

ENVIRONMENTAL HEALTH RESEARCH FOUNDATION

A NONPROFIT RESEARCH FOUNDATION SPECIALIZING IN HEALTH AND ENVIRONMENTAL SCIENCE

Benefits of Green Space – Recent Research **April 25, 2011**

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Table of Contents

EXECUTIVE SUMMARY.....3

Detailed Report

INTRODUCTION.....5

- **Key Findings5**
- **Study Methodology6**

ENVIRONMENTAL BENEFITS

- **Erosion Control and Run-off Prevention.....7**
- **Water Purification.....10**
- **Air Purification.....11**
- **Temperature Modification/Energy and Cost Savings.....13**
- **Oxygen Generation.....16**
- **Carbon Sequestration.....18**

HUMAN HEALTH BENEFITS

- **Recreation/Increased Physical Activity/Reduced Obesity.....21**
- **Healthcare/Reduced Stress.....24**

CONCLUSIONS.....26

About EHRF and the Author.....27

EHRF Policy Statement.....28

Executive Summary

The studies in this report focus on the benefits of “turfgrass” or “turf”. In everyday parlance, these terms are typically associated with the broader notion of “green space,” which typically connotes such turf-related surfaces as residential lawns, commercial or institutional turf surfaces and public facilities such as parks and playing fields. For purposes of this Report, all of these terms have been consolidated under the umbrella notion of “green space” but specifically link back to the benefits of turfgrass or turf.

Environmental Benefits

Healthy, properly maintained green space provides significant benefits to the environment in terms of water and air quality:

- **Erosion Control and Run-Off Prevention** - One of most significant functions of green space is to stabilize and protect the soil against water and wind erosion. This is particularly important in preventing nutrient run-off. Healthy, dense green space is three times more effective than weedy, unhealthy green space in preventing nitrogen run-off.
- **Water Purification** - Not only do green spaces absorb rainfall, but they also trap and remove pollutants, which are broken down by the root system and soil microbes.
- **Air Purification** - Green spaces purify and trap more than 12 million tons of dust, soil and other particulate matter. This is particularly important in urban areas due to the high incidence of asthma and other breathing disorders.
- **Temperature Modification/Energy and Cost saving** - Green spaces around homes can reduce air conditioning costs, potentially saving \$6.3 billions (U.S., 2005). Modeling studies (Manchester, U.K.) indicate that, despite the projected effects of climate change, addition of 10% green space in high density urban areas will allow cities to maintain current summer temperature levels (and thus current summer utility costs) for the next 70 years (up to 2080).
- **Oxygen Generation** - A 50 by 50 foot green space releases enough oxygen for a family of four on a daily basis, an average 18-hole golf course release enough oxygen for 4000 to 7000 people and green space along the U.S. interstate highway system releases enough oxygen for 22 million people.
- **Carbon sequestration** - While the evidence clearly suggests that properly maintained green space is a net benefit in the effort to sequester carbon from the atmosphere, further study is required to determine precisely how significant the net carbon sequestration benefit is to the environment vis-à-vis such offsetting factors as fuel expense in maintaining green space, fertilizer and pesticide use, energy for water costs, etc.

Health Benefits

Human health also benefits from properly maintained green space:

- **Recreation** - Green spaces provide ideal surfaces for a variety of recreational and sports activity and high use activities including parks and playgrounds.

- **Increased Physical Activity/Reducing Obesity** - Access to green space is an important predictor of increased physical activity (“active living”) and reduced risk of obesity. A recent study of over 40 million people in England shows that health disparities between high income and low income people are much narrower in areas with ample green space, possibly because it allows residents to become more physically active and reduce stress.
- **Healthcare/Stress Reduction** – Just being in, or viewing, green space for a few minutes reduces stress. This has been demonstrated by medical studies with hospital patients and the general public.

These data refute the notion that green space is merely ornamental or aesthetic and indicates substantial environmental and human health benefits from healthy, properly maintained green space.

Methodology

Some notes on the research methodology used are also appropriate:

- **Objective basis for sources** - The report cites primarily peer-reviewed, published studies as well as government and academic reports to document the objective basis for benefits of a healthy, properly maintained green space.
- **Most current research** - The Report summarizes the most current studies and findings (since 2000) to ensure reliance on the most up to date research. These studies in many cases reflect and build on the long history of research on the benefits of green space.
- **Standard research criteria used** – For each section of the Report, e.g. Erosion. Control, the findings and the reports themselves have been reviewed using six standard research criteria to ensure:
 - Impartial, objective and balanced review of the data
 - Adequately comprehensive review of the available data
 - Properly used “weight of evidence” to evaluate the data
 - The findings are supported by the data in the studies cited
 - The studies cited have been subjected to independent scientific peer review
 - Studies since 2000

Benefits of Green Space – Recent Research

DETAILED REPORT

INTRODUCTION

The studies in this report focus on the benefits of “turfgrass” or “turf”. In everyday parlance, these terms are typically associated with the broader notion of “green space,” which typically connotes such turf-related surfaces as residential lawns, commercial or institutional turf surfaces and public facilities such as parks and playing fields. For purposes of this Report, all of these terms have been consolidated under the umbrella notion of “green space” but specifically link back to the benefits of turfgrass or turf.

This report summarizes the latest research (since 2000) on the benefits of green space. This was done to ensure reliance on the most up to date research. These studies in many cases reflect and build on the long history of research on the benefits of green space.¹ The research was primarily conducted by a search of the published scientific literature including the available on-line (Internet) reports and publications from leading academic and government agencies to ensure the objective basis for benefits of a healthy, properly maintained green space.

Each section contains the key findings on the benefits plus analysis and commentary and key citations supporting the findings. The benefits of green space are categorized into two broad areas, environmental and health. Benefits within each category will be considered in turn.

Key Findings

- Healthy, properly maintained green space provides substantial benefits to the environment in terms of Erosion control/water purification, Air purification, Temperature modification/energy and cost saving, Oxygen generation and Carbon sequestration.
- Green space provides substantial benefits to human health in terms of Recreation/Increased physical activity/reduced risk of obesity and Healthcare/Stress reduction.
- This data rebuts the notion that the need for healthy, properly maintained green space is only ornamental or aesthetic.

¹ See for instance (1994) Beard, J.B. and Green, R.L. The Role of Turfgrasses in Environmental Protection and Their Benefits to Humans. *Journal of Environmental Quality*. 23: 452-460 and reference therein.

Study Methodology

The findings in this report reflect and employ long-standing and accepted methods of scientific review. Specifically, the data for each section of the Report, e.g. Erosion control, were compiled and reviewed to ensure that they met the following criteria:

- Impartial, objective and balanced review of data.
- An adequately comprehensive review of data.
- Proper use of “weight of evidence” in evaluating data.
- Clear linkage between the data cited and the conclusions made in the study.
- Use of independent scientific peer review to assure study quality
- Studies since 2000.

ENVIRONMENTAL BENEFITS

Erosion Control and Run-off Prevention

Findings

- 1. One of the most significant functions of green space is to stabilize and protect the soil against water and wind erosion.**
- 2. The New York City sewage treatment system could save billions in operating costs over time if more rainwater was absorbed naturally through the City's 52,236 acres of yards as most of the 27 billion gallons of water flow is clean rainwater.**
- 3. Healthy, dense green space is three times more effective than weedy, unhealthy green space in preventing nitrogen run-off.**
- 4. When compared to a non-green space areas (like a garden or agricultural field), green space areas can reduce runoff-induced soil erosion by up to 600 times.**
- 5. The average suburban green space lot, which is about 10,000 square feet, can absorb more than 6,000 gallons of rainwater without noticeable runoff.**

Analysis and Commentary

One of the most significant functions of green spaces, whether around homes in rural, suburban or urban locations, or in parks or playgrounds, is to stabilize and protect the soil against water and wind erosion. For this reason, green space areas play an important role in preserving and protecting soil and water resources.

As noted on the University of Minnesota Sustainable Urban Landscape Information Series website²:

As an ever increasing proportion of our society resides in urban and suburban areas, there is a corresponding increase in the amount of paved and other impervious surfaces. Consequently, large amounts of poor quality storm water

² (2006) University of Minnesota. Sustainable Urban landscape Information Series. Environmental Benefits of a Health, Sustainable Lawn. Retrieved from: <http://www.sustland.umn.edu/maint/benefits.htm>

runoff are quickly channeled to storm sewer systems that dump directly into nearby lakes, streams and rivers. This can significantly contribute to decreased water quality in the receiving water bodies through sedimentation and pollution. Our lawn grasses provide one of the most effective groundcovers available to prevent erosion and increase water infiltration into the soil.

Key Citations

- Twenty-seven billion gallons of water flow through New York's sewage system every year, but most of it is clean rainwater. If more were absorbed naturally through the City's 52,236 acres of yards, the 120-year-old water-treatment system could save billions in operating costs over time.

(2008) Solecki, W., Patrick, L., Grady, K., Cox, J., and Ervin, K. Urban Forests in Our Midst: Environmental Benefits of Open Spaces in City Backyards. CUNY Institute for Sustainable Cities, Hunter College, New York, NY, December 18, 2008, prepared for Landmark West!, New York, NY, www.landmarkwest.org, E. Mason project coordinator.

- A lawn is 6 times more effective than a wheat field and 4 times better than a hayfield at absorbing rainfall.

(2010) Grass Facts. Department of Agriculture. State of Michigan. Retrieved from: http://www.michigan.gov/mda/0,%201607,7-125-1570_2476_2481-9345--,00.html

- A reduction in surface runoff water is a benefit of turfgrass and is a key component to protecting surface water quality. A turf area can absorb far more than one inch of rain water without runoff, assuming it's not coming down too fast. This is because a turf area can reduce runoff to virtually nothing. When compared to a non-turf area (like a garden or agricultural field), grass areas can reduce runoff-induced soil erosion by up to 600 times.

(2005) Whiting, D., R. Tolan, B. Mecham, and M. Bauer. Water-wise gardening: creating practical turf areas. Colorado State University Cooperative Extension. Retrieved from: www.cmg.colostate.edu/gardennotes/411.pdf

- When soil is planted to turf, more water infiltrates and filters through the soil-turfgrass ecosystem, enhancing groundwater recharge, rather than increasing surface runoff.

(2002) UCRTRAC Newsletter. Better Turf thru Agronomics. University of California, Riverside Turfgrass Research Program. Retrieved from: <http://ucrturf.ucr.edu/>

- The average suburban lot of turf grass, which is about 10,000 square feet, can absorb more than 6,000 gallons of rainwater without noticeable runoff.

(2000) Hoffman, H., Dozier, M. Use of Grass Buffer Strips in Reducing Non-point Source Herbicide Runoff on the Texas Blackland Prairie. Texas Agricultural Experiment Station and Texas Agricultural Extension Service. Texas A&M University System.

- Green spaces reduce runoff during wet weather; this is crucial for preventing combined sewage overflows (CSOs). CSOs contain not only stormwater but also untreated human and industrial waste, toxic materials, and debris. They are a major water pollution concern for the approximately 772 cities in the U.S. that have combined sewer systems.

(2010) National Pollutant Discharge Elimination System. Combined Sewer Overflows. United States Environmental Protection Agency. Retrieved from http://cfpub.epa.gov/npdes/home.cfm?program_id=5

- Weedy, unhealthy lawns had 3 times more nitrogen runoff than a healthy, dense turf.

(2004) Easton, Z. Nutrient and pesticide loss in runoff and leachate from turfgrass. M.S. Thesis. Cornell University;

(2006) Easton, Z., Landscape impact on suburban runoff: determining nutrient loading rates based on land use. Ph.D. Thesis Cornell University; cited in

(2011) Hochmuth, G., Neill, Sartain, Unruh, J.B., Martinez, Trenholm and Cisar, J. Urban Water Quality and Fertilizer Ordinances: Avoiding Unintended Consequences: A Review of the Scientific Literature. University of Florida IFAS Extension, Report SL 283, Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, original publication date March 2009, revised January 2011. <http://edis.ifas.ufl.edu/ss496>

Water Purification

Findings

- 1. Not only do green spaces absorb rainfall, but they also trap and remove pollutants, which are broken down by the root system and soil microbes.**

Analysis and Commentary

Green spaces play an important role in preserving and protecting water resources by trapping and removing pollutants in stormwater runoff. Trapped pollutants are broken down by the root system and soil microbes.

Key Citations

- Turfgrasses help purify water entering underground aquifers by its root mass and soil microbes acting as a filter to capture and breakdown many types of pollutants.

(2010) Grass Facts. Department of Agriculture. State of Michigan. Retrieved from: http://www.michigan.gov/mda/0,%201607,7-125-1570_2476_2481-9345--,00.html

- Research over the last ten years has demonstrated that storm water runoff from a healthy, relatively dense lawn rarely occurs, even on modest slopes. In fact, in all but very intense rainfall occurrences, stormwater runoff from a healthy, relatively dense lawn is at or near zero. In addition, the dense, fibrous network of roots helps to trap and remove nutrients and other pollutants from water moving down through the soil. This filtering effect can actually improve water quality as it moves through the turfgrass root zone.

(2006) University of Minnesota. Sustainable Urban landscape Information Series. Environmental Benefits of a Health, Sustainable Lawn. Retrieved from: <http://www.sustland.umn.edu/maint/benefits.htm>

- The turfgrass system can efficiently reduce groundwater and surface water contamination from fertilizers and pesticides applied by capturing, retaining and using them. Turf also protects water sources when excessive applications are inadvertently applied. Fertilizers or pesticides that are applied to bare soil are more likely to contaminate water sources than those applied to turf.

(2003) Streich, A., Rodie, S. and Gaussion, R. Turf in the Landscape. University of Nebraska – Lincoln Extension, Institute of Agriculture and Natural Resources. Retrieved from: <http://digitalcommons.unl.edu/extensionhist/1720/>

Air Purification

Findings

- 1. Well maintained green space purifies and traps more than 12 million tons of dust, soil and other particulate matter annually, protecting human health and the environment.**
- 2. Maintenance of green space in urban areas is especially important for air purification, because urban areas contain the most particulate matter, due to abundance of motorized vehicles, and because of the high incidence of asthma and other breathing disorders in inner city urban areas.**

Analysis and Commentary

Air purification includes not only removal of dust, soil and particulate matter, but also removal of important atmospheric pollutants. As the State of Michigan Department of Agriculture reported, “well maintained turf and landscaping purifies and traps more than 12 million tons of dust, soil and other particulate matter annually.”³ Dust particles are known to carry harmful bacteria and fungi.⁴ Particulate matter less than ten microns in diameter have been associated with serious human health effects, including asthma, cardiovascular disease⁵ and other respiratory illnesses, as well as environmental damage.⁶ Clearly, removal of dust, soil and particulate matter by green spaces and landscaping protects human health and the environment.

Urban areas contain the most particulate matter, due to an abundance of motorized vehicles.⁷ Moreover, turfgrass removes air pollutants such as hydrogen fluoride⁸, ozone, peroxyacetyl nitrate⁹ and sulfur dioxide,⁴ which are well known or potential sources of respiration irritation.¹⁰ Given the high incidence of asthma and other breathing disorders

³ (2005) Grass Facts. Department of Agriculture, State of Michigan. Retrieved from: http://www.michigan.gov/mda/0,1607,7-125-1570_2476_2481-9345--,00.html

⁴ (2001) Arizona State University College of Liberal Arts and Science. Ill winds carry toxic dust. ScienceDaily. June 6, 2001. Retrieved from: <http://www.sciencedaily.com/releases/2001/06/010605072529.htm>.

⁵ Brooks, RD. Cardiovascular effects of air pollution. 2008. Clinical Science 115: 175-87.

⁶ U.S. Environmental Protection Agency, Particulate Matter: Health and Environment. <http://www.epa.gov/pm/health.html>

⁷ Tire wear and diesel engine exhaust are thought to be major sources of particulate matter, especially particulate matter less than ten microns in diameter, the particulate matter of most concern for health effects. See footnote 3 for more information.

⁸ <http://www.atsdr.cdc.gov/mhmi/mmg11.html#bookmark02>

⁹ <http://het.sagepub.com/content/17/4/212.abstract>

¹⁰ Ozone and sulfur dioxide are known respiratory irritants (<http://www.greenfacts.org/glossary/pqrs/respiratory-irritant.htm>); these respiratory irritants are also damaging to trees (www.na.fs.fed.us/spfo/pubs/misc/tree_care/aib372-e.htm).

in inner city urban areas¹¹, this means that maintenance of green spaces in urban areas is especially important for air purification.

Key Citations

- Well maintained turf and landscaping purifies containments and traps more than 12 million tons of dust and dirt released annually into the U.S. atmosphere.

(2010) Grass Facts. Department of Agriculture, State of Michigan.
http://www.michigan.gov/mda/0,1607,7-125-1570_2476_2481-9345--,00.html

- Turf removes atmospheric pollutants such as ozone, hydrogen fluoride, and peroxyacetyl nitrate from the air.

(1999) Texas Turfgrass Research. Texas Turfgrass Consolidated Progress Reports.
<http://aggieturf.tamu.edu/aggieturf2/publications/>

- Dust particles carry living bacteria, fungi, and possibly even viruses; some of these microorganism are known to cause disease. Vegetated, grassy areas cause the wind to slow down and deposit its dusty load, removing these airborne contaminants.

(2001) Arizona State University College of Liberal Arts and Science. Ill winds carry toxic dust. ScienceDaily. June 6, 2001. Retrieved from
<http://www.sciencedaily.com/releases/2001/06/010605072529.htm>.

- Urban areas contain the most particulate matter, due to an abundance of motorized vehicles. Well maintained turfgrass shields the soil and traps the particles which prevent harmful pollutants such as sulfur dioxide, ozone, hydrogen fluoride, and peroxyacetyl nitrate from being carried into the atmosphere.

(2006) Almeida, S. M., Farinha, M. M, Ventura, M. G., Pio, C. A., & Freitas, M. C. Measuring air particulate matter in large urban areas for health effect assessment. *Water, Air & Soil Pollution*, vol .179, pp. 43-55.
<http://www.springerlink.com/content/8rkm7j1175343vx0/>

¹¹ (2002) K.M. Mortimer, L.M. Neas, D.W. Dockery, S. Redline, I.B. Tager. The effect of air pollution on inner-city children with asthma. *Eur. Respir. J.* 19: 699-705. retrieved from:
<http://www.ersj.org.uk/cgi/content/abstract/19/4/699>

Temperature Modification/Energy and Cost Savings

Findings

- 1. Green spaces not only can moderate temperature increases in suburban areas but also is becoming increasingly recognized as important in urban areas, not only now but in planning for the future.**
- 2. Trees, shrubs and lawn areas around homes can reduce air temperatures from 7° to 14° F. through the effects of shading and the cooling effect of the transpiration and evaporation of water through plant leaves. This can directly result in curbing summer air conditioning costs.**
- 3. One estimate suggests that strategic planting of lawns and other landscape plants could reduce total U.S. air conditioning energy requirements by 25 percent, potentially saving 64.5 billion kilowatt hours of energy (approximately 30 million tons of coal) and \$6.3 billion.**
- 4. Manhattan is on average seven degrees hotter than surrounding suburban areas. The heat-island effect, as its known, could be reduced during the summer if enough paved yards were replaced with green spaces.**
- 5. The use of urban green space offers significant potential in moderating the increase in summer temperatures expected with climate change. Modeling data (Manchester, U.K.) indicate that adding 10 per cent green space in high-density residential areas and town centers kept maximum surface temperatures at or below 1961–1990 baseline levels up to the 2080s. Conversely, if green space in high-density residential areas and town centers is reduced by 10 per cent, surface temperatures will be 7°C [12.6°F] or 8.2°C [14.8°F] warmer by the 2080s. These results indicate that, despite the projected effects of climate change, addition of 10% green space in high density urban areas will allow cities to maintain current summer temperature levels (and thus current summer utility costs) for the next 70 years.**

Analysis and Commentary

As noted by Prof. Watschke (1990)¹²:

All plants play an important role in controlling climate. Turfgrasses are among the best exterior solar radiation control groundcovers because of their capacity to efficiently intercept solar radiation.

¹² (1990) Watschke, T.L. (Professor, Pennsylvania State University). The environmental benefits of turfgrass and their impact on the greenhouse effect. *Golf Course Management*, February 1990, 150-154, and references therein.

As a result, when the sidewalk or street is well over 100 °F, the temperature of the lawn areas will remain around 75 °F.

Green spaces not only can moderate temperature increases in suburban areas but also are becoming increasingly recognized as important in urban areas, not only now but in planning for the future.

Key Citations

- Trees, shrubs and lawn areas around homes can reduce air temperatures from 7° to 14° F. through the effects of shading and the cooling effect of the transpiration and evaporation of water through plant leaves. This can directly result in curbing summer air conditioning costs. One estimate suggests that strategic planting of lawns and other landscape plants could reduce total U.S. air conditioning energy requirements by 25 percent.

(2006) University of Minnesota. Sustainable Urban landscape Information Series. Environmental Benefits of a Health, Sustainable Lawn, and references therein. Retrieved from: <http://www.sustland.umn.edu/maint/benefits.htm>

- The most recent US government estimates, based on a survey of over 100,000 households, is that total energy consumption on air conditioning in 2005 - the most recent year that data is available - was 258 billion kilowatt-hours (kWh) and cost \$25.3 billion. Consequently, a 25% reduction in total U.S. air conditioning energy requirements would save 64.5 billion kWh and \$6.3 billion.

(2005) United States Department of Energy. U.S. Energy Information Administration. 2005 Residential energy Consumption Survey—Detailed Tables. Retrieved from: http://www.eia.doe.gov/emeu/recs/recs2005/c&e/detailed_tables2005c&e.html

- The front lawns of 8 average houses have the same cooling effect as 24 (3-4 ton capacity) home central air conditioning units. [This works out to 8.75 tons of air conditioning capacity per front yard.]

(2010) Grass Facts. Department of Agriculture. State of Michigan. Retrieved from: http://www.michigan.gov/mda/0,%201607,7-125-1570_2476_2481-9345--_00.html

- Manhattan is on average seven degrees hotter than surrounding suburban areas. The heat-island effect, as its known, could be reduced during the summer if enough paved yards were replaced with grass.

(2008) Solecki, W., Patrick, L., Grady, K., Cox, J., and Ervin, K. Urban Forests in Our Midst: Environmental Benefits of Open Spaces in City Backyards. CUNY Institute for Sustainable Cities, Hunter College, New York, NY, December 18, 2008, prepared for Landmark West!, New York, NY, www.landmarkwest.org, E. Mason project coordinator.

- The use of urban green space [including turf grass] offers significant potential in moderating the increase in summer temperatures expected with climate change. The modeling data presented here indicates that adding 10 per cent green in high-density residential areas and town centers kept maximum surface temperatures at or below 1961–1990 baseline levels up to the 2080s. Conversely, if green cover in high-density residential areas and town centers is reduced by 10 per cent, surface temperatures will be 7°C [12.6°F] or 8.2°C [14.8°F] warmer by the 2080s.

(2007) Gill, S., Handley, J.F., Ennos, R., and Pauleit, S. Adapting cities for climate change: the role of green infrastructure. *Built Environment*, 33 (1), 97-115. Retrieved from:

http://www.fs.fed.us/ccrc/topics/urban-forests/docs/Gill_Adapting_Cities.pdf

Oxygen Generation

Findings

- 1. Green spaces absorb carbon dioxide and water and use sunlight during photosynthesis to produce organic compounds for growth and release oxygen to the environment.**
- 2. The amount of oxygen produced by green spaces is phenomenal – a 50 by 50 foot lawn release enough oxygen for a family of four, an average 18-hole golf course release enough oxygen for 4000 to 7000 people and the grass and trees along the U.S. interstate highway system releases enough oxygen for 22 million people.**

Analysis and Commentary

Production of oxygen by plants is part of the fundamental process of photosynthesis. All plants, including green spaces, absorb carbon dioxide and water from the atmosphere and use sunlight to produce organic compounds for growth and release oxygen into the environment. The amount of oxygen released by green space alone is truly phenomenal.

Key Citations

- A 50 by 50 foot turf grass lawn (2500 square feet) releases enough oxygen for a family of four.

(2010) Grass Facts. Department of Agriculture. State of Michigan. Retrieved from: http://www.michigan.gov/mda/0,%201607,7-125-1570_2476_2481-9345--_00.html

Supporting Study:

A turf area of 50-by-50 square feet produces enough oxygen to meet the daily needs of a family of four.

(1990) Watschke, T.L. (Professor, Pennsylvania State University) The environmental benefits of turfgrass and their impact on the greenhouse effect. *Golf Course Management*, February 1990, 150-154, and references therein.

- An average 18-hole golf course produces enough oxygen to support 4,000 to 7,000 people. Georgia has 430 courses therefore Georgia alone produces enough oxygen for more than one million people.

Georgia Agriculture website: http://www.georgiaag.com/did_you_know.htm

Addition sources of support for this information:

- 1) The average 18-hole golf course has 150 acres with approximately half maintained turf, equivalent to 3.27 million square ft.
(2009) Throssell, C., Lyman, G., Johnson, M., Stacey, G. Golf Course Environmental Profile Measures Water Use, Source, Cost, Quality, and Management and Conservation Strategies. *Applied Turfgrass Science*. doi: 10.1094/ATS-2009-0129-01-RS.
 - 2) Watschke (1990) indicates that a 50' by 50' (2500 square ft) turf lawn releases enough oxygen for four people.
 - 3) An 18-hole golf course of 75 acres (3.27 million square ft) releases enough oxygen for 5200 people, supporting the estimate provided by the State of Georgia.
- The grass and trees along the U.S. interstate highway system release enough oxygen to support 22 million people.

(2010) Grass Facts. Department of Agriculture. State of Michigan. Retrieved from: http://www.michigan.gov/mda/0,%201607,7-125-1570_2476_2481-9345--,00.html

Carbon Sequestration

Findings

- 1. Urban green spaces provide an important sink to offset carbon emission in the USA while also adding to the amounts of carbon sequestration annual in U.S. cropland, grazing land and forest soils.**
- 2. Focusing on soils alone, carbon sequestration within urban green spaces in the USA is estimated to sequester 12 to 15 million tons of carbon per year, an amount comparable to the US Department of Agriculture's Conservation Reserve Program and equivalent to 14% of the privately owned, cultivated cropland in the USA.**
- 3. While the evidence clearly suggests that properly maintained green space is a net benefit in the effort to sequester carbon from the atmosphere, further study is required to determine precisely how significant the net carbon sequestration benefit is to the environment vis-à-vis such offsetting factors as fuel expense in maintaining green spaces, fertilizer and pesticide use, energy for water costs, etc.**

Analysis and Commentary

Carbon sequestration is the removal and storage of carbon from the atmosphere in carbon sinks (such as oceans, forests or soils) through physical or biological processes, such as photosynthesis. Examples of carbon sequestration would be the removal of the main greenhouse gas carbon dioxide from the atmosphere and its incorporation into plants and eventually into organic material in soil.¹³

Key citations

- Our results indicate that well maintained turfgrass can sequester atmospheric carbon at a high rate, about 400 pounds of carbon dioxide per acre per year, due to its high production and high root turnover.

(2002) Qian, Y. & Follett, R.F. Assessing Soil Carbon Sequestration in Turfgrass Systems Using long-Term Soil Testing Data. *Agron. J.* 94: 930-935.
- Carbon sequestration within urban landscapes in the USA is estimated to sequester 12 to 15 million tons of carbon per year, an amount comparable to the

¹³ (2007) Bremer, D. Turfnews. Carbon sequestration in turfgrass: an eco-friendly benefit of your lawn. Retrieved from: www.ksuturf.com/bremer/p7bpassets/Turf%20C%20seq%202007.pdf

US Department of Agriculture's Conservation Reserve Program and equivalent to 14% of the privately owned, cultivated cropland in the USA.

(2002) Qian, Y. & Follett, R.F. Assessing Soil Carbon Sequestration in Turfgrass Systems Using long-Term Soil Testing Data. *Agron. J.* 94: 930-935.

- Turfgrasses, as well as other crops and plant ecosystems, play key roles in removing carbon from the atmosphere and translocating and storing it in soils. Thereafter, some of the organic matter will remain even after the plant or root dies.

(2007) Bremer, D. Turfnews. Carbon sequestration in turfgrass: an eco-friendly benefit of your lawn. Retrieved from:

www.ksuturf.com/bremer/p7bpassets/Turf%20C%20seq%202007.pdf

- The greatest carbon sequestration rates occur during the first 25 to 30 years after establishment of turfgrass. This is because new lawns aerates the soil and such soils have the potential to absorb and store a lot of atmospheric carbon.

(2007) Bremer, D. Turfnews. Carbon sequestration in turfgrass: an eco-friendly benefit of your lawn. Retrieved from:

www.ksuturf.com/bremer/p7bpassets/Turf%20C%20seq%202007.pdf

- In a follow up their 2002 study, Qian and co-authors noted that their experiments confirmed that urban turf-grass systems provided a significant sink for soil organic sequestration. They cautioned:

To consider the net impact urban grassland on the atmosphere's greenhouse effect, however, we need to consider fuel expense in maintaining turfgrass, fertilizer and pesticide use, energy for pumping water to irrigate and the fluxes of other greenhouse gases (mainly N₂O and CH₄) in addition to soil carbon sequestration. Additional work is needed to evaluate the total carbon budget and fluxes of the other greenhouse gasses in turfgrass systems.

(2010) Qian, Y., Follett, R. F., & Kimble J.M. Soil Organic Carbon Input from urban Turfgrasses. *Soil Sci. Soc. Am. J.* 74: 366-371.

- A recent, detailed study of public parks in Irvine, California, revealed that the net carbon sequestration rates depended on the frequency of fertilizer use as fertilizers contribute to the production of greenhouse gases such as NO₂. When fertilizer is used twice per year (the low end of the frequency of application recommended by the City of Irvine), green spaces contributed to carbon sequestration, capturing 108 grams of carbon per square meter per year. In contrast, when fertilizer is used 15 times per year (the high end of the frequency of application

recommended by the City of Irvine), green space contributed to carbon emissions, releasing 258 grams of carbon per square meter per year.

(2010) Townsend-Small, A and Czimczik, C.I. Carbon Sequestration and Greenhouse Gas Emissions in Urban Turf. *Geophys. Res. Lett.* 37: L02707, doi:10.1029/2009GL041676, 2010;

(2010) Townsend-Small, A and Czimczik, C.I. Correction to “Carbon Sequestration and Greenhouse Gas Emissions in Urban Turf.” *Geophys. Res. Lett.* 37: L06707, doi:10.1029/2010GL042735, 2010

- This same study of public parks in Irvine, California, also documented that athletic fields do not contribute to carbon sequestration due to the extensive restoration necessary to maintain safe playing surfaces. This includes annual tilling and re-sodding to replace dead grass, and frequent aeration to offset compaction. It is well known from agricultural studies that these practices disrupt soil carbon accumulation.

(2010) Townsend-Small, A and Czimczik, C.I. Carbon Sequestration and Greenhouse Gas Emissions in Urban Turf. *Geophys. Res. Lett.* 37: L02707, doi:10.1029/2009GL041676, 2010;

(2010) Townsend-Small, A and Czimczik, C.I. Correction to “Carbon Sequestration and Greenhouse Gas Emissions in Urban Turf.” *Geophys. Res. Lett.* 37: L06707, doi:10.1029/2010GL042735, 2010

HUMAN HEALTH

Recreation/Increased Physical Activity/Reduced Obesity

Findings

- 1. Green spaces provide an ideal surface for a variety of recreational and sports activity, including high use areas such as public parks and playgrounds, sports fields, etc.**
- 2. Considerable evidence is now developing from studies in the U.S., Europe and Japan that access to green space is an important predictor of a higher level of physical activity (called “active living”), reduced risk of obesity and longer life (reduced mortality from cardiovascular disease and reduced overall mortality).**
- 3. A recent study of over 40 million people in England shows that health disparities between high income and low income people are much narrower in areas with ample green space, possibly because it allows residents to become more physically active and reduce stress.**

Analysis and Commentary

The facts on obesity and the health consequences for Americans are well known. Studies in the U.S., Europe and Japan have clearly shown that the presence of green spaces can make a significant impact on the level of physical activity and reduce the risk of obesity. Clearly this needs to be applied in the U.S.

Key Citations

- Turf provides an ideal surface for recreation and sports fields. Unlike other landscape plants, the turfgrass growing point is near the soil surface. This allows turf to be mowed at relatively low heights, which provides optimal playing surfaces for many recreational activities. Turf also is very wear tolerant and resilient compared to other groundcovers, which is necessary in high use areas such as soccer fields, backyard play areas and courtyards.

(2003) Streich, A., Rodie, S. and Gaussion, R. Turf in the Landscape. University of Nebraska – Lincoln Extension, Institute of Agriculture and Natural Resources. Retrieved from: <http://digitalcommons.unl.edu/extensionhist/1720/>

- A study in Marion County, Indiana, of children and youth aged 3 to 16 who lived closest to neighborhood green spaces, including parks and recreational facilities, were more likely to have normal body weights as measured by age-adjusted body

weight index (BWI-z) scores. The authors speculate that this was due to increased physical activity or time spent outdoors.

(2008) Bell, J.F., Wilson, J.S., and Liu, G.C. Neighborhood Greenness and 2-Year Changes in body Mass Index of Children and Youth. *Amer. J. Prevent. Med.* 35:547-553.

- A study in the Netherlands found that residents of neighborhoods with abundant greenspace generally enjoy better health than urban dwellers without access to natural areas. This positive link was found to be most apparent among the elderly, housewives, and people from lower socioeconomic groups.

Wolf, K.L. 2010. Active Living - A Literature Review. In: Green Cities: Good Health. College of the Environment, University of Washington. Retrieved from: http://depts.washington.edu/hhwb/Thm_ActiveLiving.html

- In a study of European urban adults, residents of areas with the highest levels of greenery were three times as likely to be physically active and 40% less likely to be overweight or obese, than those living in the least green settings.

Wolf, K.L. 2010. Active Living - A Literature Review. In: Green Cities: Good Health. College of the Environment, University of Washington. Retrieved from: http://depts.washington.edu/hhwb/Thm_ActiveLiving.html

- A remarkable 5-year study of senior citizens in Japan found that having readily available space for taking walks and the presence of parks and tree-lined streets near the residence were significant predictors of higher survival rates. Living in areas with walkable greenspaces positively influenced the longevity of urban senior citizens independent of their age, sex, marital status, baseline functional status, and socioeconomic status.

Wolf, K.L. 2010. Active Living - A Literature Review. In: Green Cities: Good Health. College of the Environment, University of Washington. Retrieved from: http://depts.washington.edu/hhwb/Thm_ActiveLiving.html

- A study comparing income-levels and health of over 40 million people in England shows that health disparities between high income and low income people are much narrower in areas with ample green space. The gap in all-cause mortality was about half as large in areas with ample green space as the gap in areas with the least green space. The authors speculated that the green space may reduce health disparities by enabling residents to become more physically active and reduce stress. The accompanying editorial concludes that the study “offers valuable evidence that green space does more than pretty up a neighborhood; it appears to have real effects on health inequality, of a kind that politicians and health authorities should take seriously.”

(2008) Mitchell, R., and Popham, F. Effect of exposure to natural environment on health inequalities: an observational population study. *Lancet* 372:1655-1660.

Retrieved from: [http://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(08\)61689-X/fulltext](http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(08)61689-X/fulltext)

(2008) Hartig, T. Green space, psychological restoration, and health inequality. *Lancet* 372:1614-1615. Retrieved from:

[http://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(08\)61669-4/fulltext](http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(08)61669-4/fulltext)

Healthcare/Reduced Stress

Findings

1. Medical studies have demonstrated that being in, or viewing a green space for a fairly short period of time, just a few minutes, reduces stress. This has been demonstrated not only for hospital patients but also for the general public.

Analysis and commentary

Medical studies have not only demonstrated that viewing green spaces reduces stress but also blocks pain sensation by providing an overwhelmingly pleasant positive distraction. This is truly remarkable.

Key Citations

- Recently, strong studies using experimental designs have produced additional convincing evidence that viewing nature [including green spaces] reduces patient pain as well as stress. These investigations support the interpretation that nature serves as a positive distraction.

(2010) Ulrich, Quan, X. and Zimring, C. The Role of the Physical Environment in the Hospital of the 21st Century: A Once-in-a-Lifetime Opportunity. Report prepared for TriPoint Hospital Center. Retrieved from: http://www.cleveland.com/healthfit/index.ssf/2010/09/blueprint_for_healing_-_hospi.html

As background relevant to assessing the credibility of nature findings in healthcare environments, it should be mentioned that many studies of populations other than hospital patients have produced strong evidence that even fairly brief encounters with real or simulated nature settings can elicit significant recovery from stress within three minutes to five minutes at most. Investigators have consistently reported that stress-reducing or restorative benefits of simply viewing nature are manifested as a constellation of positive emotional and physiological changes. Stressful or negative emotions such as fear or anger diminish while levels of pleasant feelings increase. Laboratory and clinical studies have shown that viewing nature produces stress recovery quickly evident in physiological changes, for instance, in blood pressure and heart activity. By comparison, considerable research has demonstrated that looking at built scenes lacking nature (rooms, buildings, parking lots) is significantly less effective in fostering restoration and may worsen stress.

(2010) Ulrich, Quan, X. and Zimring, C. The Role of the Physical Environment in the Hospital of the 21st Century: A Once-in-a-Lifetime Opportunity. Report prepared for TriPoint Hospital Center. Retrieved from: [tinyurl.com/healthdesignstudy as cited in http://www.cleveland.com/healthfit/index.ssf/2010/09/blueprint_for_healing_--_hospi.html](http://www.cleveland.com/healthfit/index.ssf/2010/09/blueprint_for_healing_--_hospi.html)

- Landscape plantings, including lawn areas around the home and workplace, have been shown to affect people positively. A healthy, maintained lawn area creates an inviting view for those passing by and provides an aesthetically pleasing, natural backdrop for other landscape elements. Uniformity of the lawn surface helps confer a sense of coherence and harmony to the entire landscape scene. It is this peacefully appearing setting that is believed to contribute to a person's feeling of well being and a decrease in emotional tension. It has also been noted that patient recovery rate is faster where they have a view to a landscaped setting versus a view of adjacent buildings only.

(2006) University of Minnesota. Sustainable Urban landscape Information Series. Environmental Benefits of a Health, Sustainable Lawn. Retrieved from: <http://www.sustland.umn.edu/maint/benefits.htm>

- Findings from several studies have converged in indicating that simply viewing certain types of nature and garden scenes (includes green spaces) significantly ameliorates stress within only five minutes or less. Further, a limited amount of research has found that viewing nature for longer periods not only helps to calm patients, but can also foster improvement in clinical outcomes -- such as reducing pain medication intake and shortening hospital stays.

(2002) Ulrich, R.S. Health Benefits of Gardens in Hospitals. International Exhibition Floriade. 2002. Retrieved from: http://www.planterra.com/research/research_3.php

CONCLUSIONS

- 1. This literature review has demonstrated that green spaces have a number of health and environmental benefits that are fully supported by the contemporary scientific literature.**
- 2. The Report debunks the notion that the only benefits of green spaces are ornamental or aesthetic.**

About EHRF and the Author

The Environmental Health Research Foundation (EHRF) is a nonprofit, nonpartisan scientific research foundation seeking to improve the analysis and communication of health and environmental science. Its goal is to further the understanding of science related to health and the environment, and especially the interaction between the environment and human health.

Headquartered in Chantilly, Virginia, EHRF accomplishes this objective through its national network of scientists who are experts in relevant academic fields. By bringing together scientists with appropriate areas of expertise, EHRF fosters an approach to addressing health and environmental issues of broad public importance that is based on the most up-to-date scientific information.

EHRF Executive Director Dr. John Heinze brings over 20 years of research, management, and communications experience to the EHRF. In addition to his expertise in microbiology, molecular biology, genetics, and toxicology, Dr. Heinze has authored over 35 scientific papers and presentations to international conferences and workshops.

Since 1995, Dr. Heinze has served as a senior science adviser on health and environmental issues, including the communications aspects of such issues. A particular focus has been on communication of health and environmental safety information including activities ranging from those focused on single substances to broad issues affecting numerous materials.

Dr. Heinze received his doctorate in microbiology from the University of Illinois at Champaign-Urbana, and conducted two years of postdoctoral study in molecular biology and genetics at the National Institutes of Health in Bethesda, Maryland.

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