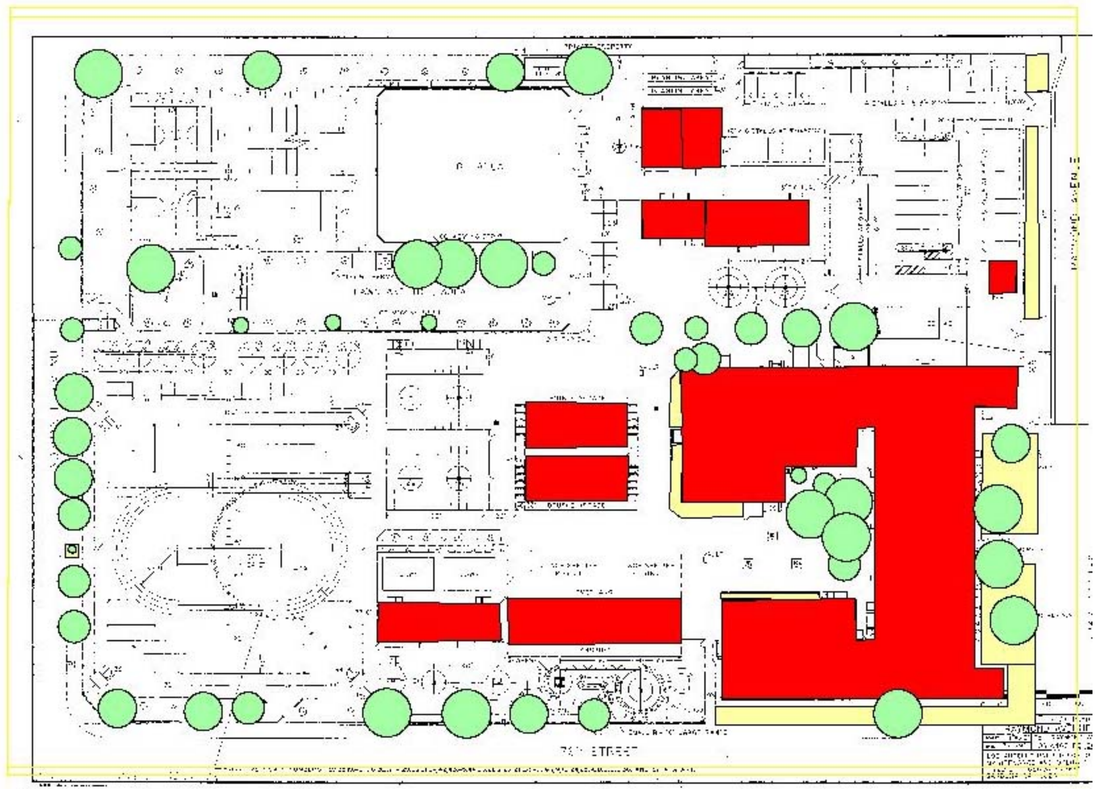
Before Planting, Canopy Coverage: 12%



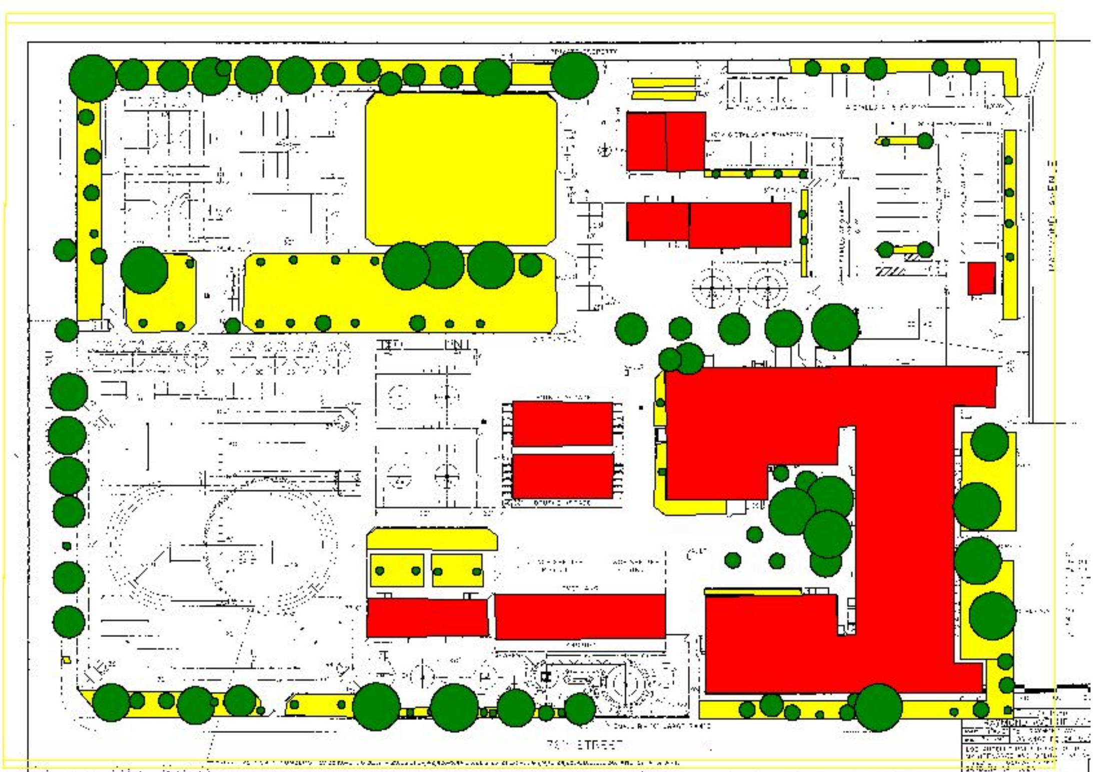
After Planting (2000), Canopy Coverage: 16%

North is toward the top of the page. Trees are green, buildings are red, and grass is yellow.

Raymond Avenue School



Before Planting, Canopy Coverage: 6%



After Planting (2000), Canopy Coverage: 8%

North is toward the top of the page. Trees are green, buildings are red, and grass is yellow.

Open Charter Elementary School

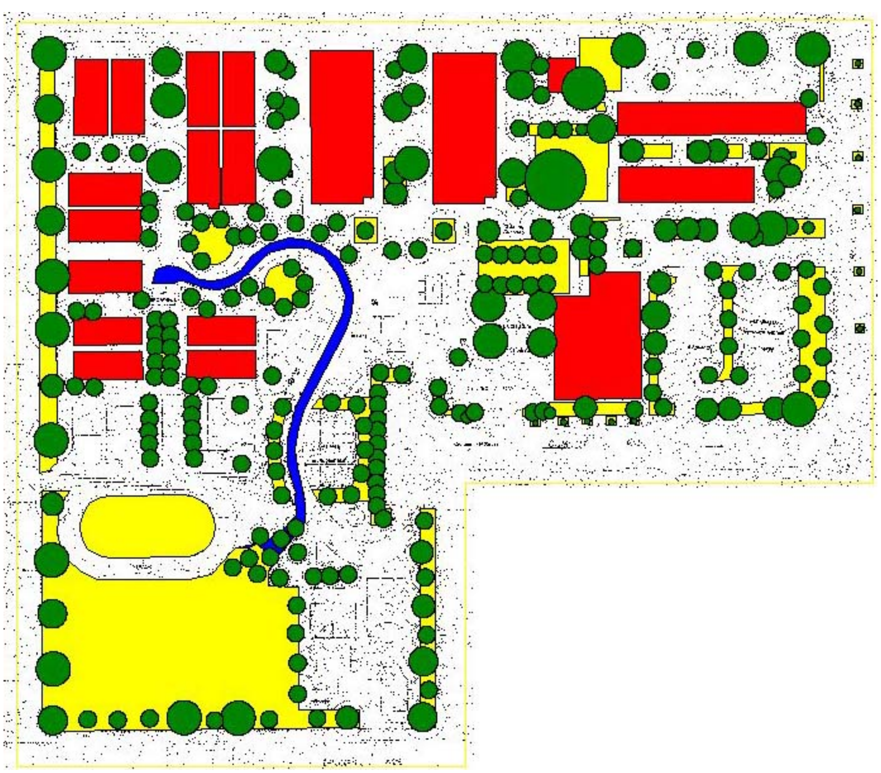
Before Planting, Canopy Coverage: 12%

After Planting (2000), Canopy Coverage: 14%

North is toward the top of the page. Trees are green, buildings are red, and grass is yellow.

Broadous Elementary School

Before Planting, Canopy Coverage: 9%



After Planting (projected), Canopy Coverage: 16%

North is toward the top of the page. Trees are green, buildings are red, and grass is yellow.

Tree canopy cover before project implementation was an average of 9% of school area. Tree planting increased this by 3%. Ten years of growth should increase cover to 20%, and 23% in twenty years. Each additional percentage of canopy cover decreases midday maximum air temperature by 0.04 to 0.2ºC (Simpson 1998), translating to 0.12-0.6ºC decreases in temperature at school sites now, and 0.44-2.2ºC decreases in ten years. Reduction in ambient temperatures also reduces the formation of photochemical smog.

We note here that the model returned divergent results for the growth models for different schools. For example, the model projected a 3% increase in coverage for Buchanan Street Elementary School for the ten years following planting, while projecting a 9% increase for Open Charter Elementary. These differences are attributed to differences in the proportion of mature trees already on the school site (which contribute proportionally more to the growth projections), the species of trees present, and the current health of the trees.

Air Quality

Prior to tree planting, existing trees on school sites removed an average total of 9 pounds of pollutants per acre each year. The economic value of this removal is approximately $22 per acre each year. For the 40 schools this value is equal to $5,280 in air pollution reduction each year. After tree planting, the average total per acre increased to 11 pounds per year ($6,576 for all 40 schools). In ten years, the amount of pollution reduction should increase to 20 pounds per acre ($11,660/year for all 40 schools), almost doubling from initial conditions.

Carbon

Almost half of tree mass is carbon and trees are an important sink of carbon globally. By sequestering carbon, trees reduce the total quantity of greenhouse gases and mitigate the effects of global warming. Prior to tree planting, trees at school sites contained 4.03 tons of carbon per acre, meaning that all forty schools would sequester at total of 967 tons of carbon. A more critical number is the rate at which trees take in or sequester carbon. Because of the age of the trees existing at schools sites, this rate increased dramatically with the planting of young, faster-growing specimens, increasing 50% from 0.04 to 0.06 tons per acre per year. After planting, the Phase I schools should sequester on average 14.4 tons of carbon yearly. This rate will increase during the next ten years and level off after twenty years. The model provided results that suggested a lower total of carbon sequestration after tree planting than before. This result is likely an artifact of the assumptions made by the model assigning biomass values to diameter classes.

Stormwater Runoff

Trees and permeable surfaces at school sites reduced stormwater runoff by 6.6% prior to tree planting. Increase in tree canopy and permeable surfaces immediately resulted in an additional 2% reduction in runoff, with projected future growth providing additional reduction to 13.7% after 10 years, doubling the runoff reduction capability. Trees provide the equivalent stormwater reduction as a detention basin with a capacity of 378 cubic feet per acre before project implementation, increasing through project implementation to 432 cubic feet per acre, and projected to 756 cubic feet per acre in ten years. If the schools in this assessment are representative, in ten years the Phase I schools will collectively reduce the need for stormwater storage by 179,000 cubic feet.

Energy Use

Energy savings from tree shading varied dramatically among tree sites. Trees must directly shade buildings (and their windows and air conditioners) to show energy savings in CITYgreen. The limit for such effects is 35 feet. The percentage savings from preexisting canopy varied from 2.2% at Buchanan Elementary to 22% at Open Charter.

Buildings and Permeable Surfaces

	Permeable Before	Permeable After	Buildings	Acres
Buchanan	0.44 (9%)	0.51 (11%)	0.73 (15%)	4.75
Tulsa	0.45 (10%)	0.69 (15%)	0.41 (9%)	4.44
Open Charter	0.53 (7%)	1.53 (20%)	0.66 (8%)	7.80
Raymond	0.27 (4%)	1.14 (16%)	0.96 (13%)	7.15
Average	***7.5%***	***15.5%***	***11.3%***	***6.0***
Broadous	0.50 (5%)	1.98 (21%)	1.25 (14%)	9.22

Tree Benefits

Tree Canopy	**Before**	**After**	**10 Year**	**20 Year**
Buchanan	7%	10%	13%	17%
Tulsa	12%	16%	26%	26%
Open Charter	12%	14%	23%	29%
Raymond	6%	8%	19%	21%
Average	***9%***	***12%***	***20%***	***23%***
Broadous	9%	16%	-	-
Carbon Storage (tons per acre)				
Buchanan	2.30	3.10	4.34	5.61
Tulsa	5.36	5.11	9.39	9.46
Open Charter	5.95	4.80	8.26	10.03
Raymond	2.53	2.34	5.78	6.47
Average	***4.03***	***3.84***	***6.94***	***7.89***
Broadous	5.03	5.29	-	-
Carbon Sequestration (tons per year per acre)				
Buchanan	0.05	0.07	0.08	0.13
Tulsa	0.06	0.07	0.21	0.22
Open Charter	0.03	0.05	0.16	0.16
Raymond	0.03	0.04	0.17	0.21
Average	***0.04***	***0.06***	***0.15***	***0.18***
Broadous	0.01	0.12	-	-
Energy Savings (% per year)				
Buchanan	2.2%	3.9%	4.1%	8.1%
Tulsa	21.5%	23.6%	26.0%	26.0%
Open Charter	22.2%	23.4%	32.1%	32.7%
Raymond	3.0%	6.2%	6.2%	6.4%
Average	***12.2%***	***14.3%***	***17.1%***	***18.3%***
Broadous	19.9%	20.1%	-	-

Stormwater Benefits

Runoff Reduction	**Before**	**After**	**10 Year**	**20 Year**
Buchanan	5.0%	6.7%	8.9%	11.5%
Tulsa	8.6%	10.9%	17.4%	17.5%
Open Charter	8.5%	9.4%	15.7%	15.8%
Raymond	4.3%	5.6%	12.9%	14.1%
Average	***6.6%***	***8.1%***	***13.7%***	***14.7%***
Broadous	6.5%	11.2%	-	-

Avoided Storage/Acre				
Buchanan	289	378	497	631
Tulsa	482	576	989	996
Open Charter	491	495	849	852
Raymond	248	278	648	687
Average	***377.5***	***431.8***	***745.8***	***791.5***
Broadous	386	574	-	-

Air Pollution Benefits

Ozone Removal (lb/acre)	Before	After	10 Year	20 Year
Buchanan	2.4	3.3	4.6	5.9
Tulsa	4.3	5.4	9.9	10.0
Open Charter	4.2	4.7	8.0	9.7
Raymond	2.1	2.7	6.7	7.4
Average	***3.3***	***4.0***	***7.3***	***8.3***
Broadous	3.2	5.6	-	-
SO_2 Removal (lb/acre)				
Buchanan	0.8	1.0	1.4	1.9
Tulsa	1.3	1.7	3.1	3.1
Open Charter	1.3	1.4	2.5	3.0
Raymond	0.7	0.8	2.1	2.3
Average	***1.0***	***1.2***	***2.3***	***2.6***
Broadous	1.0	1.7	-	-
NO_2 Removal (lb/acre)				
Buchanan	1.4	1.9	2.6	3.4
Tulsa	2.4	3.1	5.7	5.7
Open Charter	2.4	2.7	4.6	5.6
Raymond	1.2	1.6	3.8	4.3
Average	***1.9***	***2.3***	***4.2***	***4.8***
Broadous	1.8	3.2	-	-
PM10 Removal (lb/acre)				
Buchanan	2.1	2.8	4.0	5.1
Tulsa	3.7	4.7	8.6	8.6
Open Charter	3.6	4.0	6.9	8.4
Raymond	1.8	2.3	5.8	6.5
Average	***2.8***	***3.5***	***6.3***	***7.2***
Broadous	2.8	4.8	-	-
CO Removal (lb/acre)				
Buchanan	0.3	0.4	0.5	0.7
Tulsa	0.5	0.6	1.1	1.1
Open Charter	0.5	0.5	0.9	1.1
Raymond	0.2	0.3	0.8	0.9
Average	***0.4***	***0.5***	***0.8***	***1.0***
Broadous	0.4	0.6	-	-

These differences in energy savings are attributed to the orientation of the trees relative to the structures and their windows and air conditioners. However, all schools showed similar percentage increases in energy savings from tree planting, which compared to initial conditions, represented anywhere from nearly doubling to marginal benefits. The immediate benefit from shading by new trees should lower energy costs by about 2% (average 14.3% total energy savings from trees), with 5% savings after 10 years (average 17.1% total energy savings) and 6% (average 18.3% total energy savings) after 20 years. By comparison, retrofitting incandescent lighting fixtures to fluorescent would save 10-15% per year on a typical energy bill.

Other Benefits and Costs

The CITYgreen program is designed to calculate nature's services based on existing mathematical models. There are a number of benefits and costs that are not quantified by the program. For example, the health benefits of reduced pollution are not calculated. Psychological advantages for children of having a shady and green environment are clear benefits of the program that are not expressed in economic terms (Rivkin 1997). The educational opportunities provided by the planning and implementation of the program are many but difficult to quantify. The activities of tree planting and installing more permeable surfaces can be modeled in more detail, which has been completed by TreePeople's TREES program (Jones & Stokes Associates 1998). Another unquantified benefit is that of trees in parking lots reducing volatile emissions from parked vehicles (Scott, Simpson, and McPherson 1999). All parked vehicles emit pollutants from tires, gas tank, and engine. These emissions increase as the vehicle grows hotter. Cooling by shade trees reduces these emissions. Urban agriculture and food security will be another benefit of the sustainable school designs. At these schools, fruit trees are planted, which can provide food for the students and local residents when mature.

On the cost side, trees can be emitters of volatile organic compounds (VOCs) such as isoprene and monoterpene that react with nitrogen oxides to produce ozone (Benjamin and Winer 1998). Of the species planted at Cool Schools sites, those classified as having high ozone forming potential were Coast Live Oak, Brisbane Box, and Carrotwood. A second consideration in tree choice for future plantings is their allergenic potential. Some species are much worse for children's allergies than others. For example, mulberry and olive trees are particularly bad offenders and have in fact been banned by several southwestern cities for this reason (Tragow 1971; Mendoza 1996). In addition, we have made no effort to quantify the cost of installation, upkeep, and irrigation of trees. The CITYgreen program calculates benefits only; additional study would be necessary to evaluate the total costs of the program. The sustainable schools have built some of these costs into the design through the use of cisterns.

In addition to costs and benefits not evaluated by the CITYgreen program, some questions arise concerning the results of the program itself. For example, the model for future tree growth produces some unexpected results. It seems that because tree growth is predicted based on measured tree size, the predicted future growth of trees that are large when first surveyed is much greater than for smaller trees.

Tree Care

These benefits depend on trees being well cared for and allowed to grow to their full potential. To ensure that all of the benefits of new trees are realized, close controls must be established to ensure that tree trimming follows the standards set by the International Society of Arboriculture. For example, at Raymond Elementary, 18 of the 46 trees (40%) existing before project implementation were rated in "poor" or "dying" condition. At Buchanan Elementary, 26 of 53 pre-existing trees (50%) were in poor or dying condition.

Conclusions

According to the CITYgreen model results, Phase I of the Cool Schools program achieved its goals of reducing energy consumption, reducing air pollution, absorbing carbon dioxide, and reducing stormwater runoff. The model results illustrate the importance of project design to each of the objectives: energy reduction depends on planting trees close to structures, stormwater reduction requires increases in permeable surfaces.

Even after project implementation, school sites are covered by an average of 73% pavement and 11% buildings. There is room for improvement still in adding permeable surfaces.

The production of VOCs by trees should be a factor considered in choosing tree species for planting. This concern should not dominate, but be weighed against the benefits of high emitting species.

The Cool Schools Program provides benefits that are enjoyed by the students and staff of participating schools, in addition to the members of the local community. As noted by McPherson (1997), the program also provides ancillary benefits to other public agencies through its air quality improvements and stormwater reduction. Such agencies as the Los Angeles Regional Water Quality Control Board or the South Coast Air Management District therefore may be potential supporters of future phases of the program.

Recommendations

As suggested by the conclusions above, future phases of the Cool Schools Program could be improved through implementation of the following recommendations.

Increase permeable surfaces in planting designs. As shown by the higher stormwater benefits of the Broadous design, permeable surfaces are central to stormwater reduction. One way to do this would be to cut out more pavement surrounding trees, removing strips of asphalt rather than smaller wells.

Locate trees closer to structures for greater cooling, especially on the south and west sides. While plantings around the perimeter of schools are esthetically pleasing and contribute to overall cooling, more direct benefits are gained from plantings closer to structures.

Plant tree species that have low ozone-forming potentials. Benjamin and Winer (1998) provide an extensive list of species and their VOC emission rates.

Prioritize planting at schools with low tree canopy coverage. Some schools already enjoy significant cooling effects from trees. Larger percentage improvement can be made at schools with less tree canopy.

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