Restoring Mined Lands at the University of Kentucky's Robinson Forest: A Comprehensive Report of Restoration Activities

2015-2017

Mission

Green Forests Work's (GFW) mission is to re-establish healthy and productive forests on formerly mined lands in Appalachia.

Vision

GFW's vision is to create a renewable and sustainable multi-use resource that will provide economic opportunities while enhancing the local and global environment by converting reclaimed, non-native grasslands and scrublands into healthy, productive forestland.

Our reforestation projects provide jobs for equipment operators, nursery workers, and tree planters, and improve the environment by eradicating exotic species and restoring ecosystem services. With the help of our partners and volunteers, this vision is quickly becoming a reality…

Since 2009, we have planted more than two million trees on more than 3,200 acres,
but there are nearly one million acres left to reforest.

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Twenty year old research plots on a surface mine in Breathitt County Kentucky show how the Forestry Reclamation Approach allows native forests to be re-established after reclamation.

Front Cover: Active reclamation to pasture post-mining land use taking place on a surface mine adjacent to Robinson Forest. Photo © Michael Garland

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BACKGROUND

Robinson Forest is the University of Kentucky's experimental forest that is used for research, extension, and education. It is comprised of two main tracts: 1) The main block (Figure 1) contains second-growth forest and is the largest contiguous forest in the area (4,200 ha); 2) The Paul Van Booven Wildlife Management Area (PVB-WMA) tract (1,900 ha) contains previously mined land that was reclaimed to pasture/hayland and wildlife habitat (Figure 2). Because of its large size and unfragmented nature, the main block of Robinson Forest supports the full range of neotropical migratory bird species that are expected in this part of North America. Some wildlife species that are or are being considered for federal listing under the Endangered Species Act of 1973 are found in the Forest, such as the Indiana bat (*Myotis sodalis*), northern long-eared bat (*Myotis septentrionalis*), Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), Cerulean Warbler (*Setophaga cerulea*), and the Kentucky arrow darter (*Etheostoma spilotum*). On the other hand, the PVB-WMA mostly consists of early successional habitat dominated by exotic plant species, providing very few ecosystem services relative to the main block. The reclaimed areas have remained in a state of arrested natural succession for approximately 30 years due to the excessive soil compaction caused by reclamation. Without intervention, the mined areas are likely to stay this way for decades if not centuries.

To restore the original forest composition and the many ecosystem services it provided, Green Forests Work has been conducting mined land reforestation projects and other restoration work in Robinson Forest since 2015 (Figure 3). This report is organized by the restoration activities that have taken place, which include mined land reforestation, establishing demonstration plots on invasive species removal techniques, and improving stream crossings.

Figure 1. Second-growth mixed mesophytic forest in the main block of Robinson Forest.

Figure 2. Typical cover on surface mined lands reclaimed to pasture, hay, or wildlife habitat post-mining land use, as seen in this photo at the PVB-WMA.

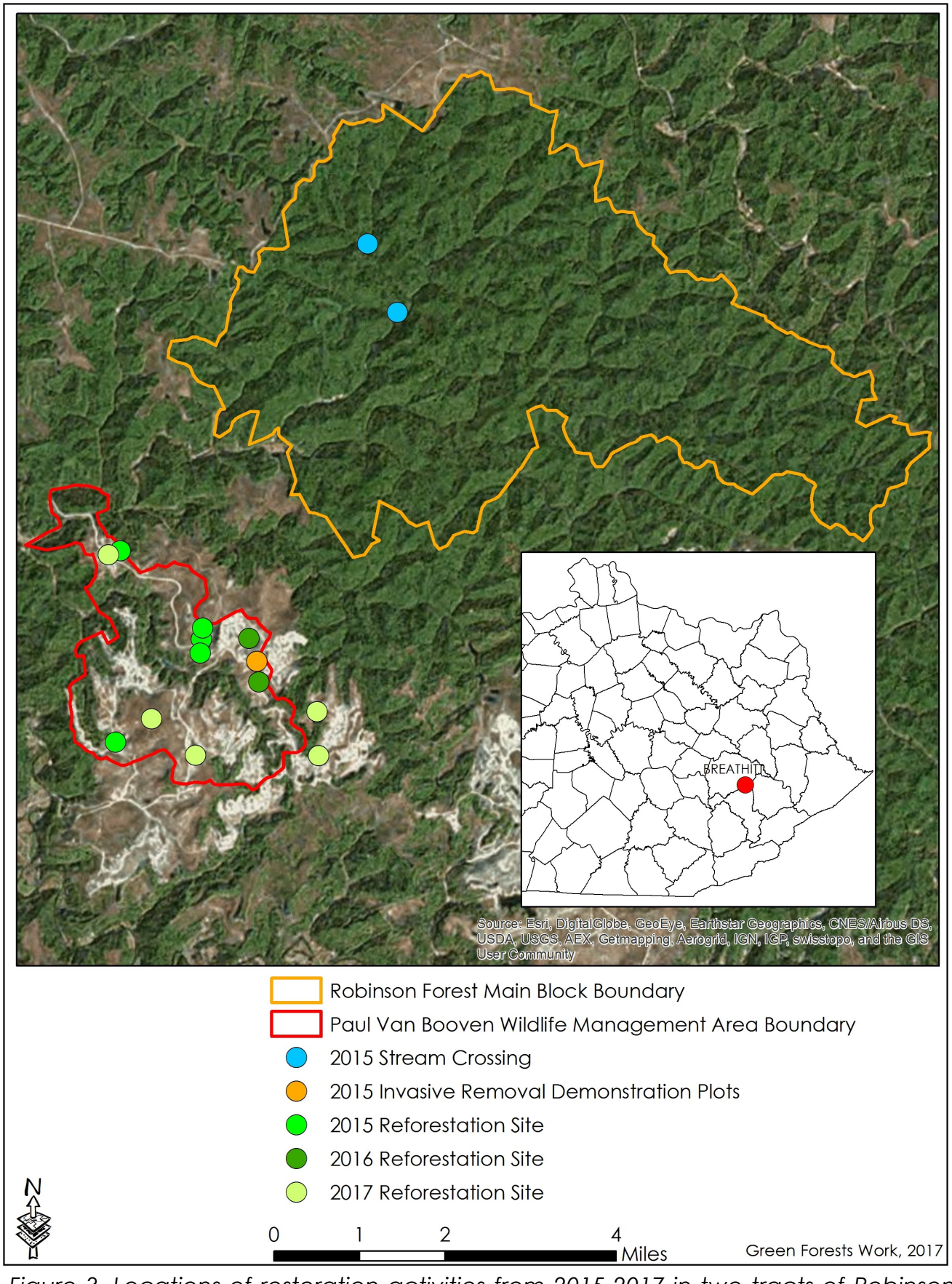

Figure 3. Locations of restoration activities from 2015-2017 in two tracts of Robinson Forest.

SUMMARY

Mined Land Reforestation

- From 2015-2017, more than 60 acres of surface mined land in the PVB-WMA and more than 30 acres on adjacent property were reforested with 70,000 native trees and shrubs by a combination of volunteers and professional tree planters.
- Approximately 400 volunteers representing 22 unique groups from at least 10 different states were engaged during 14 volunteer events.
- American chestnuts were planted at several of the reforestation sites and an American chestnut orchard was established.
- Two experimental studies were incorporated with reforestation projects.

Invasive Species Removal Demonstration Plots

- Demonstration plots for examining three methods of Autumn olive removal (mulcher, basal bark, and chainsaw) were established in 2015 along the main road of the PVB-WMA and monitored for three years.

Stream Crossing Improvement

- In 2015, two sections of road near stream crossings that were eroding into Clemons Fork were properly sloped and reinforced with geotextile fabric, rock, and cellular confinement material to minimize surface runoff and erosion into the stream which is inhabited by Kentucky Arrow Darters.

Education & Outreach

- Three tours and professional training opportunities were offered at the reforestation site and stream crossing improvement area. Approximately 130 individuals attended these events.
- The reforestation sites were used as outdoor classrooms for six university courses (UK FOR 356; UK NRE 320; UNC ENEC 698) from 2015-2017, reaching 108 students.
- Three educational kiosks were built and erected in the project areas: two were located near stream crossings and one was located between Sites 2 and 5 on PVB-WMA.

THE APPALACHIAN REGIONAL REFORESTATION INITIATIVE: THE BEGINNING OF GREEN FORESTS WORK

Surface mining in Appalachia has replaced approximately one million acres of eastern deciduous forest, one the most diverse and valuable forests in the world, with primarily non-native grasses and shrubs. Understanding the reasons behind this requires a brief history of mine reclamation, starting with the Surface Mining Control and Reclamation Act (SMCRA) of 1977. This act created the U. S. Office of Surface Mining Reclamation and Enforcement (OSMRE), whose mission was to enforce a new set of reclamation guidelines that would standardize reclamation practices for the mining industry. Prior to SMCRA, some mining operations practiced "shoot 'n shove" mining, where overburden was "shot" off the coal seam and "shoved" downhill. Revegetation requirements were minimal and varied from state to state, as there was no national standard. The loose piles of overburden could support tree growth, but they were also highly unstable. As a result, large landslides occurred and created a hazard to public safety. SMCRA addressed this issue by requiring more intense grading. The overburden was used to backfill the mined area to achieve the approximate original contour, but the grading led to severe soil compaction. Native hardwood trees could not tolerate the compaction and competition from aggressive groundcovers, so mining operations moved away from forestry reclamation (i.e. planting trees) to establishing hayland/pasture to meet revegetation requirements. Without management, the pastures were quickly (within 10 years) overcome with invasive, exotic species and resided in a state of arrested succession. Researchers foresaw the unintended consequences of SMCRA and began developing a method of reclamation in the 1980s that would allow both stability and tree growth. By 2004, there were numerous scientific studies supporting what became known as the Forestry Reclamation Approach (FRA).

The OSMRE created ARRI in 2004 to coordinate the implementation of the FRA. After making progress with the active mining industry, ARRI members began to look back at the sites reclaimed under SMCRA that led to their establishment, so called "legacy" mines. Experimental re-reclamation of legacy mines by ARRI members revealed the need for increased scale to stimulate the economic development and environmental improvement Appalachia needed, thus the idea of Green Forests Work was born. Further research laid the groundwork for the modified version of the FRA that we use today.

MINED LAND REFORESTATION

Reforestation Procedure

Simply planting trees on formerly mined lands would result in reforestation failure, which is why mine operators planted grasses and legumes instead. The site must be re-reclaimed in order to support tree growth. The methods used in this process are a modified version of the Appalachian Regional Reforestation Initiative's (ARRI) Forestry Reclamation Approach (FRA). For further details on ARRI, the FRA, and changes in mine reclamation, see page 5. The following explanation of the reforestation procedure is applicable to every year of mine land reforestation work.

Unwanted Vegetation Removal

Formerly mined lands are mostly dominated by non-natives such as autumn olive (*Elaeagnus umbellata),* sericea lespedeza *(Lespedeza cuneate)*, and tall fescue (*Festuca arundinacea*). Native trees rarely regenerate naturally, and the ones that do are often severely stunted due to soil compaction. To mitigate the soil compaction, the existing woody vegetation must be removed. An effort is made to avoid native plants that are growing similarly to those on undisturbed sites. Local contractors are hired to perform brush removal using a large bulldozer with a brushing blade (Figure 4). The debris is pushed into piles around the project perimeter. The brush piles quickly decompose and provide suitable medium for natural regeneration. In the meantime, they also provide food and shelter for wildlife. If there is too much brush, an air-burner is brought on site to incinerate the debris.

The effectiveness of controlling unwanted vegetation at improving tree survival is still largely unknown. Targeted herbicide applications are made on a case-by-case basis.

Figure 4. The unwanted vegetation is cleared using a dozer with a blade.

Soil Decompaction

Mitigating soil compaction is the most important factor in putting mined lands on a trajectory toward becoming a native forest again; it allows the site to naturally regenerate while tree plantings facilitate the process. To mitigate soil compaction, local contractors are hired to deep-rip the ground using a large bulldozer equipped with one or two, 3-4-foot long ripping shank(s), mounted behind each track (two shanks; Figure 5) or between the tracks (single shank). The rips are spaced eight feet apart, and the sites are cross-ripped (rips in perpendicular directions) to create an 8-foot by 8-foot grid after cross-ripping (Figures 6-7). Ripping in done when the soil is dry to maximize soil fracturing, typically in the fall.

Figure 5. Dozer with dual ripping shanks mounted behind each track.

Figure 6. This picture highlights the difference in ripped (right) and un-ripped (left) ground after ripping in a single direction.

Figure 7. A project site after cross-ripping. Note the crosshatch pattern.

Native Tree and Shrub Planting

In the spring following ripping, the site is planted with a variety of native trees and shrubs by volunteers, professionals, or a combination of both. Volunteer events provide a great opportunity for education and outreach (page 20). Locally adapted one-year-old, bareroot seedlings are purchased from the State's Division of Forestry and local private nurseries. Plantings primarily consist of native hardwoods for their future timber value, but also consist of soft woods and shrubs to increase biodiversity, benefit wildlife and pollinators, and support initiatives that aim to re-establish declining species such as Shortleaf Pine (*Pinus echinata*). The planting prescription varies for each site. Site specific factors such as soil characteristics, elevation, surrounding forest cover, and others are used to develop a species list and the prevalence of each species. The trees and shrubs are planted near the intersections of the cross-rips, where the least soil compaction exists. As the site matures, it will take on a less uniform structure and blend with the surrounding area.

MINED LAND REFORESTATION

2015

From 2014-2015, six different sites in the PVB-WMA were planted (Figure 8), reforesting over 39 acres with 26,550 seedlings (Table 1). The unwanted vegetation was controlled with a broad spectrum herbicide, and the woody vegetation was incinerated using an on-site air-burner in 2014. Soil decompaction took place in August 2014 using a D-9 bulldozer equipped with two, 3-foot long shanks. For more details on site preparation, see pages 6-7.

Site 1 served as the sole volunteer reforestation site in the spring of 2015. Approximately 6,140 bareroot seedlings were planted on approximately 8.7 acres throughout five volunteer events. Nearly 130 volunteers from Appalachian State University (NC), Boy Scouts of America (KY), Berea College (KY), Drew University (NJ), Elon University (NC), Emory University (GA), Georgetown College (KY), Mitchell College (CT), Sierra Club (KY), University of Kentucky (KY), and the University of North Carolina (NC) contributed approximately 700 work-hours during these volunteer events.

In addition to planting one-year-old bareroot seedlings at Site 1, 200 1-gallon containerized American basswood (*Tilia americana*), sourwood (*Oxydendrum arboreum*), and yellow poplar (*Liriodendron tulipifera*) seedlings were planted in December 2014 to benefit pollinators and serve as perch trees for songbirds.

After the volunteer events, the sites were completed by professional tree planters.

Funding for this year's activity was primarily provided by the US Forest Service - State and Private Forestry through the National Fish and Wildlife Foundation.

Aerial photograph of sites 2, 5, and 6 after cross-ripping. The patch with orange colored soil is maintained as a grassland for elk viewing.

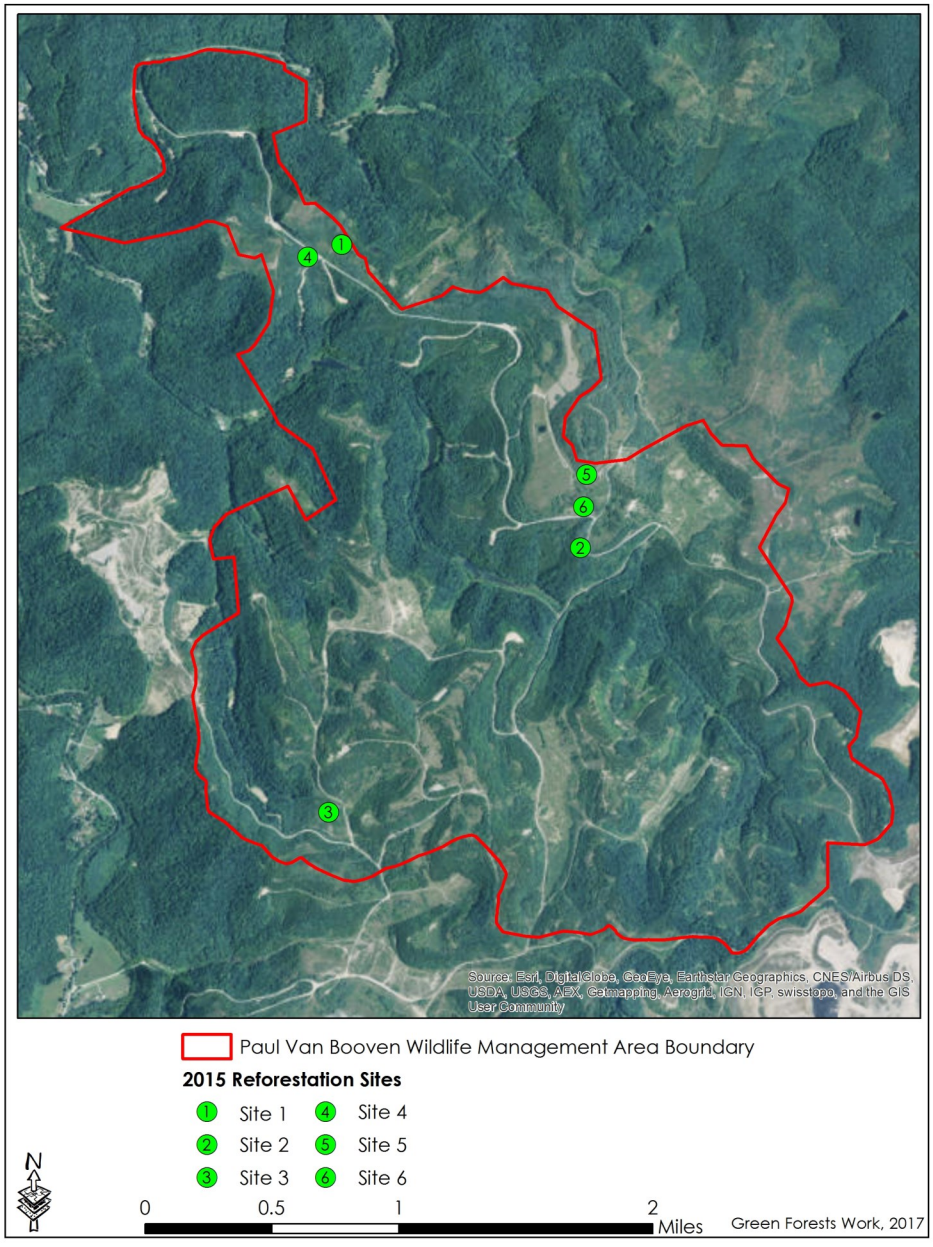

Figure 8. Reforestation sites in the PVB-WMA in 2015.

Event No.	Event Date	Event Type	Acres Planted	Trees Planted	Volunteer Participants	Site No.
1	12/18/2014	Volunteer	0.3	200[1]	3	1
2	3/11/2015	Volunteer	3	2,040	51	1
3	3/13/2015	Volunteer	1.5	1,020	19	1
4	3/14/2015	Volunteer	1	680	10	1
5	3/27/2015	Volunteer	2	1,400	14	1
6	3/28/2015	Volunteer	1.5	1,000	35	1
7	4/6 - 4/17/2015	Professional	30	20,210	0	1-6
Total			**39.3**	**26,550**	**132**	

[1] 1-gallon containers

Table 1. Summary of 2014-2015 reforestation events.

MINED LAND REFORESTATION

2016

Two sites in the PVB-WMA were reforested in 2016 (Figure 9), and Site 1 (2015 site) was interplanted, totaling nearly 14 newly reforested acres with more than 9,000 seedlings planted (Table 2). At Site 7, the woody vegetation was eliminated in February 2016 using an air-burner to maximize project area. Brushing was not needed at Site 8. Soil decompaction at both sites took place in March 2016 using a D-9 bulldozer equipped with two, 3-foot long shanks. For more details on site preparation, see pages 6-7.

At Site 7, nearly 40 volunteers from Appalachian State University (NC), Drew University (NJ), Xavier University (OH), and Radford University (VA) planted approximately 1,800 seedlings on approximately 2.6 acres. The remaining acreage was planted by local professionals.

Site 8 was used as an experimental site for determining the carbon sequestration potential of Shortleaf Pine (*Pinus echinata*) compared to mixed pine and oak and grass/shrub land. The ability of a native pine to compete with migratory and non-native southern pine (Loblolly) species was also examined. Students from the University of North Carolina (UNC) designed and conducted the project experiment for their capstone project in an environmental science class (Figure 10). Volunteers from Keene State College (NH), the University of Massachusetts (MA), and the UNC students planted the entire site. Monitoring at the site began in 2017 (see page 14).

Severe browse was noted in Site 1 during the winter of 2015/2016, likely due to white-tailed deer. To offset some seedling loss and damage, an interplanting was conducted in the spring of 2016 by 85 volunteers from Viper Elementary (KY), Hazard High School (KY), Buckhorn High School (KY), and Indianapolis Christian Theological Seminary (IN). Prior to planting, the students participated in an educational activity on pollinators and how the reforestation project will produce pollinator-friendly habitat (Figure 11).

Funding for 2016 restoration work was also provided by the National Fish and Wildlife Foundation's Appalachian Forest Renewal Initiative and the Tracy Farmer Institute for Sustainability and the Environment.

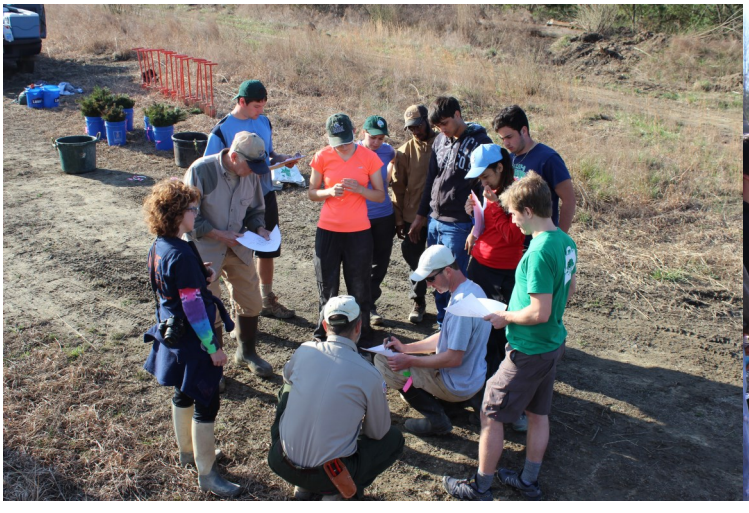

Figure 10. Students from UNC review their plot layout before hitting the field to plant.

Figure 11. Students are educated on pollinators prior to the interplanting event.

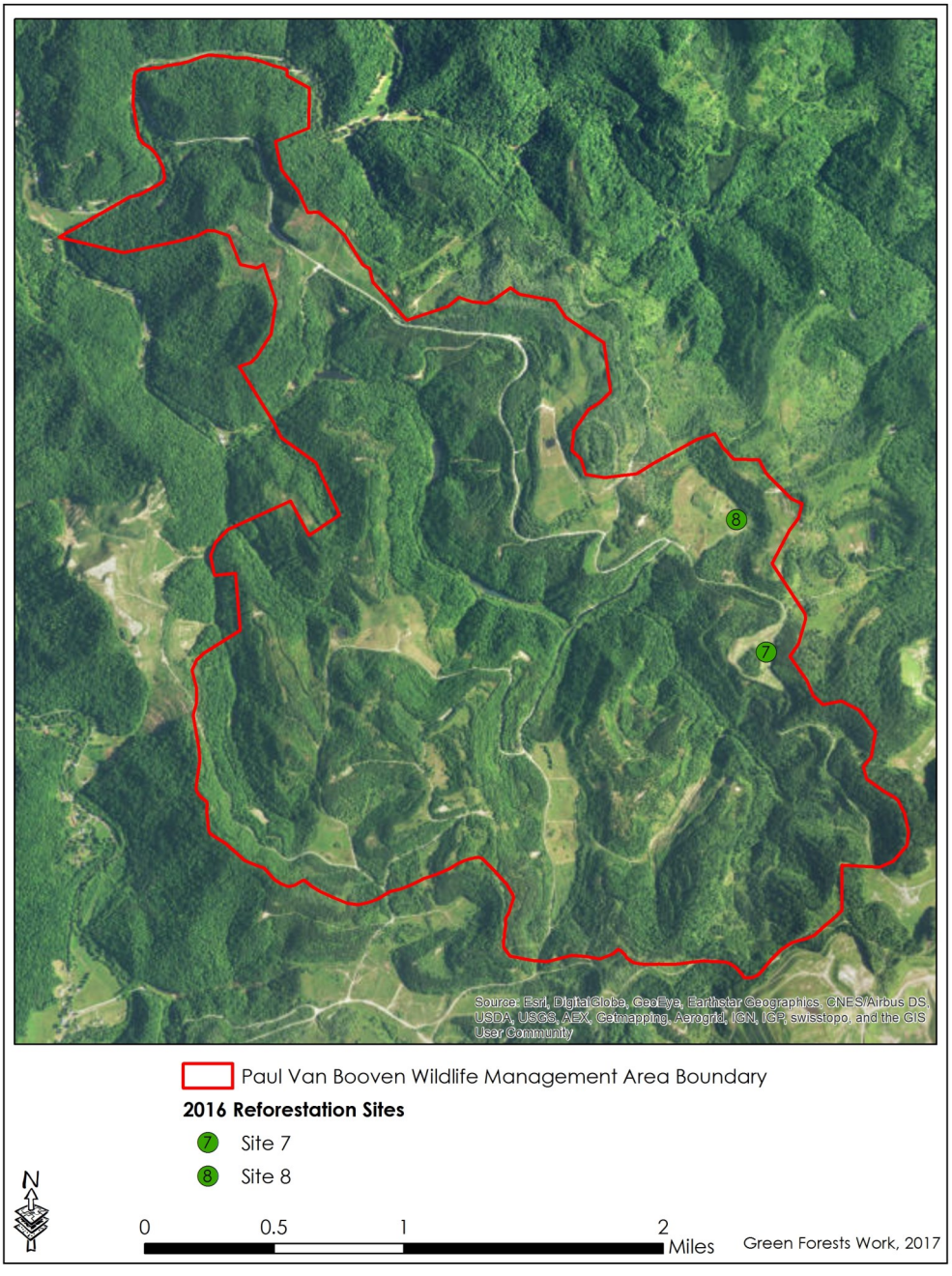

Figure 9. Reforestation sites in the PVB-WMA in 2016.

Event No.	Event Date	Event Type	Acres Planted	Trees Planted	Volunteer Participants	Site No.
1	3/09/2016	Volunteer	2.6	1,800	39	7
2	3/15/2016	Volunteer	0.75	600	16	8
3	3/16/2016	Volunteer	3.2	1,300	22	8
4	4/15/2016	Volunteer	2.2[1]	1,500	85	1
5	4/30 - 5/2/2016	Professional	5.7	3,907	0	7
Total			**14.5[2]**	**9,107**	**162**	

[1] Interplanting

[2] Unique acres. Interplanting not included.

Table 2. Summary of 2016 reforestation events.

MINED LAND REFORESTATION

2017

Three sites in the PVB-WMA and two sites on Revelation Energy's property were reforested in 2017 (Figure 12), and Site 1 was interplanted, totaling nearly 43 newly reforested acres with more than 34,000 seedlings planted (Table 3). Brush removal at Sites 9-10 took place in December 2016 using a D-6 bulldozer. Sites 11-12 were recently reclaimed, so brushing was not needed. Soil decompaction also took place in December 2016 at Sites 9-10 using a D-9 bulldozer equipped with two, 3-foot long shanks mounted behind each track. Revelation Energy performed ripping on their property using a D-11 with a single, 3-foot long shank mounted between the tracks. For more details on site preparation, see pages 6-7.

Sites 9-12 were reforested as part of a University of Kentucky, Department of Forestry study on the impacts of mammal herbivory on Kentucky surface mine reforestation efforts. Each of the four sites contained three, 1/3-acre seedling plots: 1) No exclusion, where herbivores have complete access to seedlings; 2) Half exclusion, where tree protectors are placed around each seedling (Figure 13); 3) Full exclusion, where tree protectors are placed around each seedling and the plot is surrounded by an 8-foot tall fence. Each plot contains an equal mix (108 seedlings/species) of white oak (*Quercus alba*), black locust (*Robinia pseudoacacia*), and shortleaf pine (*Pinus echinata*) and was planted by professionals who also installed the tree protectors, resulting in 3,888 total seedlings planted. Areas surrounding the study plots were also reforested using a variety of native species.

The areas surrounding the study plots at Sites 9-10 were primarily planted by approximately 106 volunteers, including participants from the Dimensions of Political Ecology conference (multiple states and countries represented), Christian Theological Seminary (IN), Sierra Club (KY), and from Eastern Kentucky University (KY), Hazard Community and Technical College (KY), and a newly formed initiative, Kentucky Writers and Artists for Reforestation (Figure 14).

Figure 13. A professional planter installs a tree protector around a seedling in one of the half exclusion plots.

Figure 14. Kentucky Writers and Artists celebrated our two-millionth tree planted in an area surrounding the study plots at Site 9.

Photo © Michael Garland.

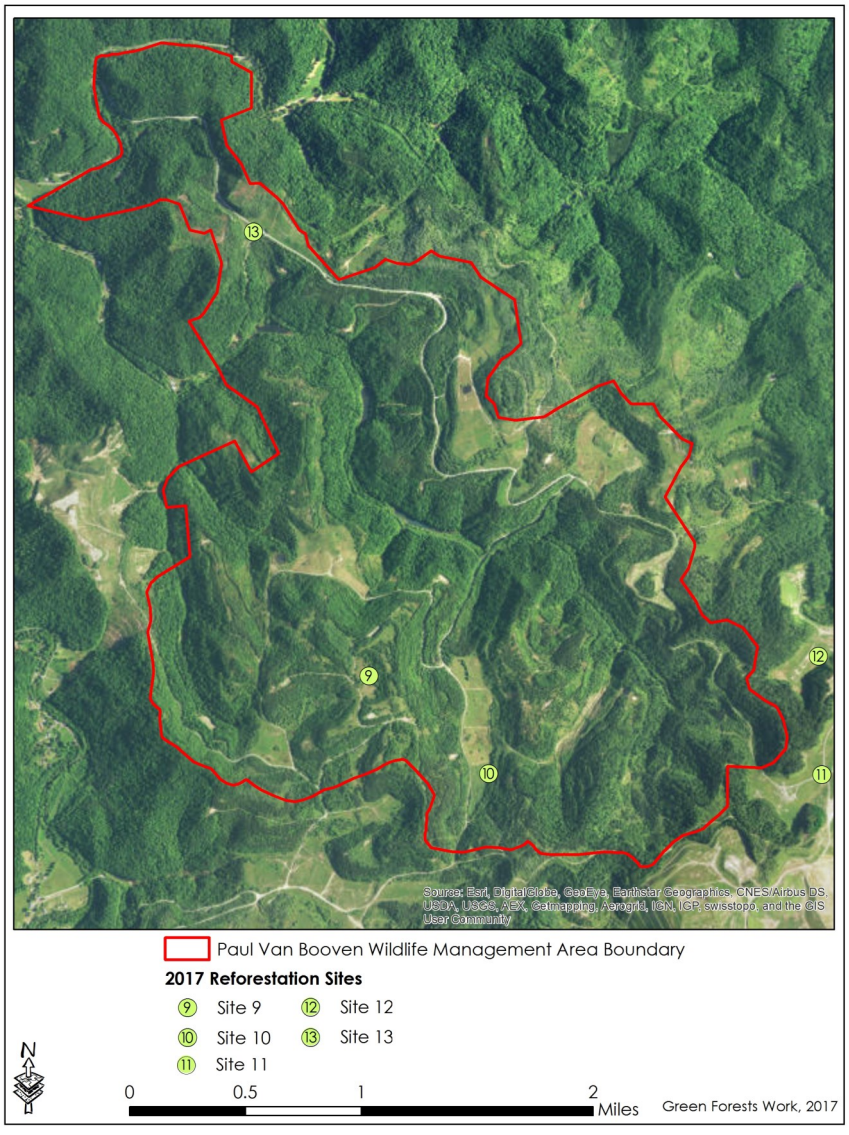

Figure 12. Reforestation sites in 2017.

Event No.	Event Date	Event Type	Acres Planted	Trees Planted	Volunteer Participants	Site No.
1	2/7/2017	Professional	34	21,050	0	9, 11, & 12
2	2/23/2017	Volunteer	1	600	10	10
3	3/6/2017	Volunteer	1.0[1]/0.25	375	34	10
4	3/24/2017	Professional	3	3,900	0	9-10
5	3/24/2017	Professional	10[1]	5,000	0	1
6	4/19/2017	Volunteer	0.25	100	22	13
7	4/22/2017	Professional	0.75	500	0	9
8	4/22/2017	Volunteer	3.5	2,420	40	9
9	4/23/2017	Professional	0.25	120	0	9
Total			**43[2]**	**34,065**	**106**	

[1]Interplanting

[2]Unique acres. Interplanting not included.

Table 3. Summary of 2017 reforestation events.

MINED LAND REFORESTATION

Site 13 was planted as an American chestnut orchard (*Castanea dentata*) using the The American Chestnut Foundation's most advanced generation of potentially blight-resistant seedlings. Volunteers from Hazard High School planted the seedlings and placed a tree protector and weed mat around each tree (Figure 15). This site was prepared during 2015, but experienced high mortality due to herbivory and weather. Members of the Christian Theological Seminary planted a few ceremonial American chestnuts at Site 10 as well after singing a *Blessing of the Chestnut*.

Severe browse was noted in Site 1 during the winter of 2015/2016, likely due to white-tailed deer. The intensity of browse at this site is partly what prompted the University of Kentucky browse study. To offset some seedling loss and damage, an interplanting was conducted in the spring of 2016 (see page 10) and again in 2017.

Students from the University of North Carolina returned to Site 8 to remeasure the 2016 plots (see page 10) and collected soil samples from the site to test for *Phytophthora*, which causes crown and root rot diseases in many trees and shrubs.

Funding for this year's activity was provided by the Kentucky Sustainable Forestry Initiative, Brad and Shelli Lodge-Stanback, the Arbor Day Foundation, and Treecycler.

Figure 15. An American chestnut is protected from herbivory and competition with a shelter and weed mat in a chestnut orchard established by students from Hazard High School.

2015-2017 Summary

From 2015-2017, including a winter 2014 planting, more than 60 acres of surface mined land in the PVB-WMA and more than 30 acres on adjacent property were reforested with nearly 70,000 native trees and shrubs; approximately 400 volunteers representing 22 unique groups from at least 10 different states were engaged during 14 volunteer events (Table 4).

Six of the sites (Sites 8-12) are being used for two on-going experiments: 1) Site 8 is being used by UNC undergraduates to examine the carbon sequestration potential of Shortleaf Pine compared to mixed pine and oak and grass/shrub land, and the ability of a native pine to compete with migratory and non-native southern pine species. 2) Sites 9-12 are a part of a University of Kentucky study on the impacts of mammal herbivory on Kentucky surface mine reforestation efforts.

The American Chestnut Foundation's most advanced generation of potentially blight-resistant seedlings have been included in the planting mix at numerous sites, and an American chestnut orchard was created at Site 13.

Event No.	Event Date	Event Type	Acres Planted	Trees Planted	Volunteer Participants	Site No.
1	12/18/2014	Volunteer	0.3	200	3	1
2	3/11/2015	Volunteer	3	2,040	51	1
3	3/13/2015	Volunteer	1.5	1,020	19	1
4	3/14/2015	Volunteer	1	680	10	1
5	3/27/2015	Volunteer	2	1,400	14	1
6	3/28/2015	Volunteer	1.5	1,000	35	1
7	4/6 - 4/17/2015	Professional	30	20,210	0	1-6
8	3/09/2016	Volunteer	2.6	1,800	39	7
9	3/15/2016	Volunteer	0.75	600	16	8
10	3/16/2016	Volunteer	3.2	1,300	22	8
11	4/15/2016	Volunteer	2.2[1]	1,500	85	1
12	4/30 - 5/2/2016	Professional	5.7	3,907	0	7
13	2/7/2017	Professional	34	21,050	0	9-12[2]
14	2/23/2017	Volunteer	1	600	10	10
15	3/6/2017	Volunteer	1.0[1]/0.25	375	34	10
16	3/24/2017	Professional	3	3,900	0	9-10
17	3/24/2017	Professional	10[1]	5,000	0	1
18	4/19/2017	Volunteer	0.25	100	22	13
19	4/22/2017	Professional	0.75	500	0	9
20	4/22/2017	Volunteer	3.5	2,420	40	9
21	4/23/2017	Professional	0.25	120	0	9
Total			**96.8[3]**	**69,722**	**400**	

[1]Interplanting

[2]Sites 11-12 located outside PVB-WMA

[3]Unique acres. Interplanting not included.

Table 4. Summary of 2014-2017 reforestation events.

INVASIVE REMOVAL DEMONSTRATION

2015

Demonstration plots for examining methods of Autumn olive (*Elaeagnus umbellata)* removal were established in the fall of 2014 (Figure 16). Four, 30-m by 5-m plots were established adjacent to the main road in the PVB-WMA, making it convenient for drive-by demonstrations.

In the spring of 2015, three of the plots were treated and one remained untreated as a control. Treatments included mulching/ herbicide (Figure 17), chainsaw/herbicide (Figure 18), and foliar herbicide application (Figure 19). Mulching was performed using a heavy-duty forestry mulcher mounter on a skid -steer. Stumps from the mulcher and chainsaw treatments were treated with herbicide to prevent resprouting. Herbicide used for all treatments consisted of Garlon 4 and diesel fuel (40% Garlon 4 and 60% diesel).

Funding for this project was provided by the National Fish and Wildlife Foundation's Appalachian Forest Renewal Initiative.

Figure 16. Autumn olive removal demonstration sign along main road of PVB-WMA.

Figure 17. Mulcher demonstration plot.

Figure 18. Basal bark demonstration plot.

Figure 19. Chainsaw demonstration plot.

Monitoring was performed in the late summer of 2015 and 2016. Shrubs within the plots were measured for the number of stems, height, stem diameter at ground level, and canopy spread. Data showed an inverse relationship between the size of the autumn olive and the number of stems present. Essentially, plots with the larger shrubs contained fewer stems (Table 5). This relationship could be the result of stem exclusion where larger shrubs outcompete smaller shrubs for light, nutrients, and water resources.

Treatment implementation was successful and 100% of Autumn olive was killed in the treatment plots. An assessment of the plots was performed in the late summer of 2015 and no resprouts or newly germinated autumn olive was detected in the treatment plots. The plots were inventoried again in late summer of 2016 and some resprouting and new plants were found (Table 5). Data for the 2016 survey suggested that the basal bark treatment was most effective for preventing resprouting (0% resprouted) followed by chainsaw (17% resprouted) and mulcher (60% resprouted). A similar trend was seen with regards to new sprouts. Basal bark had 15 new sprouts, chainsaw had 24, and mulcher had 34. Interestingly, the most expensive and time-consuming treatment (mulcher) proved to provide less control than the least expensive and time-consuming treatment (basal bark).

The effectiveness of mechanical Autumn olive removal with a bulldozer will be determined during reforestation site monitoring, beginning fall of 2016.

Treatment	Stems (#)		Height (m)		Diameter (cm)		Resprouts (%)	New Sprouts
	2014	2016	2014	2016	2014	2016	2016	2016
Mulcher	123	108	3.69	0.21	18.09	2.38	60	34
Basal Bark	122	15	3.89	0.07	27.17	0.07	0	15
Chainsaw	95	40	4.26	0.16	27.99	1.69	17	24
Control	78		4.54		30.64			

Table 5. Autumn olive response before (2014) and after (2016) treatment.

STREAM CROSSING IMPROVEMENT

2015

There are two major road networks in Robinson Forest that follow the Clemons Fork and Coles Fork streams. The earthen roads are primarily positioned in the riparian areas of these streams and each contains several stream crossings. Of particular concern was the Clemons Fork road because of its close proximity to the forest facilities, where it is traversed daily for access to long-term hydrologic research sites on the forest. Each time a vehicle crossed through the stream, sediment was released,, which could have a deleterious effects on stream biota, including the Kentucky arrow darter (*Etheostoma spilotum*).

In October 2015, two sections of the Clemons Fork road were identified for improvement (Figure 19). The first area (Stream Crossing 1) was a sloped section of road that was eroding into Clemons Fork. At this location, a 550G bulldozer was used to slope the road for proper drainage. Next, 130' of geotextile fabric (12'x130') was applied along with 14 tons of #2 stone and 7 tons of #57 stone. These activities will armor the roadbed and minimize surface runoff and erosion into the stream.

The second area was a stream crossing located near the confluence of Shelly Rock Fork and Big Millseat Branch (Stream Crossing 2), both within the Clemons Fork watershed. The crossing and approaches were 210' in length (Figure 20). Here, the same bulldozer was used to re-shape the existing road. Subsequently, 60' of geotextile fabric (12'x60') was placed underneath 60' of cellular confinement material (10'x60') (Figure 21). The confinement material was then filled with in-situ material (sand and rock) which had been excavated from the road surface. On top of the native soil we applied geotextile fabric and stone to the top of the cellular confinement. The crossing improvement used 150' of geotextile on top of 60' of confinement material and capped with 35 tons of stone (#2's and #57's).

Funding for this project was provided by the National Fish and Wildlife Foundation's Appalachian Forest Renewal Initiative.

Figure 20. Unimproved approach prior to construction.

Figure 21. Geotextile and confinement fabric placement.

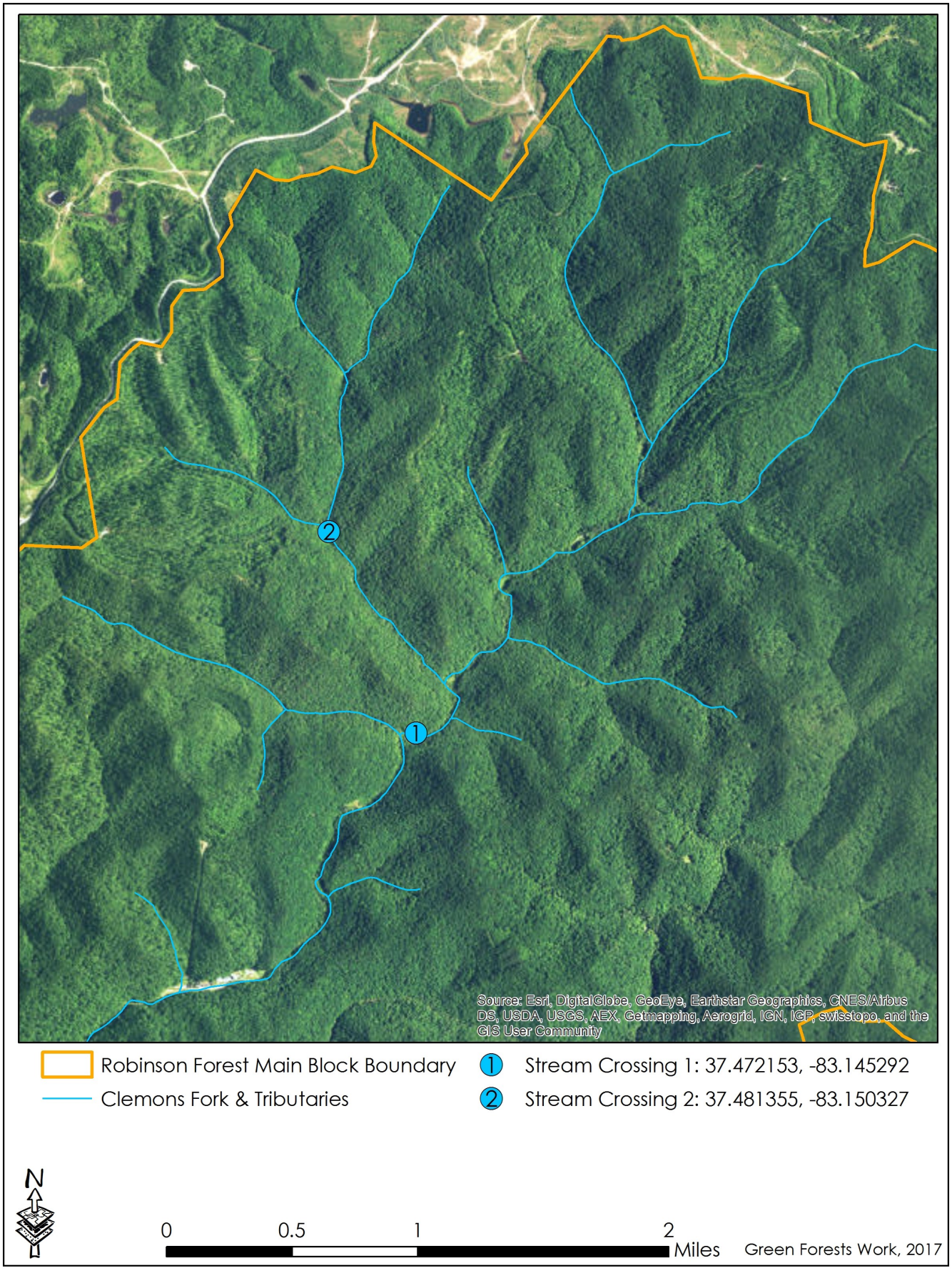

Figure 19. Stream crossing locations in the main block of Robinson Forest.

EDUCATION & OUTREACH

2015-2017

As one of few public lands in Kentucky that contains surface mined and healthy native forests, Robinson Forest provides unique opportunities for education and outreach. The following highlights a few of those opportunities.

Volunteer Events

Although the majority of GFW's planting labor is performed by professionals, volunteer tree planting events are great way to educate people on important issues related to deforestation caused by surface mining and to empower people to take action. Volunteers are taught tree planting techniques, the history of reclamation, methods used to implement the reforestation project, as well as the benefits of reforestation.

News Coverage

Some of the planting events were covered by local media, allowing GFW's message to be extended beyond the planting event:

- http://www.kentucky.com/news/local/article44561835.html
- http://www.wymt.com/content/news/Students-help-restore-old-reclaimed-coal-mine-375917091.html

Educational Materials

- Two educational kiosks explaining the stream crossing improvements were installed near the stream crossings.
- A kiosk explaining mine land reforestation was installed near Site 2.
- The sites were used for teaching NRE 320 and FOR 356 University of Kentucky courses in 2015, 2016, and 2017(six classes).
- Students from UNC used a reforestation site as an outdoor classroom for a project they did to examine reforestation growth in 2016 and 2017.
- The 2016 and 2017 reports prepared by the UNC students will be used to help inform future research needs.
- The projects were highlighted on GFW's social media platforms, website, and newsletter.
- An article highlighting the project will be published in KY Woodlands.
- Work will be highlighted in a chapter of a book entitled: **Engaging Appalachia: A Guidebook for University-Community Partnerships**

Tours & Demonstrations

- June 2015: The project sites were used during the American Society of Mine Reclamation and Appalachian Regional Reforestation Initiative annual conference field trip.
- January 2016: Natural Resources Conservation Service and Kentucky Division of Forestry personnel were given a demonstration on Green Forests Work's site preparation methods.
- August 2016: The kiosk explaining the stream crossing improvement was used during a demonstration event for Kentucky Division of Forestry.
- 2016: Eight ministers toured the site as part of a retreat to Appalachia.

Students from UNC collect data from Site 8 in 2017.

Students from Viper Elementary and Hazard High School learn proper tree planting techniques at 2015 planting event.

NRCS and KY Division of Forestry employees see site preparation procedures at January 2016 field demonstration.

Volunteers at the 2017 Earth Day event learned about the need for reforestation in Appalachia.

Students from UNC performing data collection.

Volunteers at Site 7 learn about the history of reclamation from ARRI partner.

DISCUSSION

Robinson Forest is a top priority for mined land reforestation efforts in the state. Since the main block of Robinson Forest supports numerous species of concern and services many others, protecting the forest's health is critical so the many ecosystem services it provides can continue to function optimally. Surface mines jeopardize forest health by providing a plentiful seed source of non-native and invasive plants. Replacing the unwanted vegetation with native trees and shrubs will not only protect the surrounding forest's health, but it will also increase its resilience to other threats such as climate change, as larger and more complex contiguous forests are more capable of adapting. The newly created forest will also benefit wildlife in the short term by creating an early successional habitat, which many species depend on for breeding, habitat, or food sources.

In addition to the many ecological reasons for conducting restoration in and around Robinson Forest, it is also a prime location because of the unique opportunities for research, education, and outreach it provides, as it is one of few public lands in Kentucky that contains surface mined land and healthy native forests. The research that is being conducted will help make future management decisions, such as thinning, the effectiveness of herbicide use at improving tree survivability or whether some groundcover may improve tree survival, and how to increase tree survival in heavily browsed areas. The many projects and demonstration plots have made the PVB-WMA a great location for training environmental professionals and providing hands-on activities for students in environmental fields. Involving local school groups in the planting events exposes younger students to these fields and the opportunities for them in their region.

Green Forests Work hopes to continue mined land reforestation in the PVB-WMA until all the disturbed areas have been restored.

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