# Afforestation

**Initiative Summary:**
Establishing new forests ("afforestation") increases the amount of carbon in biomass and soils compared to preexisting conditions. Planting and afforestation can take place on land not currently experiencing other uses, such as abandoned mine lands (AMLs), oil and gas well sites, marginal agricultural land, and riparian areas.
This analysis focuses on the carbon sequestration benefit of afforestation only, and does not address the multiple co-benefits (water, habitat, etc.).

**Goals:**
Increase carbon sequestration on land not being utilized (i.e., AMLs, oil and gas well sites, marginal agricultural land, and riparian areas). Scenarios were designed for practicality to include a scaled usage (25%, 50%, 100%) of available land in each of the previously referenced land-use categories.

**Implementation Period**: 2013–2020

**Potential GHG Reduction ($MMtCO_2e$):** Varies by scenario. See analysis, below.
Scenarios were designed for practicality, and to illustrate the potential benefits and costs under various levels of implementation (Table 1).

**Table 1. Summary of Scenarios Used for Quantification of Afforestation**

| Land-Use Category | Total Acreage Available for Planting (2013–2020) | Acreage Available by Scenario | | |
|---|---|---|---|---|
| | | Planting Scenario | Total Acreage Available | Annual Acreage Available |
| Abandoned Mine Lands | 250,000 | 25% | 62,500 | 7,813 |
| | | 50% | 125,000 | 15,625 |
| | | 100% | 250,000 | 31,250 |
| Oil and Gas Well Sites | 3,250 | 25% | 2,093 | 262 |
| | | 50% | 4,185 | 523 |
| | | 100% | 8,370 | 1,046 |
| Marginal Agricultural Land | 2,915,843 | 25% | 728,961 | 91,120 |
| | | 50% | 1,457,922 | 182,240 |
| | | 100% | 2,915,843 | 364,480 |
| Riparian Areas | 30,000 | 2013 and 2014 TreeVitalize + CREP | | 4,500 |
| | | 2015 – 2020 CREP | | 3,500 |

N/A = not available.

The sections below detail the methods and assumptions used for each of the vegetation types planted and the variety of land-use types considered in this option.

### A. GHG Benefits

Forests planted on land not currently in forest cover will likely accumulate carbon at a rate consistent with the accumulation rates of average forest in the region. Therefore, carbon sequestered by afforestation activities was assumed to occur at the same rate as carbon sequestration in average PA forest. Average

carbon storage was found based on USFS GTR-NE-343 assuming afforestation activity with a forest type distribution of 50% Maple-Beech-Birch and 50% Oak-Hickory. For most afforestation, a 25-year project period was assumed, such that the average rate of forest carbon sequestration (in all forest carbon compartments, including soil, live and dead biomass, forest floor, understory, and downed wood) was estimated at 5.02 $tCO_2e$/ac/yr (Table 2). In riparian buffers, the amount of carbon sequestration achieved over time was quantified using a carbon sequestration rate of 4.38 $tCO_2e$/ac/year. To calculate this rate, average carbon densities for Elm-Ash-Cottonwood forests (obtained from USFS data within the EPA's GHG State Inventory Tool, 2012) were divided by 35, based on the assumption of an average stand age of 35 years obtained from FIA data and averaged with the Maple-Beech-Birch rate. Forests planted in one year continue to sequester carbon in subsequent years. Thus carbon storage in a given year is calculated as the sum of annual carbon sequestration on cumulative planted acreage.

**Table 2. Forest Carbon Sequestration Rates for Afforestation Activity**

| Forest Types | $tCO_2e$/ac/yr (average) |
|---|---|
| Oak-Hickory | 5.2 |
| Maple-Beech-Birch | 4.9 |
| Elm-Ash-Cottonwood | 4.4 |

$tCO_2e$/ac/yr = metric tons of carbon dioxide equivalent per acre per year.
Source: J.E. Smith et al. 2006, GTR-NE-343.

## B. Land Areas Available for Afforestation

For each of the vegetation types analyzed, a scaled implementation of planting on 25%, 50%, and 100% of the land-use category was considered. A gradual ramp-up was assumed, such that full implementation of each scenario would be achieved in 2020.

### *B.1. Abandoned Minelands*

With 250,000 acres of AMLs statewide, these sites provide a potential opportunity for carbon sequestration. Restoring AMLs, however, can be challenging and very costly due to the need for site preparation because of uneven terrain and the legacy of their prior use.

### *B.2. Oil and Gas Well Sites*

With advent of drilling in the Marcellus shale the number of well pads and wells drilled per year has significantly increased. In the calculations we use an average well pad size of 5 acres. We assume four wells per pad and an average (2007 – 2011) of 977 wells drilled per year for a total available acreage of 1,221.

### *B.3. Marginal Agricultural Land*

Marginal agricultural land is restricted by various soil physical/chemical properties, or environmental factors, for crop production. Based on an analysis of the 1992 U.S. Geological Survey National Land Cover Dataset, together with soil characteristics obtained from the NRCS STATSGO (State Soil Geographic) dataset, Niu and Duiker (2006) reported that marginal agricultural land area in PA totaled 1.18 million hectares (MMha) (approximately 36% of all land area in the state). This land was placed in the "marginal agricultural land" category because of its combination of soil and land cover characteristics, and includes land with high water table, steep slopes (high erodibility), shallow soils, stoniness, and low fertility.

### *B.4 Riparian Areas/Buffers*

This analysis combines projected acreage from the Tree Vitalize and CREP forest riparian establishment programs. It builds on successes of highly successful programs such as Tree Vitalize1 to target that establishment of 1,000 acres/year in riparian areas for years 2013 and 2014. It also targets the annual establishment of 3,500 acres from 2013 through 2020. Annual carbon sequestration is based on cumulative acreage planted under this scenario.

## C. Economic Cost

Economic analyses typically employ four categories: opportunity cost (of planting forest rather than another, potentially more lucrative land use), conversion cost, maintenance cost, and measuring/monitoring costs (Walker et al. 2007). For this analysis, opportunity cost was assumed to be zero because the land considered in each of the scenarios is currently underutilized.

One-time costs of afforestation include site preparation and planting. These costs are incurred in the year of planting, one time only. Ongoing costs of maintenance and monitoring are incurred annually on all acreage planted in all years of policy implementation. The assumed costs of site preparation, planting, and ongoing maintenance for each land use type appear in Table 3.

**Table 3. Economic Costs of Site Preparation, Establishment, Maintenance, and Monitoring**

| Land Use Type | One-Time Costs | | Annual Costs |
|---|---|---|---|
| | Site preparation | Planting | Monitoring |
| Abandoned Mine Lands | $2,500.00 | $680.00 | $29.00 |
| Oil & Gas Well Sites | $0.00 | $680.00 | $29.00 |
| Marginal Agricultural Land | $0.00 | $680.00 | $29.00 |
| Riparian Areas | $0.00 | $680.00 | $29.00 |

## D. Summary

Tables 4 and 5 summarize the cumulative and annual (2020) results, respectively, of greenhouse gas reductions, NPV and levelized cost effectiveness for each scenario of each land use type. NPV is the sum of the discounted costs—in other words, the economic cost or benefit of implementing the option, calculated in 2010 dollars. Levelized cost-effectiveness is the NPV of a scenario divided by the GHG benefit of that scenario. This is expressed in $/tCO$_2$e sequestered or avoided, and is intended to give a sense of the cost of each scenario standardized for its actual GHG benefit.

**Table 4. Cumulative Results (2013-2020) of Afforestation for Various Land-Use Types in PA**

| Land-Use Category | Total Acreage Available for Policy Implementation | | | Cumulative GHG Benefit 2013–2020 (MMtCO$_2$e) | | | Net Present Value 2013–2020 ($ million (in $2010)) | | | Levelized Cost-Effectiveness ($/tCO$_2$e) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 25% | 50% | 100% | 25% | 50% | 100% | 25% | 50% | 100% | |
| Abandoned Minelands | 62,500 | 125,000 | 250,000 | 1.41 | 2.83 | 5.65 | $151.1 | $302.2 | $604.3 | $106.94 |
| Oil and Gas Well Sites | 2,443 | 4,885 | 9,770 | 0.06 | 0.11 | 0.22 | $1.4 | $2.9 | $5.7 | $25.90 |
| Marginal Agricultural Land | 728,961 | 1,457,922 | 2,915,844 | 16.48 | 32.96 | 65.91 | $426.7 | $853.4 | $1,706.8 | $25.90 |
| Riparian Areas | 30,000 | | | 0.62 | | | $13.0 | | | $21.11 |

[1] See: http://www.treevitalize.net/.

$/tCO$_2$e = dollars per metric ton of carbon dioxide equivalent; MMtCO$_2$e = million metric tons of carbon dioxide equivalent.

**Table 5. Annual (2020) Results of Afforestation for Various Land-Use Types in PA**

| Land-Use Category | Total Acreage Available for Policy Implementation | | | 2020 GHG Benefit per (MMtCO$_2$e) | | | 2020 Net Present Value ($ million (in $2010)) | | | Levelized Cost-Effective-ness ($/tCO$_2$e) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 25% | 50% | 100% | 25% | 50% | 100% | 25% | 50% | 100% | |
| Abandoned Minelands | 7,813 | 15,625 | 31,250 | 0.31 | 0.63 | 1.26 | $16.4 | $32.7 | $65.5 | $52.12 |
| Oil and Gas Well Sites | 305 | 611 | 1,221 | 0.01 | 0.03 | 0.05 | $0.17 | $0.34 | $0.68 | $13.93 |
| Marginal Agricultural Land | 91,120 | 182,240 | 364,480 | 3.66 | 7.32 | 14.65 | $51.0 | $102.0 | $204.1 | $13.93 |
| Riparian Areas | 30,000 | | | 0.13 | | | $1.3 | | | $9.60 |

**Implementation Steps:** ***Target Programs, Goals Support Full Implementation of These Programs***

- The TreeVitalize initially sought an $8 million investment in tree planting and care in southeastern Pennsylvania over a 4-year period. The goals of the program included planting 20,000 shade trees, restoring 1,000 acres of forests along streams and water-protection areas, and training 2,000 citizens to plant and care for trees. DCNR initiated preliminary discussions with regional stakeholders in the summer of 2003, and appointed a Project Director in January 2004. Planning, assessment, and resource development continued through 2004. Tree-planting activities began in the fall of 2004 and have continued. Subsequently, the regional Tree Tenders program was launched in 2005. Although TreeVitalize is not a permanent entity, the collaborations created and capacity built will continue to increase tree cover and promote stewardship through expansion across other regions of the state. See: http://www.treevitalize.net/aboutus.aspx.

- Numerous programs are in place Statewide—USDA CREP (where USDA subsidized farmers to keep highly erodible acres in warm-season grass)—that may in fact be a significant source of biofuel in switchgrass. In addition to warm-season grasses, CREP subsidizes riparian forest buffer practices. One cost-shared practice is the installation of streambank fencing to exclude livestock and allow for natural forest regeneration. Another practice was riparian forest plantings. CREP has proven to be highly successful in the expansion of forested riparian buffers throughout the Ohio and Chesapeake Bay drainages, including the installation of well over 3,400 acres of forested riparian buffers and planting more than 4,800 acres of native grasses.

- Other buffer initiatives include TreeVitalize, Stream ReLeaf[2], the Chesapeake Bay Urban Tree Canopy Expansion Initiative, and a suite of initiatives offered under the guidance of cooperators, including the Alliance for the Chesapeake Bay, The Chesapeake Bay Foundation, The Western Pennsylvania Conservancy, and DEP lists. A watershed forester working in the Rural and Community Forestry (CFM) section coordinates BOF efforts in riparian projects. Bureau of Forestry (BOF) Service Foresters throughout the state work with landowners to implement watershed programs on private lands.

- Since 2000, this cooperative effort among state, federal, and nonprofit organizations has resulted in the restoration of over 2,100 miles of forested buffers in the Chesapeake Bay drainage alone.

[2] http://www.dep.state.pa.us/dep/deputate/watermgt/WC/Subjects/StreamReLeaf/default.htm

- A Keystone Opportunity Zone model program could be created to package incentives for private investment in establishing forests on marginal lands.

***Enabling Programs, Programs May Provide Relevant Information in Support of Implementation***

• DEP's Bureau of Abandoned Mine Reclamation develops plans for handling AML in Pennsylvania. In the era of the Department of Environmental Resources, BOF had a program called Project 20 for mine land reclamation.[3]

**Potential Overlap:** None.

**Data Sources:**

- J.E. Smith et al. 2006. *Methods for Calculating Forest Ecosystem and Harvested Carbon With Standards Estimates for Forest Types of the United States*, GTR NE-343. USFS Northern Research Station. (Also published as part of the DOE Voluntary GHG Reporting Program).
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[3] See: http://www.depweb.state.pa.us/abandonedminerec/site/default.asp?abandonedminerec.