Reforestation and Afforestation May Aid High Density, Low Emission Energy Production In Reducing CO_2 and Slowing Climate Change

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TABLE OF CONTENTS

LIST OF FIGURES

Introduction:

Climate change has the potential to change our environment drastically. One major contributor to climate change is the accumulation of CO_2 in the atmosphere. The accumulation of atmospheric CO_2 has been aided by continued deforestation around the globe. Since the industrial revolution there has been a 40% increase of CO_2 in the atmosphere [1]. We could see a 30% increase in energy demand by 2040 [2] contributing even more CO_2 into the atmosphere.

Wind turbines and solar panels are being built all around the globe to attempt to lower CO_2 emissions. They are not free from CO_2 emissions, but are considerably lower than the burning of fossil fuels [3]. However; these low density power sources are notably difficult and expensive to recycle at the end of their life-cycles [4]. With continued advancements in carbon capture technology and high density energy production, considerably lower CO_2 emissions can be seen from more dense power sources than with wind and solar power production. There is a land usage cost to all power production as well. Low density power production such as wind turbines and solar panels use a considerably larger footprint than high density energy sources such as nuclear and fossil fuels [1]. There is a secondary issue with renewable energy sources, approximately 5% of global warming is caused by heat islands, usually urban areas where the land attributes have changed and absorb more heat from solar rays [5]. Urban populations may grow as much as 70% by 2050 and will increase this affect [5]. Growing land attribute changes for solar and wind energy may also be contributing to the heat island affect [6,7]. By using more dense power production, when wind turbine and solar panel power plants are decommissioned at the end of their life-cycles the land use could be converted back to forests with reforestation and afforestation.

This research discusses the potential to remove CO_2 from the atmosphere and continue to lower CO_2 emission. Reforestation and afforestation can remove atmospheric CO_2. Above and in the ground surface plants and microbes bind carbon from CO_2 [8]. Temperate Forests, like those in the United States, sequester more CO_2 than any other carbon sink [8]. The annual rise in atmospheric CO_2 is 3 billion metric tons less than what is released, due to large natural carbon sinks [9]. One acre of temperate forest can hold more than 5000 trees [10] and grow a healthy stand of 900 mature trees [11]. A mature, approximately 20 to 30-year-old, temperate forest tree can sequester on average 21.77 kg of CO_2 per year [12]. An examination of a single temperate forest stand from 2006 indicated that from that stand 53.3 – 70.7 metric tons of carbon can be sequestered above ground per year [13]. In 2017 the United Kingdom's Committee on Climate Changes determined that to meet their CO_2 goals they would need to return 20% of their farmland back to historic forest stands [14]. According to a United States' agriculture census, from 2012 to 2017 approximately 14.3 million acres of farmland was retired and could be potential reforested land [15].

The reforestation or afforestation of historically forested areas in the Northeast United States can theoretically remove a considerable amount of the domestic CO_2 emissions. Adding in the reforestation of the land from low density power plants as they reach the end of their life-cycles could substantially increase that CO_2 reduction. Geographic information systems were used with the United States Geological Survey's land use data and the United States

Energy Information Administration's energy production maps to determine where temperate forest trees could be planted and to quantify the potential CO_2 uptake.

Research Design:

Energy density and CO_2 uptake may be the key to reducing climate change. The focus of efforts can be shifted from just lowering emissions with solar and wind power to low emissions, high density energy with added reforestation and afforestation. Land cover and area maps from the United States Department of the Interior, USDI, [16, 17] were used to isolate marginal land within the estimated historically forested areas of pre-colonial North America. Using the Energy Information Administration's, EIA, energy production maps [18], the location of solar panel and wind turbine power production plants were identified. These locations are where trees can potentially be planted. The potential CO_2 uptake can then be estimated.

The following outline is the process that was followed to develop the analysis, all image processing was performed using ArcGIS Pro:

1. The map shape files were downloaded from their specific internet locations.
    a. Area map, USDI [16]
    b. Land cover map, USDI [17]
    c. Solar panel power map, EIA [18]
    d. Wind turbine power map, EIA [18]
2. An Image of the estimated forests of precolonial era, year 1620 was downloaded
    a. A shape file of the precolonial forests was developed by georeferencing the image to the ESRI charted territories base map

b. A feature class was created for the areas historic forest shape file

c. The forest area was traced into the feature class

d. Figure 1 illustrates the created shape file

Figure 1

Fig. 1 ArcGIS Map of Historic Forests of the Northeast United States, Wikipedia

3. Analysis development

   a. The area map was used to define the area of interest, the North Atlantic and Great Lakes States, indicated by the black outline in the following figures.

   b. The land cover, solar panel power, and wind turbine power shape files were clipped to the historic forest map, the clipped wind turbine power map is seen in Figure 2a, and the clipped solar panel power map is seen in Figure 2b.

Figure 2

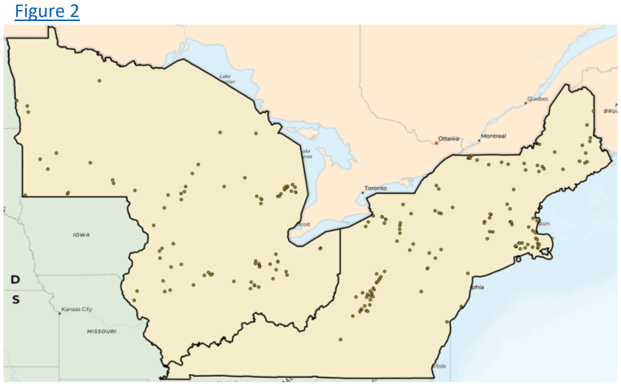

Fig 2a. ArcGIS Map of wind turbine locations in the historically forested area of the Northeast United States, Energy Information Administration [23]

Figure 3

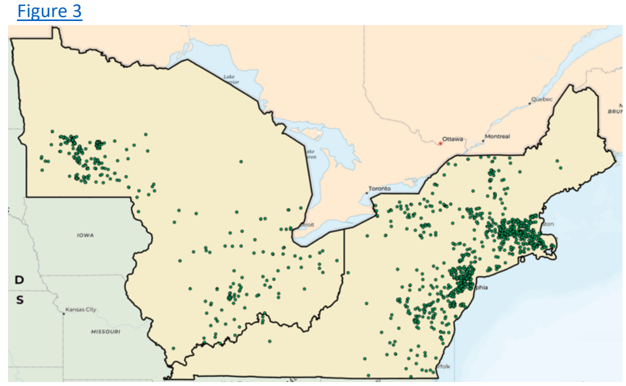

Fig.2b ArcGIS Map of solar panel locations in the historically forested area of the Northeast United States, Energy Information Administration [23]

   c. The clipped land cover map was used to isolate the marginal lands from all other land types, i.e. open water, residential, agricultural, developed, etc., seen in Figure 3.

i. Marginal lands were considered to be any grassland, or brushland within the historic forested lands, because it was assumed that these lands were stripped of trees for primitive agriculture during colonization and the expansion west.

Figure 4

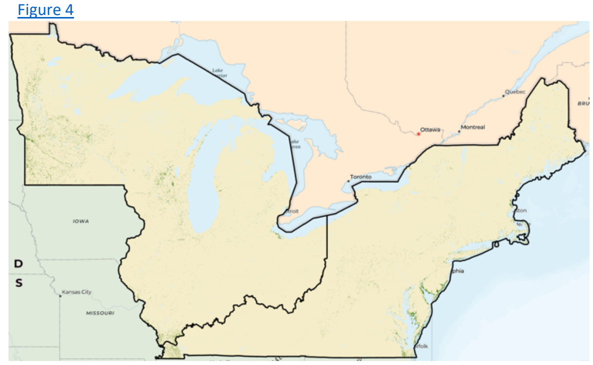

Fig. 3 ArcGIS Map of North Atlantic and Great Lakes States' potential reforestation, United States Department of the Interior

d. The marginal lands clipped map was converted to a raster.

e. An attribute table was extrapolated for the raster.

f. Summation was used on the attribute table to determine the count of 30 m raster cells that were marginal land.

g. Summation was used to determine the megawatts, MW, of power production for the solar panels and wind turbines within their clipped maps

4. Calculations

a. The land needed for each power source was estimated from the literature, 0.75 acres per MW of wind turbine power production [20], and between 5 and 10 acres per MW of solar power production [21]

b. Convert 30 m cells to acres, 30 m^2/0.000247105 acres = 0.0074 acres per cell

c. Potential CO_2 uptake, *n* acres * 900 mature trees/acre * 22.17 kg CO_2/tree

Results:

The ArcGIS preliminary analysis found 15.7 million acres of marginal land in the area. This equates to a potential of over 341 million metric tons of CO_2 uptake annually, approximately half of Texas's, all of California's or twice New York State's yearly emission [22]. The analysis determined that there is 13,351 MW of wind energy production in the area. With the estimated need of 0.75 acres of land per MW of wind turbine power [20] there is potentially over 10,000 acres of land for reforestation when these wind turbines are decommissioned. This land could potentially sequester an additional 218,000 metric tons of CO_2 per year. There is only 4,901 MW of solar energy production in the area, although the construction of solar farms is growing [21]. With the estimated need between 5 and 10 acres of land per MW of solar power [21] there is potentially 24,500 to 49,000 acres of land for reforestation. This land could potentially uptake an additional 533,000 to 1.066 million metric tons of CO_2 per year. These preliminary findings in the Northeast United States illustrate a potential sequestration of approximately 7% of the United States' yearly CO_2 emissions if this marginal land were converted back to its historic forested state.

Discussion:

Recent energy advancements in nuclear energy would allow higher production with less impact to the land and air. These advancements could allow for a shift in focus, from low density, low emissions energy sources to high density, low emissions energy sources with the addition of CO_2 sequestration plans. The development of carbon capture technology allows for the production of energy by the burning of fossil fuels with up to 90% lower emissions of CO_2

[23]. The captured CO_2 can be used in the production of fuels, building materials and much more or injected back into the ground to be stored out of the atmosphere [23]. Recently, there have been major gains in the development of a net gain self-sustaining fusion reactors. The MIT aided in the production of a 20 tesla magnet that has reached the strength needed to sustain a fusion reaction [24]. At the National Ignition Facility, NIF, at Lawrence Livermore National Laboratory in California a team of physicists have produced the ignition of burning plasma [25] the piece of the puzzle that was needed to produce a sustainable reaction. The recent development by NIF has moved the original timeline for sustainable fusion ahead. It was expected that the International Thermonuclear Experimental Reactor in France was going to create the first plasma reaction and net energy gain but it is still being built and will not be completed until 2025 and would not produce the reaction until likely 2032 [26]. These recent and rapid scientific gains illustrate that the projections by The United Kingdom's Atomic Energy Authority of having a functioning on grid fusion reactor by 2040 might be feasible and could be sooner. If the advancements in nuclear fusion do produce sustainable fusion reactors, historic challenges with energy production could become a problem of the past. In the meantime added carbon capture to high density fossil fuel energy production would lessen the emissions of CO_2 while supporting the still growing energy demands of the world. The growing possibility of fusion's high density energy production with low emissions coming in the next few decades makes the possibility of reforestation where solar panels and wind turbines will be reaching the end of their life-cycles more feasible.

Further analysis would need to be completed before rendering an adaptive management plan. There are questions about the land's value, does it have a high economic value in its current state? Is the land aesthetically valuable to the landowner, or environmental valuable due to an endangered species that lives there? The current climate would need to be considered as well. Has it changed considerably and become unsuited for reforestation? These questions and economic considerations would need to be addressed, among others, before reforestation could commence. Local biologists and ecologists would need to be consulted about the species and ecosystems in these areas to determine if reforestation can be permitted. Silviculturists, meteorologists and climatologists would be able to determine if the current climate and weather would be able to sustain forest stands in the proposed areas. The monetary cost of the endeavor could also be prohibitive funding would need to be procured. There could be a possibility for government subsidies as they are used for farming and energy production already. The forest stands once mature could also sustain the harvesting of wood products to recover some of the monetary loses or losses in value incurred by the land by the landowners.

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