DEFORESTATION FOR PHOTOVOLTAIC SYSTEMS INSTALLATION

A COST BENEFIT ANALYSIS

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INTRODUCTION

With plentiful forest land and increasing efficiency of solar energy generation, deforesting for the purpose of installing photovoltaic, or PV, systems is an intriguing means of expediting the transition to sustainable energy production. Over half of Tennessee's land is forested, and approximately 83% of that forested land is privately owned and managed, creating this opportunity for many landowners.[1]

Determining whether or not it is worthwhile to reduce our forest cover to accommodate for renewable energy generation requires the consideration of numerous quantifiable and unquantifiable factors. Researchers at the Swedish Environmental Protection Agency in 2017 qualify this question as an "unexplored area of research."[2]

This report compiles the available facts and figures into a comprehensive reference and specifically focuses on the state of Tennessee in the United States.

SUMMARY

Deforestation for PV Systems Installation	Preventing Deforestation (Status Quo)

Quantifiable Benefits

Deforestation for PV Systems Installation	Preventing Deforestation (Status Quo)
$792,219 per acre Considering: Energy Generation Life Cycle Cost	Nonurban Forests value contribution $235 per acre Urban Forests value contribution $14,447 per acre

Additional Benefits

Deforestation for PV Systems Installation	Preventing Deforestation (Status Quo)
Timber is a sustainable resource	Misc benefits, vary based on region Specific research should be conducted

Further Considerations

The value of atmospheric greenhouse gas reduction will increase in the future due to the increasing cost of CO_2. PV systems have a significantly greater GHG reduction capacity than forests, so their GHG reduction value will increase at a faster rate.

Tennessee is expected to see substantial urban growth over the new few decades. This will increase the value of urban trees and bring more nonurban trees into urban areas.

Forests do not provide the same value and services after regrowth as they had before deforestation.

In order to gain the benefits of a PV system, the entity must directly offset their carbon-based energy dependence with the solar energy.

QUANTIFIABLE BENEFITS

The environmental impact of PV systems is quantified two ways: the energy generation which substitutes for carbon-based energy production, and the Life Cycle cost of manufacturing, operating, and decommissioning the PV panels.

The environmental impact of forests is quantified by their reduction of carbon dioxide from the atmosphere as they grow, known as sequestration, as well as numerous other environmental benefits such as pollution removal and property value contribution.

PHOTOVOLTAIC SYSTEMS

We consider a solar capacity factor of 1300 for the greater Nashville area and a 5 acres per MW PV system in our calculations.

Life Cycle Assessments are analyses which are used to estimate the emissions associated with the entire process of manufacturing, operating, and decommissioning an energy source. We reference the Life Cycle Assessment Harmonization Project conducted by the National Renewable Energy Laboratory for the most accurate estimates of life cycle GHG emissions from PV systems.[21]

The CO_2 equivalence of CH_4 and N_2O emissions are considered.

Annual carbon impact of PV systems compared to the Tennessee electric grid

- 15,184 metric tons of CO_2 equivalent per acre, from offset emissions
+ 10 metric tons of CO_2 equivalent per acre, from PV Life Cycle Cost

$792,219 per acre (October 2019$ in 2020 at 3% discount rate)

FORESTS

We reference Nowak et at. at the US Department of Agriculture Forest Service for numbers on forests in Tennessee.[11]

Annual carbon impact of avoided deforestation in Tennessee

- 4.51 metric ton CO_2 per acre, through sequestration

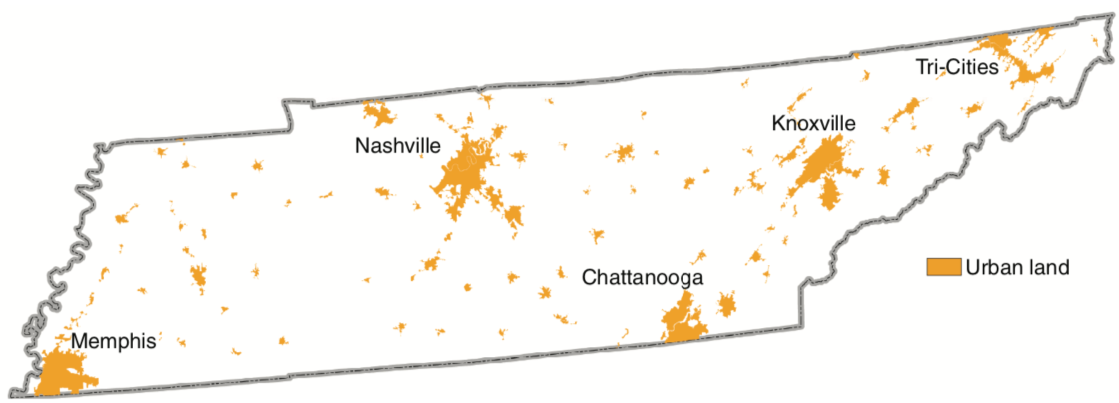
$235 per acre (October 2019$ in 2020 at 3% discount rate)

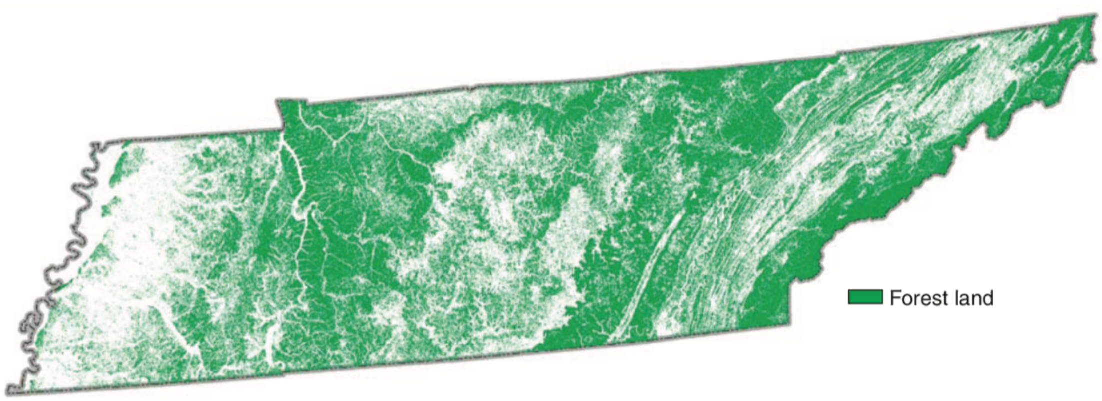
URBAN FORESTS

As landscapes urbanize, increased population density, built environments, human activity, and associated emissions tend to increase air temperatures, degrade air and water quality, and reduce human health and well-being. As a result, sustaining tree cover in urban and suburban areas becomes increasingly paramount to sustaining human health, environmental quality, and quality of life.

The U.S. Census Bureau defines “urban areas” as all territory, population, and housing units located within urbanized areas or urban clusters (areas with core population density of 1,000 people per square mile), but still includes surrounding areas with lesser population density.

The two graphics bellow illustrate the urban land (as defined by the U.S. Census Bureau) and forest land within Tennessee.





The benefits of urban forestry in Tennessee in 2009 as well as other statistics were quantified in a pilot study conducted by Nowak and David along with the US Forest Service in 2012.

In 2009, 284.1 million trees resided within approximately 1.6 million acres of urban land in Tennessee. 15% of Tennessee’s urban land use is classified as urban forest. Urban Forest, as defined by the USDA Forest Service, are areas in urban land which are at least

1 acre in size, at least 120 feet wide, and at least 10 percent stocked with trees. On average 685 trees resided on 1 acre of urban forest.[5]

The structural value of a tree is “based on the tree resource itself (e.g., the cost of having to replace a tree with a similar tree). In North America, the most widely used method for estimating the compensatory or structural value of trees was developed by the Council of Tree and Landscape Appraisers (CTLA). Compensatory values represent compensation to owners for the loss of an individual tree. CTLA compensatory value calculations are based on tree and site characteristics, specifically: tree trunk area (cross- sectional area at 4.5 feet above the ground), species, condition, and location.”

Annual value contribution of urban forests in Tennessee[5]*

- Structural Value
  - Total structural value: $89 billion
- Functional Value
  - Carbon storage: $795 million
  - Carbon sequestration: $42 million
  - Pollution removal: $229 million
  - Building energy savings: $74 million
  - Avoided carbon emissions: $4 million

In total,

$4.839 billion (October 2019$ in 2020 at 3% discount rate)

Pollutant removal rate was of urban trees is greatest for ozone, followed by particulate matter, sulfur dioxide, nitrogen dioxide, and carbon monoxide; it is actually lowest for carbon dioxide.

Essential functional values of trees which were not quantified within the study include oxygen production, water runoff management, and reduced ultraviolet radiation.

ESTIMATES

The annual value contributions above are aggregated from all the trees within Tennessee’s urban areas, not just those in urban forests. Determining the value of urban forest per acre using this data is problematic because trees located in transportation, residential, and commercial areas provide more value than trees in forest areas.

A more preferred method to determine the value of urban forest per acre is The National Tree Benefit Calculator. The National Tree Benefit Calculator uses methods from the i-Tree software suite, “an analysis tool for urban forest managers that uses tree inventory data to quantify the dollar value of benefits such as energy conservation, air quality improvement, CO2 reduction, stormwater control, and property value increase.”

The data in the table below is calculated using the National Tree Benefit Calculator (using vacant lot/park as location) with data from Nowak and David, 2012.

VALUE OF TREES IN TENNESSEE URBAN FORESTS				
Species of Tree	% of total trees	Avg diameter at breast height	Annual value ($)	Value contribution ($/year)
Chinese privet	12%	1.7	2	0.24
Eastern red cedar	6%	3.5	4	0.24
American beech	5%	1.8	3	0.15
Amur honeysuckle	5%	2	4	0.2
Red maple	5%	3.6	8	0.4
Black cherry	4%	3.7	9	0.36
Black locust	4%	2.8	10	0.4
Black tupelo	4%	3.2	12	0.48
Hackberry	4%	4	10	0.4
Chestnut oak	3%	8.5	32	0.96
Pignut hickory	3%	3.8	10	0.3
Sourwood	3%	3.3	6	0.18
Sugar maple	3%	3.7	11	0.33
Sweetgum	3%	4	9	0.27
Winged elm	3%	3.2	12	0.36
Yellow-poplar	3%	8.1	31	0.93
Flowering dogwood	2%	2.2	5	0.1
Loblolly pine	2%	4.7	8	0.16
Slippery elm	2%	1.4	4	0.08
Virginia pine	2%	4.3	5	6.54
Other	22%	4.2	16	3.52
Total value of tree (2006 dollars)				16.6
Total value of tree (October 2019)				21.09

Given that Tennessee urban forests have a density of 685 trees per acre, the annual value contribution of urban forest is approximately $14,447 per acre.

NONQUANTIFIABLE BENEFITS

The impacts of deforestation or forest preservation are not entirely quantifiable and extend beyond the dollar. A solely numerical comparison of the benefits of trees and solar is inadequate.

PHOTOVOLTAIC SYSTEMS

TIMBER AS A SUSTAINABLE RESOURCE

Deforestation isn't necessarily a bad phenomenon. The issues occur when land is deforested for intensive and soil-degrading agricultural practices. Industrial agriculture is the most significant driver of deforestation in tropical and subtropical countries, accounting for 80% of deforestation from 2000-2010.[8] The byproduct of deforestation, timber, is environmentally beneficial, especially when it used for either product manufacturing or energy generation.

Bergman et al in The Carbon Impact of Wood Products explain "the manufacture of wood products requires less fossil fuels than non-wood alternative building materials such as concrete, metals, or plastics." Additionally, wood is by nature composed of carbon sequestered from the atmosphere. Not only does the use of wood in products reduce the amount of CO_2 in the atmosphere, but it also substitutes a less sustainable resource. Among the wood products examined in their analysis, all provide a net emission savings when used in place of the selected non-wood alternative products.[10]

Oliver at the School of Forestry at Yale University finds that at most, about 50% of merchantable log is made into solid products when milled. When timber is not manufactured into products and is used for energy production instead, their calculations show that wood-based energy production is an environmentally friendly substitute to carbon-based energy production.[20]

FORESTS

Human social and psychological well-being, recreational and communal opportunities, aesthetic value, and more do not translate into a dollar value yet are arguably just as if not more important than other functions of trees.

Non-urban forest ecosystems provide benefits beyond improving air quality, such as soil conservation, biodiversity, human psychological well-being, aesthetic value, and recreational, communal, and tourism opportunities.

In terms of watershed regulation, forests’ functions include soil conservation - and hence control of siltation and sedimentation, water flow regulation - including flood and storm protection, water supply, and water quality regulation - including nutrient outflow.[15]

Biodiversity of forests is valuable because it embodies the value of information and insurance. Existing diversity is the result is evolutionary processes over several billion years during which species co-evolve and interact with each other. This diversity contains information that can be used to develop goods and services for the benefit of humankind.[15]

The extensive benefits which a forest provides to the environment and nearby human communities, its distinct properties, and any unique values which it might offer, such as tourism or especially high biodiversity, should be heavily considered before a decision to deforest.

FURTHER CONSIDERATIONS

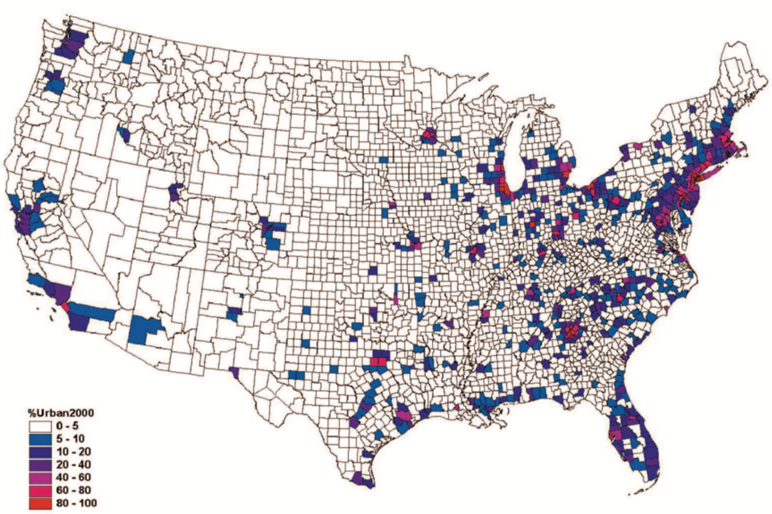
INCREASING COSTS OF GREENHOUSE GASES

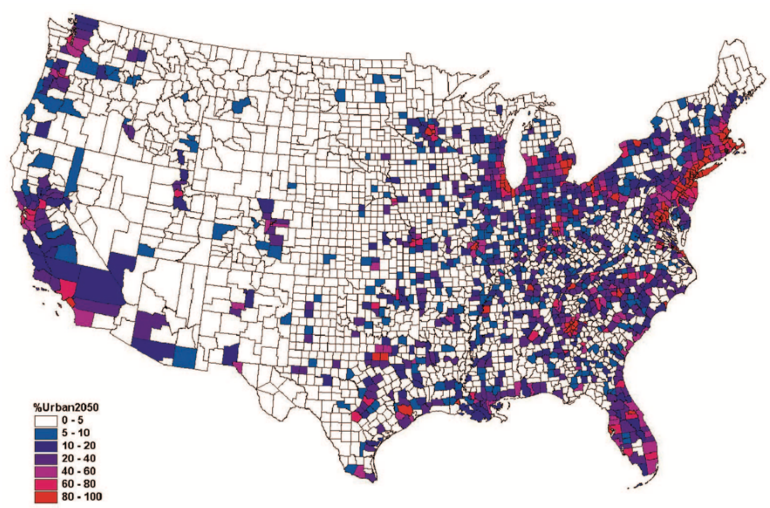
The value of GHG reduction is directly related to the amount of greenhouse gases in the atmosphere since each additional unit of GHG in the atmosphere has a compounding effect. The more GHG are prevalent in the atmosphere, the larger their influence on nature becomes. For example, according to the EPA, the social cost of CO_2 at a 3% discount rate is $42 per metric ton in 2020 but is predicted to rise to $69 in 2050.

The value of GHG reduction will also decrease as society transitions away from carbon-based energy production towards renewable energy sources. However, according to Wilmot Inc predictions, this is unlikely to make a positive difference within the Tennessee Valley Authority, or TVA, region which provides Tennessee's electricity because TVA is still expanding their non-renewable energy production as of 2019.

FUTURE URBAN GROWTH

Urban land in the United States is projected to increase from about 3.1% in 2000 to 8.1% in 2050. Tennessee in particular is predicted to have 7.8% of forestland outside of urban areas in 2000 subsumed by urban growth by 2050. The diagram below illustrates the expected urban growth from 2000 to 2050.[14]





As urban expansion continues, not only will areas which were once secluded forestry become in close contact with human developments, but already existing urban land will be strained even further. Forest land which might be disregarded today could become significantly more important in the future.

FOREST GROWBACK

Nonetheless, “deforestation, particularly of mature forests, typically involves an immediate and significant loss of ecosystem services that could take decades or centuries to recover - sometimes previous ecosystem function is entire lost.”[6] It is believed that many of these ecosystem services have not yet been identified or quantified.

REDUCING RELIANCE ON CARBON-BASED ENERGY

Ideally, the organization or entity which is installing the PV system will directly replace their reliance on the energy grid with that from the PV system and reduce their non-renewable energy usage.

However, simply allowing the energy produced from the PV system to enter the grid doesn’t directly offset carbon emissions from non-renewable energy production, but instead adds energy to the total supply

Richard York of the University of Oregon conducted a meta-analysis in the field of energy economics, finding that “owing to the complexity of economic systems and human behavior… the average pattern across most nations of the world over the past fifty years is one where… each unit of electricity generated by non-fossil-fuel sources displaced less than one-tenth of a unit of fossil-fuel-generated electricity.”[13]

If the organization or entity does not directly offset their carbon-based energy consumption, and without the incorporation of regulations, such as adding a financial cost to the consumption of carbon or the deliberate reduction of certain carbon-based energy productions, proliferating the supply of renewable energy production has far smaller carbon benefit than expected.

ENDNOTES

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