1. **Cover Page**

APPALACHIAN sustainable DEVELOPMENT

- **Project Title**: *Increasing Landscape-Scale Adoption of Agroforestry Systems in Central Appalachia through Market-Based Incentives*
- **Grantee Name**: Appalachian Sustainable Development (ASD)
- **Project PD**: Katie Commender, ASD Director of Agroforestry
- **Key team member names**:
  - Gary Bentrup, USDA National Agroforestry Center
  - Tanner Filyaw, United Plant Savers
  - Dr. Ryan Huish, University of Virginia, College at Wise
  - Katherine MacFarland, USDA National Agroforestry Center
  - Andrea Miller, Rural Action
  - Dr. Christine Small, Radford University
- **Project start and end date**: 04/15/2020 - 04/15/2024
- **Award number (FAIN)**: NR203A750013G005

2. Project Summary

Appalachian Sustainable Development's (ASD) project titled, *Increasing Landscape-Scale Adoption of Agroforestry Systems in Central Appalachia through Market-Based Incentives*, took place in the Central Appalachian states of Virginia (VA), Tennessee (TN), North Carolina (NC), Ohio (OH), West Virginia (WV), and Kentucky (KY) in collaboration with five project partners: Radford University (RU), Rural Action (RA), the USDA National Agroforestry Center (NAC), United Plant Savers (UpS), and the University of Virginia, College at Wise (UVA Wise). The purpose of this project was to conserve threatened forest ecosystems and regenerate degraded cropland, by creating financial incentives that encourage forest farming and alley cropping adoption among EQIP eligible landowners. Addressing the NRCS national priority, "increasing the pace and scale of conservation adoption," the overarching goal of this project was to merge farmers' conservation and commerce goals to create a win-win for the adoption of these agroforestry practices.

To do so, project partners sought to develop equitable and accessible markets for agroforestry products, and provided certification, marketing, processing, aggregation, and distribution services to help farmers access those markets. This project also sought to identify best practices for sustainable harvest and propagation of goldenseal, an at-risk forest botanical that shows great promise for forest farming. Various publications and tools were created to help farmers make informed decisions about agroforestry adoption and management, including the following: a Solomon's Seal chapter in *The Forest Farmers Handbook* covering site selection to processing, an *Alley Cropping: Case Studies in Appalachia* fact sheet featuring demonstration sites developed through this project, and a Forest Farming Calculator to determine break-even prices. Lastly, agroforestry training and technical assistance was provided to farmers through on-farm site visits and farm tours to showcase designs, management techniques and lessons learned. By merging conservation and commerce goals and defining best practices, this project was able to increase the adoption of forest farming and alley cropping in Central Appalachia.

3. Project Goal and Objectives

Goal 1: *Enhance forestland conservation by increasing the adoption of sustainable and profitable forest farming practices in the forest understory as financial incentive.*

Objective 1: Conserve 1,800 acres of forestland under forest farming best management practices, including the mitigation of invasive species and biodiversity enhancement.

- 60 forest landowners receive a site visit and implement forest farming practices
- 25 forest farmers receive Forest Grown Verification and/or Organic Certification

Objective 2: Attract $35,000 of additional funding as a financial incentive to support forestland conservation through profitable cultivation of forest botanicals.

- 6 herb companies submit purchase orders and 1-2 contract farming agreements
- 25 forest farmers process and sell sustainably harvested forest botanicals

Objective 3: Conduct 1 economic analysis of forest farmed botanicals to quantify profit potential and break-even price points required from buyers for financially viable operations.

Objective 4: Develop 1 "farmer-friendly" plant population assessment and 1 sustainable harvest protocols to inform best management practices within the Multi-Story Cropping (MSC) conservation practice (code 379 and Plant Enhancement Activity PLT05).

- 1 forest farming fact sheet is created with USDA NAC for national dissemination
- MSC is recommended as an approved practice in KY, VA, TN, and NC

Goal 2: *Explore Alley Cropping with medicinal herbs and shrubs as an economically viable conservation practice with market-based incentives for adoption.*

Objective 1: Establish at least 4 alley cropping demonstration sites trialing economically important medicinal herbs and shrubs, to determine best practices for crop productivity, economic viability, and ecological enhancement.

- 1 alley cropping fact sheet is created with USDA NAC for national dissemination
- Alley cropping is recommended as an approved practice in KY and TN

4. Project Background

Agroforestry is a complex, intensive, and holistic land management practice that integrates trees with crops and/or livestock to provide many ecological, economic and social benefits, including wildlife and pollinator habitat, soil erosion reduction, water quality enhancement, food and fodder, and crop diversity for increased farm income (Chamberlain et al. 2018). There are five commonly accepted temperate agroforestry practices, including windbreaks, riparian buffers, silvopasture, alley cropping, and forest farming. Of these, forest farming and alley cropping are two proven conservation practices that hold great promise for Central Appalachia. Agroforestry dates back to early civilizations, however, with advances in modern agriculture and land-use changes, the management of such systems and their associated benefits have dissipated. Through an innovative attempt to increase landscape-wide adoption of agroforestry practices, project partners created a market-based incentives system to merge conservation and commerce.

This innovative approach started with *forest farming*, the cultivation or management of non-timber products in the forest understory (Chamberlain et al. 2009). The Appalachian roots of this agroforestry practice trace back to Native Americans and early settlers of the region. It is estimated that over half of native U.S. medicinals are found in the Appalachian Mountains (Greenfield and Davis 2003), and people have been wild harvesting these plants for generations for trade and medicine. Due to overharvesting for a growing market and habitat loss over the past 300 years, wild populations of species like American ginseng and goldenseal are in decline (Chamberlain et al. 2019). Consequently, they are now listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora. Forest farming provides an opportunity to meet growing demand, while conserving wild populations for future generations.

Alley cropping, or the production of herbaceous crops in the alleyways between trees or shrubs, is another proven conservation practice with great potential for increased adoption. This project explored an innovative design, using field grown medicinal herbs and shrubs as high value specialty crops for financial incentive to adoption. As much of the harvesting and processing of field grown medicinal herbs is similar to processes employed for tobacco, the Appalachian region is already well equipped to supply the growing herbal market. This multifunctional practice can restore available nitrogen in the soil, act as an upland buffer to improve water quality, and increase crop productivity and pollinator activity in coal impacted communities. Designing these systems with medicinal shrubs, like elderberry, and perennial herbs, like peppermint, diversifies a farm's income and resilience to loss from weather, pests, and markets.

5. Project Methods

Goal 1, Objective 1. Targeted outreach was conducted, including tabling events and workshops, to expand the forest farmer network. Applicants received a forest farming site visit conducted by ASD and RA, including a report outlining existing species, optimal growing sites, management, cultivation, and sustainable harvest recommendations, and resources. UpS worked with forest farmers to apply for Forest Grown Verification (FGV) to gain access to new markets. ASD's Appalachian Harvest Herb Hub (AHHH) provided processing equipment, and aggregation and marketing services to help forest farmers sell sustainably harvested herbs to fair wage markets. UpS, RA and ASD reviewed literature and interviewed producers to develop a second edition of the *Forest Farmers Handbook*, featuring a new seed to sale chapter on Solomon's Seal.

Goal 1, Objective 2. ASD's AHHH harnessed existing market connections and attended natural products expos to develop fair wage markets for herbs grown in alley cropping and forest farming systems. Contract farming agreements, as well as annual advanced purchase orders, were secured from domestic and international herbal products companies for agroforestry producers as financial incentive for adoption. ASD and UpS leveraged private investment from herbal industry partners to offset farmer start-up costs.

Goal 1, Objective 3. ASD developed tracking forms and collected seed to sale cost of production and harvest data from forest farmers in Central Appalachia. The USDA NAC used this data and literature reviews to develop the *Forest Farming Calculator*, an economic decision support tool that calculates break-even prices of commonly produced forest botanicals. The excel-based Calculator was built with default enterprise budgets that users can modify to evaluate the impact of fixed and variable costs on profitability. Feedback was obtained through an evaluative survey and live webinar demonstration, and incorporated into the published version. This tool was showcased to farmers and natural resource professionals in presentations at conferences and webinars, and through social media and newsletter outreach.

Goal 1, Objective 4. Partners at ASD, UpS, USFS, UVA Wise, and Radford University created farmer-friendly population assessment guidelines, to help forest farmers who steward wild plants and natural resource professionals (NRPs) inventory baseline populations of forest botanicals and assess population regeneration over time. Guidelines were created based on research experience by project collaborators (e.g., Chamberlain et al. 2013; Small and Chamberlain 2018) and FairWild criteria, and will be used to implement sustainable forest farming practices.

Project collaborators also conducted on-farm sustainable harvest research on goldenseal. Adapting methods developed by project partners in black cohosh studies (e.g., Chamberlain et al. 2013; Small and Chamberlain 2018), the team conducted harvest and root production research on goldenseal to determine population regeneration rates and sustainable harvest levels. On-farm research occurred in naturally occurring and forest-farmed goldenseal populations in eastern Kentucky and southern Ohio, in cooperation with landowners and growers to develop best production and harvest practices for forest farming.

At each site, 1 x 1 m plots were established for harvest research with 0%, 10%, 30%, or 50% rhizome removal treatments and 20-25 plots per site (Table 1). Harvests were conducted in August, after flowering and seed set in 2021 and 2023, and included baseline population inventories (leaf area, number of leaves, plant height, reproductive status, stem density, and plant location mapping) and above- and below-ground biomass recordings. Results were disseminated to NRPs during conferences and NRCS technical committee meetings, giving greater data to help move forest farming towards being an approved EQIP practice. Findings were also shared with farmers via electronic newsletters, conferences, and social media. Lastly, the project team submitted preliminary results for peer-reviewed publication.

Goal 2, Objective 1. ASD and RA identified EQIP eligible landowners via local NRPs and listservs to pilot alley cropping with medicinal herbs and shrubs. Site visits were conducted, and planting plans were developed based on landowner goals and site conditions. After site preparation, demonstrations were installed in spring or fall. Upon harvest, ASD and RA helped farmers process, aggregate, and sell alley cropped herbs to secured herbal markets. Interviews were held with participating farmers to capture benefits, limitations, design considerations, management methods, economic considerations, markets, and lessons learned. This input was used to publish *Alley Cropping: Case Studies in Appalachia* on the USDA NAC's website. Farm tours were also held at demonstration sites for peer-to-peer learning to promote adoption.

6. Project Results:

Goal 1, Objective 1 – Conserve 1,800 acres of forestland under forest farming best management practices, including the mitigation of invasive species and biodiversity enhancement.

Site Visits: ASD and RA set out to conduct site visits with 60 forest landowners to aid in the implementation of forest farming practices across 1,800 acres. Throughout the project, a total of 86 site visits were conducted with forest farming adopted across 6,838.25 acres. In addition to a physical site visit, landowners received an accompanying site visit report to help facilitate the implementation of forest farming practices and sustainable forest management. In total, RA conducted 30 site visits to conserve 2,294 acres under forest farming best management practices, and ASD conducted 56 site visits with 4,544.25 acres conserved from forest farming.

FGV Certification: During the course of this project, UpS and project members were able to successfully enroll and/or renew 23 of the proposed 25 forest farmers in the FGV program. Despite falling short of the initial target by 2 enrollees, the project team was able to expand the diversity of products enrolled under FGV certification. For example, forest grown mushrooms and Sochan, a specialty edible forest herb, were added and expanded opportunities for forest farmers to sell more verified products. The team was also able to make needed updates to program marketing materials and resources for continued growth and marketing of the program beyond the life of this project, including an FGV webpage and informational rack card. The primary challenge with achieving the target of 25 forest farmers largely stems from the niche nature of forest farmed crops, historic market trends with low prices rooted in wild collection instead of cultivation, and an emerging market structure that is just starting to incentivize forest grown products. Overall, this project demonstrated that there is small-scale, steady growth in the FGV marketplace, and is underscored by steady enrollments of new FGV growers.

Goal 1, Objective 2 - Attract $35,000 of additional funding as a financial incentive to support forestland conservation through profitable cultivation of forest botanicals.

Market Access: At ASD's AHHH, a shared-use herb processing facility in Duffield, VA, farmers received processing, aggregation and marketing services to sell medicinal herbs grown in forest farming and alley cropping systems. In total, the AHHH secured advanced purchase orders from 12 domestic and international herbal products companies, out of only 6 projected, who were willing to pay premium prices for sustainably sourced herbs. These orders provided financial incentive for farmers to adopt agroforestry practices, and resulted in 31 forest farmers selling their products out of 25 originally projected and 5 alley cropping farmers selling their herbs out of only 4 projected. In addition, the AHHH also met its deliverable of securing 2 contract farming agreements, both for goldenseal. In these agreements, companies provided farmers with funding for start up costs, like planting stock. While farmers may be hesitant to invest in conservation practices like forest farming given the long-term nature of producing perennial woodland crops, these agreements mitigated risk by providing a guaranteed market and sales price. This was critical for a botanical like goldenseal, which takes 4-5 years to reach maturity for harvest from rhizome division.

Leveraged Private Investment: This type of investment is defined as the dollar amount of private-sector financial commitments from farmers and herbal products companies, outside of project costs that result from this NRCS CIG project. To help build the medicinal herb value-chain, partners set out to attract $35,000 of leveraged private investment to support forestland conservation through profitable cultivation of forest botanicals. In total, ASD, RA and UpS leveraged $57,322.97 in private investment from both farmers and herbal products companies. ASD leveraged $17,298.42 in cash investments from 8 forest farmers who expanded their agroforestry operation by purchasing new equipment, fencing, and planting stock, as well as 10 planting stock buyers who bought 22 pounds of forest botanical rootstock to start up a new forest farm. RA leveraged $32,024.55 of private investment to benefit the production of forest botanicals and support project objectives. This investment came from 398 planting stock buyers purchasing 80 pounds of ramp bulbs and 310 pounds of American ginseng seeds. Lastly, UpS leveraged $8,000 of private investment, including 100 pounds of American ginseng seeds from private industry that were distributed to approximately 158 growers. This leveraged investment helped expand forest conservation through forest farming.

Goal 1, Objective 3 – Conduct 1 economic analysis of forest farmed botanicals to quantify profit potential and break-even price points required from buyers for financially viable operations.

Forest Farming Calculator: The Forest Farming Calculator was developed to calculate the break-even prices for several forest grown botanicals. This Microsoft Excel-based tool estimates the prices per pound of dried roots that a forest farmer would need a buyer to pay to cover the cost of their expenses. To obtain a profit, the forest farmer must seek a higher price for the product. There are currently six species covered by the Calculator: goldenseal, black cohosh, bloodroot, blue cohosh, false unicorn, and American ginseng. For each species, the Calculator provides four break-even scenarios, three of which incorporate expenses for certifications (FGV, USDA Organic, and combined). The expenses for these certifications mean that these scenarios have higher break-even price thresholds. The Calculator is built upon default enterprise budgets derived from data collected during the grant period and from published literature. Users can modify the financial variables in the default budgets to fine tune the results for their enterprise and to evaluate scenarios. This tool does not require internet access and no information is tracked. However, there are links embedded in the tool that link to additional resources that will not work unless one is connected to the internet. The Forest Farming Calculator can be downloaded from the USDA NAC's website. A how-to-use video is available on ASD's website. The Calculator website has been viewed by 453 users (200 projected) and downloaded 34 times (30 projected). An article on the Forest Farming Calculator was included in an *Inside Agroforestry* newsletter - 5,600 copies of this newsletter were printed (5,000 projected), with

4,802 copies mailed to recipients and 100 copies distributed at the Gather to Grow Forest Farming Conference in Roanoke, VA where the Calculator was demoed to a class of 32 people.

Goal 1, Objective 4 – Develop 1 "farmer-friendly" plant population assessment and 1 sustainable harvest protocols to inform best management practices within the Multi-Story Cropping (MSC) conservation practice.

Goldenseal Study: Over the course of this project, partners from ASD, RU, and UVA Wise conducted field experiments on goldenseal (*Hydrastis canadensis*), an Appalachian medicinal herb (forest botanical) at-risk due to increasing demand and wild-harvest pressures. This study sought to achieve the following objectives:

1) to assess the sustainability of **wild harvesting** in goldenseal populations through experimental plant removal and annual measures of plant growth and population recovery; and
2) to compare the success of **rhizome propagation** (root transplants), based on rhizome size and section transplanted, to support forest farming as a sustainable management practice.

Harvest Sustainability Experiments

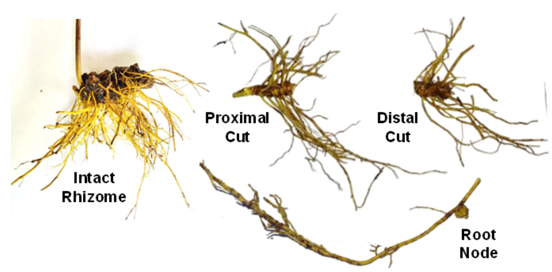
Ninety-two goldenseal sustainable harvest plots were established across four field sites in the Central Appalachian forests of OH and KY (Appendix Table 1 and Table 2). Goldenseal plants in each plot were inventoried annually, including measurement of above-ground plant height, leaf area and number of leaves, and presence of flowers or fruits. Measurements were recorded at plot establishment and repeated each year prior to harvest experiments (0, 10%, 30%, or 50% annual plant removal; Table 1).

Results from the first field season clearly demonstrated the importance of seasonal timing and plant growth stage (phenology) for population inventories and harvests. Initial plant measures were conducted 06/26-06/30/2021 and repeated 09/02-09/07/2021. Across sites, 48% to 98% plant senescence (natural late-season plant die-back) occurred between early and late summer population inventories, with considerable site-to-site variation (Table 3). Based on these findings, all future plant inventories and harvests were conducted in early August. This timing allows goldenseal populations to complete flowering and fruiting, but minimize late season natural plant senescence.

Across the four study sites, initial goldenseal populations varied in plant density and size (Table 3 and Table 4). An inverse relationship was observed between goldenseal plant density and plant size, with dense plant populations typically having shorter plants with lower leaf area and lower shoot and root weights. Less dense populations with fewer plants produced larger plants with greater shoot and root biomass. (United Plant Savers was excluded from this comparison due to earlier plant senescence).

Rhizome Propagation

Rhizomes extracted during experimental harvests were weighed for above- and below-ground biomass (fresh-weight), and transplanted into nearby propagation plots at each site. A total of 825 rhizomes were transplanted into 33 propagation plots (25 rhizomes per plot) to



evaluate plant emergence and growth in subsequent years, based on initial rhizome weight, number of buds, and portion of the rhizome planted. These included *intact rhizomes* (complete rhizome); *proximal rhizome segments* (rhizome half connected to above-ground stem); *distal rhizome segment* (rhizome half furthest from the above-ground stem); and *adventitious roots* (fibrous root hairs).

Goldenseal rhizomes harvested and transplanted in early 09/2021 were measured for survival and growth over the next two growing seasons (08/2022 and 08/2023). Initial rhizome weight was a strong indicator of transplant success, with larger rhizomes producing significantly larger plants, based on measures of leaf area (Figure 1) and plant height. This relationship (importance of initial rhizome size for plant growth) persisted two years after transplanting.

Approximately 80% of **intact rhizomes** and **proximal rhizomes sections** (cut half of the rhizome closest to the stem) survived to the first and second year after transplant, as evidenced by above-ground plant emergence (Figure 2, Left panel). Distal rhizome segments (cut half of the rhizome furthest from the stem) showed lower survival (~60% survival) one year after harvest. However, plant emergence increased in the second year after transplant (2023), resulting in similar survival for intact, proximal cut, and distal cut rhizomes after two years. Overall plant size (leaf area) remained significantly smaller for distal cut rhizomes than uncut (intact) or proximal rhizome segments, even after two years (Figure 2, Right panel). Adventitious roots (root hairs with evident buds) showed no evidence of emergence in the first or second years after transplant.

Plant Population Assessment: Culturally and economically-valued wild plants can easily be overharvested —even unintentionally— without understanding their deeper complex relationships and cycles within the environment and culture, and the resulting impact harvesting can have on them. Traditional wisdom and ecological knowledge can be very valuable in guiding place-based decisions and underlying philosophies that have been learned and practiced over many generations. The contribution of "Western science" can add another layer of understanding to these complex relationships. However, research in this realm is inadequate, leading to poorly defined and uncertain guidelines of what constitutes a "sustainable" or responsible harvest. One difficulty is that it varies considerably due to all the variables at play (e.g. the species under consideration, plant part harvested, plant life cycle, long-term regeneration rates, etc.). Even so, there are some general considerations that may help guide decisions.

One important consideration is determining baseline plant population data. For example, how many plants of the target species are in a given area? This is easier said than done, therefore a methodological protocol was written to aid in assessing baselines of plant populations in order to track changes over time. Because such protocols would differ so much based on plant type involved, this one only focuses on herbaceous perennials, such as goldenseal (*Hydrastis canadensis*), black cohosh (*Actaea racemosa*), American ginseng (*Panax quinquefolius*), ramps

(*Allium tricoccum*), and other similar plants harvested for roots. This will help forest farmers and technical service providers inventory baseline populations of wild stewarded forest botanicals and assess population regeneration over time. These methods were created in collaboration with seasoned and beginning forest farmers, botanists, and FairWild (an international certification program that ensures wild plants and plant products are sustainably harvested). The intended audience is for lay people and professionals alike.

Forest Farming Publication: Over the course of this project, an existing gap in cultivation resources was identified for the commercially valued forest herb commonly known as Solomon's Seal. Cultivation guides were primarily limited to horticultural fact sheets written about distant Solomon's Seal relatives commonly found in the landscape and gardens. To address this need, the project team determined that developing a comprehensive Solomons' Seal chapter for *The Forest Farmers Handbook*, originally developed by project partners in 2019 with another CIG project, was a suitable place to start. Through comprehensive research, literature reviews, and personal interviews, the project team was able to piece together a comprehensive seed to sale perspective of Solomon's Seal production, covering propagation techniques, drying specifications, and more. To date, 1,446 copies of the publication have been viewed and downloaded from partner websites (out of 30 projected), and more than 400 hard copies have been purchased. An excerpt of the Solomon's Seal chapter was included in a National Agroforestry Center *Inside Agroforestry* newsletter. In total, 5,600 copies of this newsletter were printed (out of 5,000 projected), 4,802 copies were mailed to recipients, and 100 copies of the newsletter were distributed at a forest farming conference.

NRCS Practice Approval: To ensure farmers had access to cost-share funding for alley cropping (311) and forest farming (479) beyond the life of this project, partners set out to approve these agroforestry practice standards for EQIP in all Central Appalachian states. Meetings were held with state NRCS staff to discuss opportunities and challenges for agroforestry in OH, WV, KY, VA, TN, and NC. Despite seeing the benefits of agroforestry, NRCS was hesitant to adopt these practices for several reasons: 1) limited technical capacity for agroforestry; 2) insufficient staffing capacity to take on agroforestry (i.e. some states did not have a state forester); and 3) lack of demonstration sites to see these practices in action. These conversations shed light on the need for agroforestry training, new hires, demonstration sites, case studies, and farm tours. Fortunately, the last three were already deliverables of this project. Based on the need for training, ASD secured foundation funding to develop Agroforestry Trainings for Natural Resource Professionals to help build technical capacity within NRCS and other agencies. Although NRCS internal hiring is beyond this project's control, partners have submitted a multi-regional cooperative agreement to NRCS to support new agroforestry hires within partner non-profit organizations. In the end, partners were able to ensure alley cropping (311) and forest farming (479) approval in OH, WV, VA and NC. However, these practices have yet to be approved for EQIP in KY and TN. Partners are hopeful that as technical capacity and new hires are developed over time, KY and TN will follow suit with agroforestry adoption, too.

Goal 2, Objective 1 – Establish at least 4 alley cropping demonstration sites trialing economically important medicinal herbs and shrubs, to determine best practices for crop productivity, economic viability, and ecological enhancement.

Alley Cropping Demonstration Sites & Farm Tours: ASD, UpS and RA developed a total of 7 alley cropping demonstration sites (out of 4 projected) across 3.5 acres (out of 2 projected) in OH, VA and KY,. Partners also showcased best practices on 7 farm tours (out of 4 projected) to encourage adoption among other farmers. UpS created a 1 acre demonstration at their Botanical Sanctuary, including shade loving species like goldenseal and Solomon's Seal under rows of Oaks. ASD established 3 alley cropping demonstration sites, including a 1) 0.85 acres at Among the Oaks Herb Farm in Beattyville, KY with annual (i.e. tulsi, chamomile, calendula) and perennial (i.e. lemon balm, comfrey, yarrow) herbs planted between rows of shrubs (i.e. elder, linden, rose); 2) 0.4 acres at Appalachian Cove Forest Farm in Duffield, VA with alleys of herbs (i.e. peppermint, calendula) and annual vegetables planted between rows of shrubs (i.e. elderberry, blueberry, raspberry, aronia, basket willow); and 3) 1 acre at MountainRose Vineyards in Wise, VA with rows of nettle and peppermint planted between rows of elderberry. Among the Oaks and Appalachian Cove both hosted two farm tours each to share best practices. Given Appalachian Cove's proximity to the AHHH, they are scheduled to continue hosting annual farm tours as a part of ASD's Summer Field School programming going forward.

RA completed 3 alley cropping plantings on 3 partner properties, establishing 0.75 acres in alley cropping production. Herbal Sage Company established a two stage planting in Meigs County, OH. A ⅛ acre planting was established in 2020, and another ⅛ acre was established in 2021. For this project, a team of RA staff and volunteers planted herbaceous species (thyme, holy basil, bee balm, butterfly weed, echinacea, etc.) between rows of elderberry, blueberry, and vitex. A second two stage ¼ acre alley cropping demonstration site was established on the property of herbalist Caty Crabb in Meigs County, OH. A group of RA staff and volunteers planted a high diversity of herbaceous species, including alleys of herbaceous herbs (echinacea, skullcap, bee balm, etc.) between rows of woody species (blueberry, witch hazel, serviceberry, pawpaw, etc.). Lastly, a third planting took place on property owned by the Southern Ohio Chestnut Company in Athens County, OH, where cotton, sunflower, cosmos, coxcomb, pumpkins, and pasture clover were planted between existing rows of orchard chestnuts and pawpaws on ⅛ acre. A total of 2 alley cropping farm field days were held at the Southern Ohio Chestnut Company where farmers participated in a peer-to-peer educational event focused on alley cropping.

Alley Cropping Publication: The project team developed *Alley Cropping: Case Studies in Appalachia* to showcase examples of how producers who established alley cropping demonstration sites through this project are using the practice to meet their conservation and economic goals. This publication, hosted on the NAC's website, provides information about the practice and details how two farms are using it, including sample layouts, photos, and other details. Information about this publication was distributed through the NAC email update, along with other partner newsletters. A total of 3,500 copies of this 10-page publication were printed and distributed to partners by the NAC for dissemination at outreach and training events. The publication has been viewed by 489 people (out of 200 projected), with 25 click throughs to download to date (out of 30 projected). An article on the publication was included in a NAC *Inside Agroforestry* newsletter, with 5,600 copies printed, 4,802 copies mailed to recipients, and 100 copies distributed at a forest farming conference. This helped exceed the projected deliverable of 5,000 printed copies distributed.

7. Project Outputs:

Publications: The following publications were developed as a result of this project:

- Small, CJ. 2023. Medicinal forest herbs: Conservation and economic development in the Appalachian Mountains. Bulletin of the Transilvania University of Braşov, Special Issue 15:35-48. -- P*eer-reviewed publication on the history, cultural importance, and diversity of plants and plant products used as forest botanicals in Appalachia; case studies on wild-harvesting, forest farming, and economic development of select forest botanicals, including goldenseal sustainable harvest research for this grant project.*
- Commender K, Miller A, MacFarland K. 2022. Alley Cropping: Case Studies in Appalachia. USDA National Agroforestry Center. – *Fact sheet outlining best practices and lessons from demonstrations.*
- Filyaw, T. 2023. Solomon's Seal. Commender K, Miller A, Sheban K, Suggs R (Eds.), The Forest Farmers Handbook: A Beginners Guide to Growing and Marketing At-Risk Forest Herbs (2nd ed., pp. 91-103). Rural Action, United Plant Savers, and Appalachian Sustainable Development. – *New cultivation guide chapter on on Solomon's Seal, covering site selection and propagation to processing.*

Software: The Forest Farming Calculator is a completed Microsoft Excel-based spreadsheet tool that can be downloaded from the NAC's website here.

Conference Attendance: The following presentations were given to disseminate information about the project's findings, tools and resources:

- Commender, K, Bentrup, G, Filyaw, T, Huish, R, Miller, A, Small, C. 2024. Increasing forest farming adoption: Resources and Lessons Learned. Gather to Grow Forest Farming Conference, Roanoke, VA. – *Regional conference presentation summarizing all of the deliverables from this NRCS CIG project, including resources created and lessons learned.*
- White, L, McKenney, P, Kepley, E, Hernandez, J, Britton, A, Small, C. 2023. Forests that heal: Appalachian biodiversity, sustainability, and medicinal herbs. Virginia Natural History Conference, Radford, VA. -- *Regional conference presentation summarizing goldenseal sustainable harvest research results for this grant project.*
- Commender, K, Huish, R, Small, C. 2022. Increasing landscape-scale adoption of agroforestry systems in Appalachia. Annual Conference of the Soil and Water Conservation Society. Denver, CO. – *National conference presentation summarizing all of the deliverables from this NRCS CIG project, including resources created and lessons learned.*
- Small, CJ. 2022. Biodiversity and mountain heritage: Conservation, culture, and medicinal forest herbs. Appalachian-Carpathian International Mountain Conference. Transilvania University, Brașov, Romania.-- *International conference presentation on the history, cultural importance, and diversity of medicinal plants in the Appalachian Mountains; comparison to rural resource extraction economies of the European Carpathian Mountains; case studies on wild-harvesting, forest farming, and economic development of select forest botanicals, including goldenseal sustainable harvest research for this grant project.*
- Commender, K, Huish, R, Small, C. 2022. Conservation of at-risk medicinal forest herbs: sustainable harvest and propagation of goldenseal in the Appalachian Mountains. 5th World Congress on Agroforestry: Transitioning to a Viable World, Quebec City, Canada. -- *International conference presentation summarizing goldenseal sustainable harvest research results for this grant project.*

- Simmons, E, White, L, McKenney, P, Passeretti, M, Small, C. 2021. Conservation of an at-risk medicinal forest herb: Sustainable harvest and propagation of goldenseal in Appalachian forests. Winter Creative Activities and Research Days, Radford University.
  -- Local conference presentation summarizing goldenseal sustainable harvest research results for this grant project.

Training and Outreach Events: Project partners presented on forest farming and alley cropping at a number of events:

- 66 people attended RA's Growing Wild-simulated Ginseng presentation at the Ohio State University Farm Science Review on Sep 11, 2020
- 6 people attended the alley cropping farm tour at the Southern Ohio Chestnut Company on September 11, 2021
- 37 people attended the Agroforestry Field Day at Southern Ohio Chestnut Company on October 14, 2022
- 309 and 437 people attended Among the Oak's virtual alley cropping farm tours on July 25, 2020 in the height of the COVID-19 pandemic
- 7 people attended Appalachian Cove's first forest farming and alley cropping farm tour on August 15, 2021, and 39 people attended the second tour on September 18, 2021
- 200 people attended the *Gather to Grow: Forest Farming Conference* on March 22-24, 2024 where project partners had several outreach booths set up

Newsletters: In April 2024, the NAC's *Inside Agroforestry* newsletter featured the Forest Farming Calculator, Solomon's Seal chapter of the *Forest Farmers Handbook*, and the Alley Cropping Case Study. A total of 5,600 copies were printed, 4,802 copies were mailed to recipients, and 100 copies were distributed at the *Gather to Grow: Forest Farming Conference*.

8. Project Impacts:

The impacts of this project are summarized in the table below. As described above, all deliverables were met and many exceeded with the exception of three: number of FGV/Organic applications/renewal, number of alley cropping fact sheet downloads, and the number of states adopting Forest Farming and Alley Cropping as approved EQIP practice. In total, this project reached 63 EQIP eligible producers. The total number of acres impacted by this project is 6,841.75 acres under two NRCS Conservation Practices as follows: 6,838.2 acres conserved under forest farming best practices and 3.5 acres conserved under alley cropping best practices. This project will have a long lasting conservation impact from these two agroforestry practices. Forest farming implemented through this project addresses a number of resource concerns by increasing plant and tree community and crop diversity (including native species), enhancing soil health, improving terrestrial habitat, and conserving at-risk plant populations through sustainable and profitable cultivation. Similarly, alley cropping demonstration sites planted during this project also have a number of conservation benefits, including: enhancing microclimatic conditions that improve crop or forage quality and quantity; reducing surface water runoff and erosion; improving soil health and air quality; enhancing wildlife and beneficial insect habitat, increasing crop diversity and carbon storage; and more. The demonstration sites and robust suite of educational tools and resources developed from this project will help raise awareness of these conservation and economics benefits. By merging farmers' conservation and commerce goals, a win-win incentive system has been developed for the ongoing adoption of these agroforestry practices.

Goals & Objectives	Deliverable/Milestone Impact Measure	Projected Value	Cumulative Value
Goal 1, Objective 1	# of forest farm site visits conducted	**60**	86
	# of acres conserved under forest farming practices	**1,800**	6,838.25
	# of FGV/Organic applications/renewals	**25**	23
	# of forest farmers selling herbs	**25**	31
Goal 1, Objective 2	# of companies submitting purchase orders	**6**	12
	# of contract farming agreements	**1**	2
	$ of leveraged private investment from companies/farmers	**$35,000.00**	$57,322.97
Goal 1, Objective 3	# of Forest Farming Calculator tools created	**1**	1
	# of Forest Farming Calculator tool views	**200**	453
	# of Forest Farming Calculator tool downloads	**30**	34
	# of Forest Farming Calculator tool print distribution	**5,000**	4,902
Goal 1, Objective 4	# of plant population assessment protocols created	**1**	1
	# of peer review goldenseal publications	**1**	1
	# of forest farming fact sheets created	**1**	1
	# of forest farming fact sheet views	**200**	1,467
	# of forest farming fact sheet downloads	**30**	1,446
	# of forest farming fact sheet print distribution	**5,000**	5,163
	# of states adopting forest farming as approved practice	**4**	2
	# of presentations to present findings, tools, documents	**2**	13
Goal 2, Objective 1	# of alley cropping pilots sites created	**4**	7
	# of alley cropping acres established	**2**	3.5
	# of alley cropping demonstration farm tours conducted	**4**	7
	# of alley cropping fact sheets created	**1**	1
	# of alley cropping fact sheet views	**200**	489
	# of alley cropping fact sheet downloads	**30**	25
	# of alley cropping fact sheet print distribution	**5,000**	8,402
	# of states adoption Alley Cropping as approved practice	**2**	0
	# of alley cropping farmers selling herbs	**4**	5
CIG Project Mgt	# of project kick-off meetings	**1**	1
	# of project activity presentations	**1**	13
	# of project fact sheets	**1**	1
	# of project closing events	**1**	1

Goals & Objectives	Deliverable/Milestone Impact Measure	Projected Value	Cumulative Value
Eligible Landowners	# of participating farmers who are EQIP eligible	**60**	63

Appendices:

Tables

Table 1. *Ninety-two plots (1 x 1 m) were established in central Appalachian forests in KY and OH for goldenseal sustainable harvest experiments. Number of plots (1 x 1 m), location, year of establishment, and harvest treatment summarized below.*

	Stidham Farm	Robinson Forest	Truth Speaker	United Plant Savers
Location	Hazard, KY	Clayhole, KY	Rutland, OH	Rutland, OH
Year established	2021	2023	2021	2021
0% harvest	5	7	5	9
10% harvest	5	6	6	6
30% harvest	5	6	7	6
50% harvest	5	6	6	2
Total number of plots	20	25	24	23

Table 2. *Timing and location of data collection for goldenseal sustainability research. All data collected in 1 x 1 meter research plots.*

Timeline	Research Site															
	United Plant Savers (Rutland, OH)				Truth Speaker Farms (Rutland, OH)				Marcus Stidham Farm (Hazard, KY)				Robinson Forest (Clayhole, KY)			
	Inventory	Measure	Harvest	Phenology	Inventory	Measure	Harvest	Phenology	Inventory	Measure	Harvest	Phenology	Inventory	Measure	Harvest	Phenology
Jun/Sept 2021	X	X	X		X	X	X		X	X	X					
2022	X				X	X			X	X						
2023	X	X							X	X	X	X	X	X	X	X
2024	X	X							X	X	X	X	X	X	X	X
2025	X	X							X	X		X	X	X	X	X
2026													X	X		

Inventory = Goldenseal population density (# of plants / m2) to assess harvest impacts, rhizome transplant success, and seasonal change

Measure = Individual plant growth measures (height, leaf area, reproductive status, population density) to assess regrowth after harvest and transplant

Harvest = Experimental harvests (0, 10, 30, 50% treatments) to determine wild-harvest sustainability

Phenology = Monitoring seasonal changes in plant emergence, leaf expansion, maturation, flowering, fruiting, and senescence at approx. 3-week intervals

Table 3. *Seasonal change in goldenseal plant density in inventory plots from late June to early September 2021, due to natural die-back during the growing season. Values represent the average number of plants per 1 m^2 plot. All values were prior to any plant harvests.*

	Marcus Stidham (KY)	Truth Speaker Farms (OH)	United Plant Savers (OH)
June 2021 Ave (min-max)	114 plants (44-236)	85 plants (20-188)	52 plants (19-99)
Sept 2021 Ave (min-max)	33 plants (2-88)	26 plants (7-75)	1 plant (0-5)
June to Sept Ave decrease	81 plants	59 plants	51 plants
June to Sept % decrease	47.6%	59.0%	98.3%

Table 4. *Comparison of initial goldenseal population parameters (pre-harvest) and first harvest plant weights across the four study sites.*

	Marcus Stidham (KY)	Robinson Forest (KY)	Truth Speaker (OH)	United Plant Savers (OH)
Plant density (# / m^2)	73.1	56.7	55.5	26.4
Plant height (cm)	13.5	19.9	20.7	13.7
Leaf area (cm^2)	143.6	204.1	174.6	118.3
Reproductive (%)	10.3	14.0	26.0	5.6
Shoot biomass (g)	2.41	3.77	3.52	2.18
Rhizome biomass (g)	3.18	3.54	4.09	3.39
Soil pH	5.2	4.8	5.1	
Soil Organic Matter (%)	12.2		5.7	
Soil Nitrate (ppm)	12.0		7.9	

<u>Figures</u>

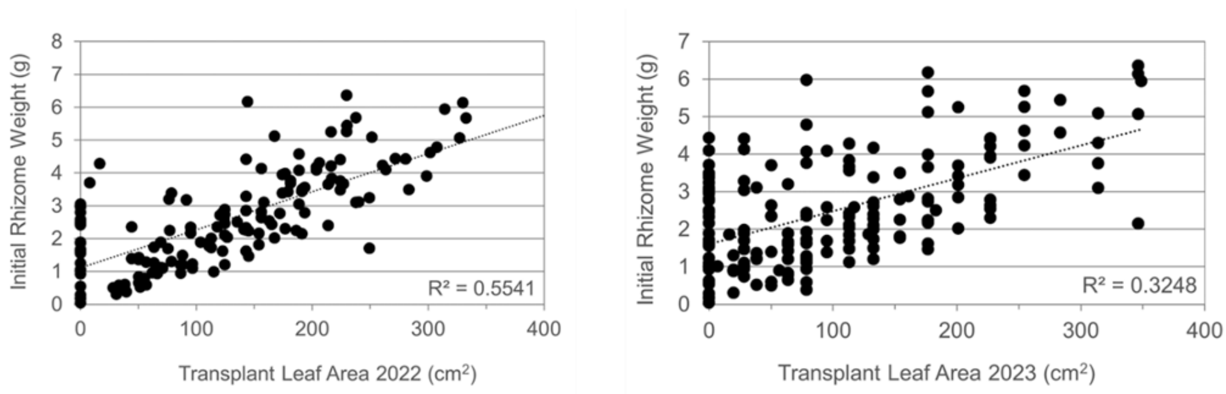


Figure 1. *Relationship of goldenseal rhizome size to plant size in the first and second years after transplant. Initial weight of goldenseal rhizomes (at the time of harvest) was a strong predictor of transplant survival and plant size over the next two growing seasons, with larger transplanted rhizomes producing plants with significantly larger leaves. Left panel: Leaf area of emerged goldenseal plants one year after transplanting rhizomes ($r^2 = 0.55$, $p < 0.01$). Right panel: Goldenseal leaf area two years after transplanting rhizomes ($r^2 = 0.33$, $p < 0.05$). .*

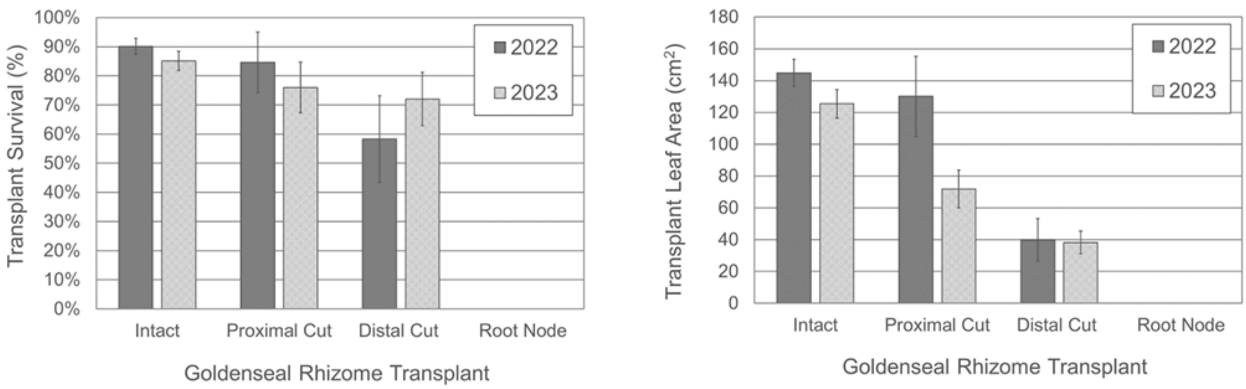


Figure 2. *Survival (left panel) and growth (right panel) of transplanted goldenseal rhizomes, based on the section of rhizome planted: intact (full rhizome); proximal segments (rhizome half closest to the above-ground stem); distal segment (rhizome half furthest from the above-ground stem); root node (adventitious roots or root hairs with evident buds). Left panel: Most intact and proximal rhizomes sections (~80%) survived to the first and second year after transplant. Distal rhizome segments had lower initial survival (~60% survival) but increased by the second year after transplant (2023), resulting in similar survival for intact, proximal cut, and distal cut rhizomes after two years. Right panel: Plants grown from distal rhizome segments remained significantly smaller than intact or proximal segments, even after two years. Root nodes showed no evidence of emergence in the first or second years after transplant.*

Literature Cited:

Chamberlain, J.L., Emery, M.R., Patel-Weynand, T. (eds). 2018. Assessment of Non-Timber Forest Products in the United States Under Changing Conditions. Gen. Tech. Rep. SRS–232. USDA Forest Service, Southern Research Station, Asheville, NC. 260 p.

Chamberlain J.L., Mitchell, D., Brigham, T., Hobby, T., Zabek, L., Davis, J. 2009. Ch. 9: Forest farming practices. In: Garrett HE (ed). North American agroforestry: an integrated science and practice, 2nd edition. American Society of Agronomy, Madison, WI.

Chamberlain, J.L., G. Ness, C.J. Small, S.J. Bonner, E.B. Hiebert. 2013. Modeling below-ground biomass to improve sustainable management of *Actaea racemosa*, a globally important medicinal forest product. For. Ecol. Manage. 293:1–8.

Chamberlain, J.L., Small, C.J., Baumflek, M. 2019. Sustainable forest management for nontimber products. Sustainability (Special Issue: Sustainable Forest Management) 11:2070–2691.

Greenfield, J.; Davis, J.M. Collection to Commerce: Western North Carolina Non-Timber Forest Products and Their Markets; Report for the Department of Horticultural Science; North Carolina State University: Raleigh, NC, USA, 2003.

Small, C.J., J.L. Chamberlain. 2018. Experimental harvest and regrowth in Appalachian black cohosh (*Actaea racemosa*, Ranunculaceae) populations: Implications for sustainable management of a medicinal forest herb. J. Torrey Bot. Soc. 145:109–120.

Plant Population Assessment Methods to Help Inform Best Harvest/Management Practices and Track Changes over Time.

Introduction

Culturally and economically-valued wild plants can easily be overharvested—even unintentionally—without understanding their deeper complex relationships and cycles within the environment, and the resulting impact harvesting can have on them. Traditional wisdom, including traditional ecological knowledge, can be very valuable in guiding place-based decisions and underlying philosophies that have been learned and practiced over many generations. The contribution of "Western science" can add another layer of understanding to these complex relationships. However, research in this realm is inadequate, leading to poorly defined and uncertain guidelines of what constitutes a "sustainable" or responsible harvest. One difficulty is that it varies so much considering all the variables at play (e.g. the species under consideration, plant part harvested, plant life cycle, long-term regeneration rates, and countless environmental factors). Even so, there are some general considerations that may help guide decisions. One important consideration is determining baseline plant population data. For example, how many plants of the target species are in a given area?) This is easier said than done, therefore this methodological protocol was written to help forest farmers and technical service providers inventory baseline populations of wild stewarded forest botanicals and assess population regeneration over time. These methods were created in collaboration with seasoned and beginning forest farmers, botanists, and FairWild (an international certification program that ensures wild plants and plant products are sustainably harvested). The intended audience is for lay people and professionals alike.

Because such protocols would differ so much based on plant type involved, this one only focuses on herbaceous perennials (e.g. goldenseal (*Hydrastis canadensis*), black cohosh (*Actaea racemosa*), American ginseng (*Panax quinquefolius*), ramps (*Allium tricoccum*), and other similar plants). (Population assessment protocol for different types of plants (besides herbaceous perennials) may be created in the future.) Goldenseal is the target species selected for the case study assessment (embedded into the steps below as an example to help visualize the process). Certain aspects of this protocol can be applied to many other types of target species and harvesting methods as well, with minor adaptations for other aspects (such as larger plot sizes for larger plants—including woody perennials—that have a lower density per area). Formulas are included in the appendix to help users understand the math behind it all, so they can adapt the methods to different plant types and circumstances if desired.

The first goal in this assessment is to measure the geographic area of the target species' population of interest. The second is to estimate the density and number of individuals of the target species within that population. From here, several inferences can be made regarding the population, especially if data is collected over multiple years and comparisons can be made. The data is captured through smartphone apps and/or traditional measuring and data collection techniques. Please recognize that it is very difficult to get extremely accurate information without counting/measuring each individual within a population, as this is often not a logical option (depending on the size and number of individuals within the population). Therefore, the following methods require several layers of estimation and extrapolation. While the resulting data may naturally not be extremely accurate, it can still be helpful in general assessments and provide the ability to see significant changes over time (e.g. increases or decreases in the population density and health). One way to visualize this concept is to think of the "Jelly Bean Jar Game" where contestants estimate the number of jelly beans in a large clear jar (without opening it) by counting the number of jelly beans in one subsample (e.g. jelly beans in view on the bottom layer of the jar), and then multiply that by the number of layers in the jar to estimate the total number, always making room for a range of error (more or less). The person with the closest correct number wins the jar of jelly beans. While assessing plant population numbers is not quite as simple as that game, the general concept applies, of counting a subsample of the whole, and extrapolating estimates from that. You may need to read through these methods several times and test them out in the field to be able to fully comprehend them.

Overview of Steps

1. Measure population area of target species. (Map out where the patches are, draw a perimeter around the whole population of interest, and determine the geographic area within that created perimeter.)
2. Gather data in subsample plots. (Find out how many individuals there are in a given small sample area.)
3. Estimate density intensity percentages of the target species within the whole population. (How does the density of the target species vary in different areas within the population?)
4. Extrapolate numbers to the whole population. (Determine an informed estimate of the number of individuals of different sizes/ages within the whole population.)

Equipment list:

- Three sticks or stakes ("Step-in posts" used by farmers for poly wire electric fencing work well.)
- String (Bright-colored mason string works well.)

- Measuring tapes
- Smartphone with various apps (or long surveyor tape measures if a smartphone is not available)
- Paper and pencil

Protocol Steps in Detail

1. **Measure Population Area of Target Species.** You will need to determine the extent of the population you are going to assess. This will involve knowing where the target species is concentrated and mapping a perimeter around them, and then determining the geographic area within that perimeter. The resulting area calculation will be used in step 4 to generate population census results.
    - **1.1.** <u>General exploratory observations (Find and mark target species locations generally).</u> If you are unsure of the extent of the population, begin by exploring the area to search for the target species. If you have a smartphone, you may use an app (for example, "GPS Tracks") that uses GPS tracking that allows you to mark waypoints as you find individuals or patches; some apps allow you to take pictures at the waypoints as well, which may be helpful to remember the general density of the patches you found. When you are done exploring the area, and feel like you have covered the extent of the population, you can zoom out on the map to see a bird's-eye view of where you have found patches of the target species. This will be helpful as a preliminary step to help you know where to walk to measure the perimeter of the population you want to assess (see Figure 1).

Figure 1. Dropped pins (waypoints) roughly marking where goldenseal patches were found.

1.2. Create a perimeter map of the population and calculate its geographic area. Walk the perimeter of the population using an app that uses GPS to track steps and which measures the area of a resulting polygon (such as "GPS Fields Area Measure Map"). Before you begin, choose a memorable landmark or leave some kind of marking (like flagging tape tied to a branch), so you are sure to end at the same point you began to close off the polygon. While you are walking the perimeter, make more casual observations of the target species within the population to get a better feel for the varying densities within. When you have completed the polygon, the app will calculate an estimated area for you (see Figure 2.) If you do not have a smartphone, you can mark the perimeter with flagging or other appropriate markers, then measure the distance between the corners with a long measuring tape, and the angles from the corners to the next corner with compass points. From there, you can calculate the area within the polygon using basic geometry. There may be more than one target population/polygon that may be combined and calculated as one population, depending on your circumstance and personal judgements. (For example if the target species is only occurring on the north slopes of three different nearby hill sides, that could result in three polygons that could—for the purposes of these methods—all be considered one population).

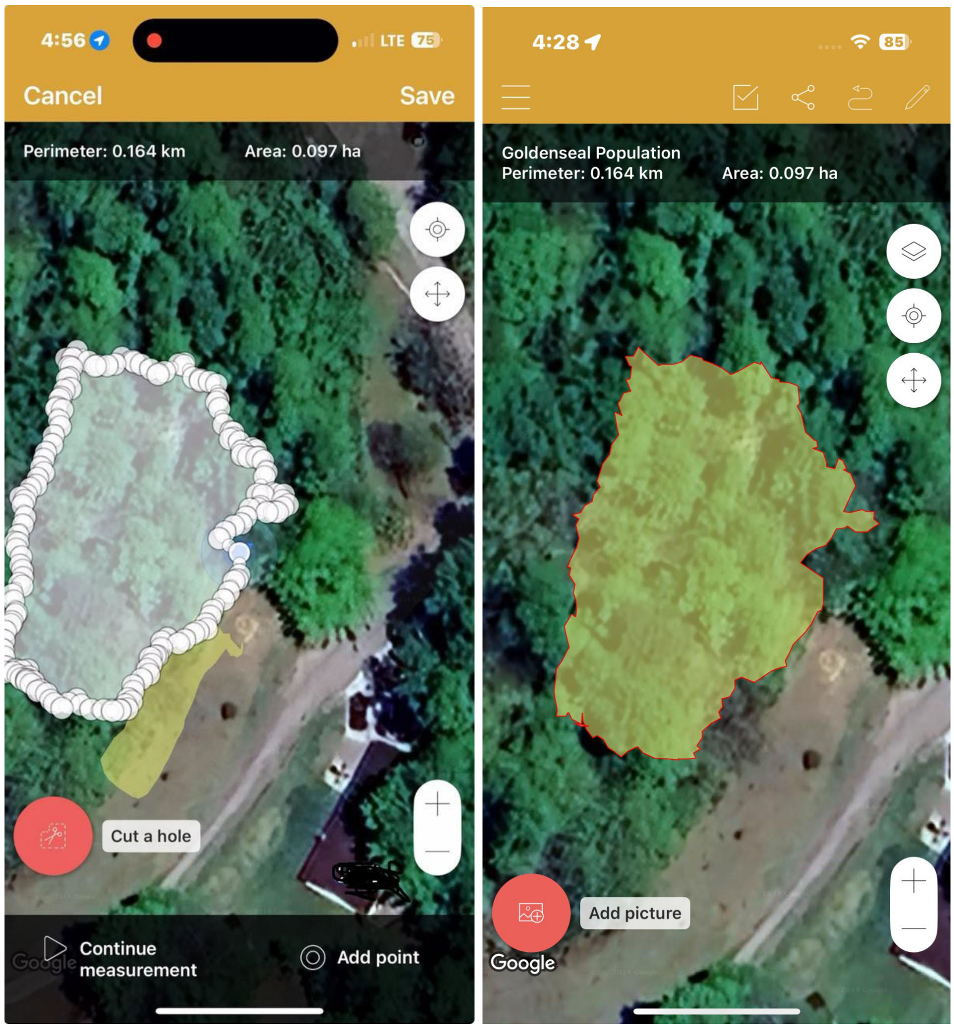


Figure 2. The "GPS Fields Area Measure Map" App tracks footsteps (left, white dots) to measure the perimeter and area of the polygon (right), estimating the area, in this example, to be 0.097 Hectares (970 square meters) (top right).

1.3. Document site attributes. At some point, be sure to write down site attributes such as the percentage of canopy cover overhead, general notes about co-occurring species, slope aspect, and other information you may feel is relevant to reflect the condition of the site. This information can go into a written general description for the population that may inform future decisions.

2. Gather Data in Subsample Plots. Now it is time to "count the bottom layer of jelly beans in the jar." The tricky thing here, though, is that there are usually varying densities of the target species (the “jelly beans”) within a population, unlike a jelly bean jar where each layer is generally the same density. To do this, you will be creating a stick and string plot reader tool to help you count individuals within four different density intensities within the population. The data you gather here will be used to extrapolate the numbers for the whole population in step 4.

2.1. Create the stick and string plot reader tool. Obtain three sticks or stakes that you can push into the ground. “Step-in posts” (used by farmers for poly wire electric fencing) work very well for this (see Figure 3). One stick will represent the center of a circular plot; the other two sticks will represent the outer edges of the circle as they swivel around the center, tied together by strings. The two strings tied between the center stick and the outer two sticks will be the radius of the circle. The area of the circle will be a square meter. The radius of the circle (from stick to stick including the string), therefore, should be 56.4 cm long. (The area of a circle is pi times the radius squared ($A = \pi r^2$). This may take some time to get the correct measurements as tying knots often unpredictably change the length of the string.

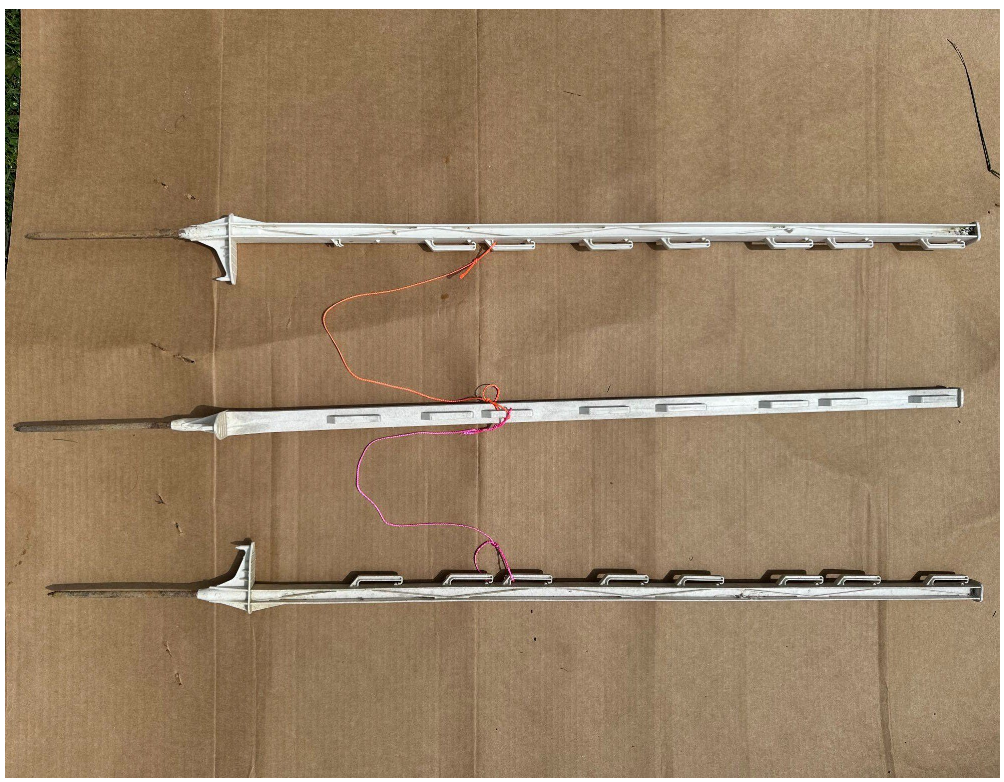


Figure 3. Stick and string plot reader tool consisting of three step-in posts and two strings tying them together.

2.2. Find varying density intensities within the population to measure. Find places where there are high, medium, low, and very low densities; four different “density intensities” (DI) within the population. You can best visualize the densities by the percent cover they have in a given area. Table 1 shows the four DIs with the respective coverage values based on logical variation of natural herbaceous perennial plant populations after testing this out on several different species. Figure 4 shows a visual representation of the goldenseal density intensities.

Table 1. Density Intensity (DI) Values

Density Intensities (DI)	% Coverage of ground
High	60–100%
Medium	25–60%
Low	5–25%
Very Low	0–5%

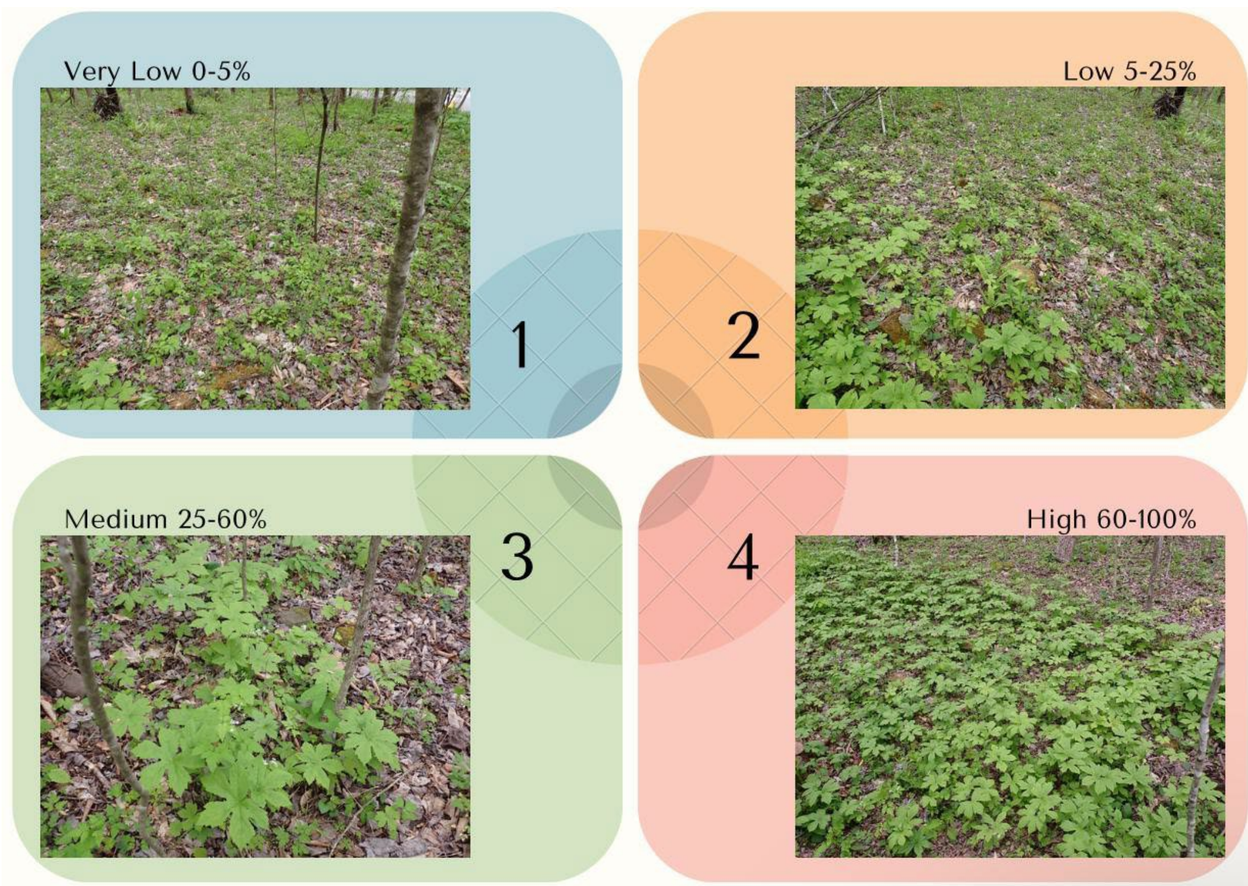


Figure 4. Visual representation of the goldenseal density intensities.

2.3. <u>Practice determining size-class categories.</u> It will be valuable to not only know how many individuals may be in a population, but also how many of those are in various developmental stages: mature reproducing (flowering or fruiting), mature but not reproducing, intermediate, and young (see figures 5–8 for how this applies to goldenseal). This will need to be determined species by species, and guidelines can be created for each. (Note: "Individuals" may actually be two stems from the same underground rhizome, so while technically, they may be one plant or one individual, in this case, they may be counted as two since you won't be digging them up at this point to find out. But functionally, two stems/leaves coming out of one rhizome may reflect a larger underground rhizome anyway, so it may balance out). You will need to get a feel for these four different categories in the field before starting data collection in your plots.

Figure 5. Young Size/Age Category: could include seedlings or just noticeably smaller plants. Note— size varies depending on the season.

Figure 6. Intermediate Size/Class Category: Plants that are in a transitional "juvenile" stage between young and mature. The exact measurements separating young, intermediate, and mature may need your own judgment based on the population observations at hand.

Figure 7. Mature Non-Reproducing Size/Class Category: Plants that seem to be the size/age of reproducing individuals, but with no evidence of experiencing a reproductive stage that year.

Figure 8. Mature Reproducing Size/Class Category: Plants that have evidence of experiencing a reproductive stage for that year (left to right: flower, young fruit, mature fruit, or a fruit stem where a fruit used to be attached). Note— Goldenseal flowering occurs in the spring when the leaf hasn't fully expanded yet, so the leaves will look quite small as if they are in the "Intermediate" stage. Adjust age/size categories based on specific plant characteristics.

2.4. Gather data in plots. Randomly choose a location for three plots within each DI (for a total of 12 plots). Mark your starting point (suggested 12 noon position in a certain cardinal direction, and with a unique rock or stick laid down or poking in the dirt) and methodologically go clockwise around, counting each individual in the circular plot, designating what size class they are in, to be marked in a smartphone app or on paper. It is suggested that at least two people help gather this data—one to count and call out what each plant's size/age category is, and another acting as scribe). It may be helpful to have the scribe repeat what the counter says so the counter knows she/he caught it correctly, and so the counter doesn't go too fast. The width of the pie slice can be wider or narrower depending on the target species' density within the plot (this is just to help make sure there is no double counting or missing individuals (see Figure 9, and follow the link for a video representation of data collection using this method https://drive.google.com/file/d/1mAAiP3g6aU85LZ2DtTxFHPGBS1gmJyRE/view?usp=sharing)

Figure 9. Stick and string plot reader tool forming a plot in a dense goldenseal patch. The middle stick represents the center of the circular plot, while the other two swivel around the center on their strings to complete the circle. Notice the orange flagging near the base of the right "stick" or post, which is tied onto a small loose tree branch stuck in the ground to mark the beginning and end of the plot reading. (Video linked above.)

3. **Estimate Density Intensity Percentages of the Target Species within the Whole Population.** The next step is to "count the number of jelly bean layers in the jar" for each density intensity (DI), in other words, determine how the density of the target species varies in different areas within the population. This information will be used in step 4 to extrapolate plant numbers for the whole population.
    3.1. To help you make more accurate estimates of the DI percentages within the population (e.g what is the total area of all patches with high-density intensities, and what percentage of the whole population does that represent), use the perimeter area app (used in step 1.2) to mark and measure the DI percentages

within the population. To do this, walk around patches of the various DI categories to calculate the area of each patch within the population. To make it easier, you do not have to walk around patches of all four DI types. For example if the entire range has less area with high density, medium density, and low density, but the very low DI covers the largest area within the population, walk around the smallest density areas first (it would be high, medium, low in this case). You do not need to walk around the “very low” patches in this example due to that population being the largest & it covers the rest of the assessed area (see Figure 10 for illustration). The resulting area measurements for each DI category can be added (e.g. all the high DI patch areas can be added together to get a total, and you can do the same thing for all the medium and low DI patches), and then subtract that from 100% to get the remaining very low DI (assuming the very low DI covers the largest area. This “bird's eye view” method will help you estimate the percentages of each DI in the population if you have polygons around each DI patch marking them. (You may also want to use the app “GPS Fields Area Measure Map” suggested above to help calculate the areas of each DI. each DI.) This step may work better for some situations than others; you will need to be the judge on that. If this method does not work with your circumstance (e.g. the size of your population is too large to walk around each patch of target species), use the alternate approach in step 3.2 below.

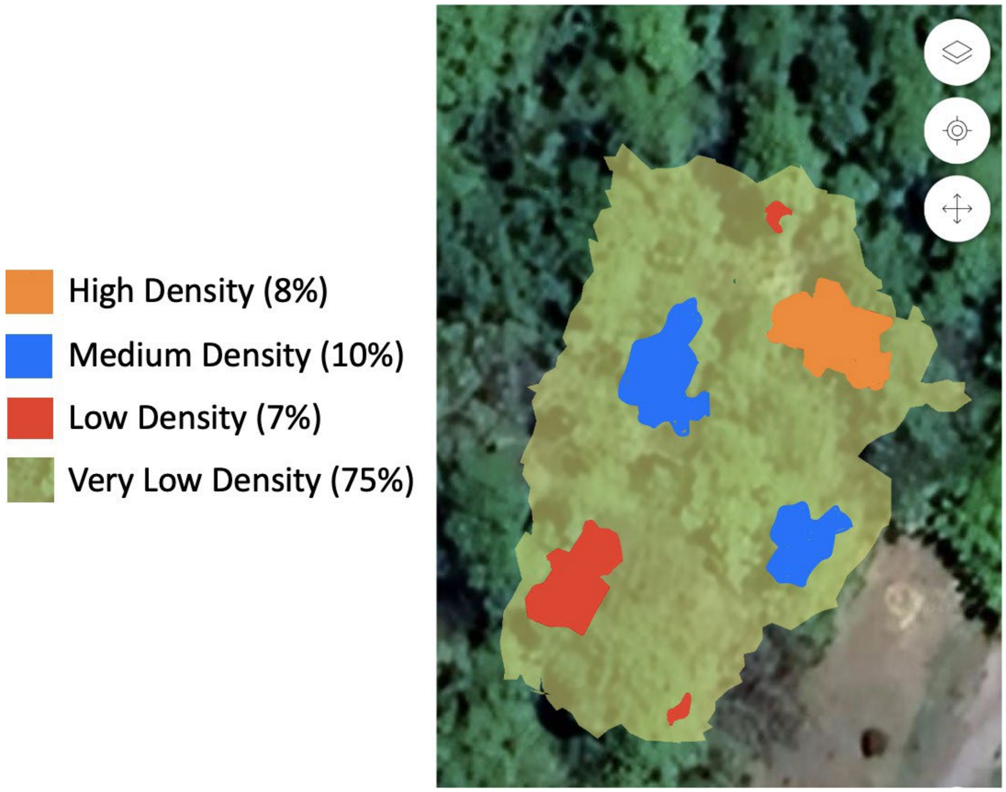


Figure 10. Patches of High, Medium, Low, and Very Low Density Intensities (DI) within the entire population. Note that Very Low covers the spaces between the other DIs, due to it having the highest area coverage. The Very Low DI percentage can be calculated simply by subtracting the total of the others from 100.

3.2. **Alternative Method from 3.1**: Determine a representative sub-polygon within the larger polygon to estimate DI percentages without walking the perimeter of each patch.

3.2.1. Determine a representative sub-polygon. Since it is difficult to estimate the DI percentages for the full population, especially over a large geographic area, a subsample polygon (preferably a square or rectangle) that you feel represents the approximate percentages of the four density intensities of the whole population can be selected. (It is easier to estimate the smaller polygon than the full population, visually.) This sub-polygon should be small enough that you can see all the plants within one frame of view as you are standing in front of it (perhaps around 50 square meters).

3.2.2. Estimate the DI percentages within the sub-polygon. Without the presence of natural landmarks (e.g. fallen logs and identifiable trees or large rocks that can “connect the dots” to make a square or rectangle), you may put flagging down on the corners and center of the sub-polygon. Using imaginary lines (or real ones using string) in the sub-polygon, divide it into quadrants to help you visualize the percentages of each DI within the sub-polygon (to visualize 25%). If you feel this subsample polygon represents the DI percentages of the whole population (from your perspective from step 1.1 and subsequent steps) then these same approximate percentages can be applied to the full population. (To help calibrate a more accurate estimate, if more than two people are there, have the people present estimate the DI percentages independently and then compare differences.) Again, as explained in the protocol introduction, these estimates are not going to be exact, but it can still be helpful in general assessments and provide the ability to see significant changes over time.

3.3. Take photos and panoramic videos from the same locations each year. Consistent visual records of the population will add depth to the data collection and help inform long-term decisions. At some point during the population assessment (perhaps most logically during step 3), mark specific locations to take annual (or more frequent) representative photographs and slow-spanning panoramic videos of different areas within the population that you feel represent the varying dynamics and feel for the broader population. Mark these areas with an exact GPS coordinate and permanent rebar or stake and write down the compass direction you took the photo from so you can take it from the same vantage point each year. Take these photos/videos at the same time each year for visual comparisons; you may be able to see changing trends over time. One app that would be helpful to use for this is Solocator. It marks the compass direction, the gps coordinates, and allows you to take notes, and then embeds all that data in the picture (see figure 11).

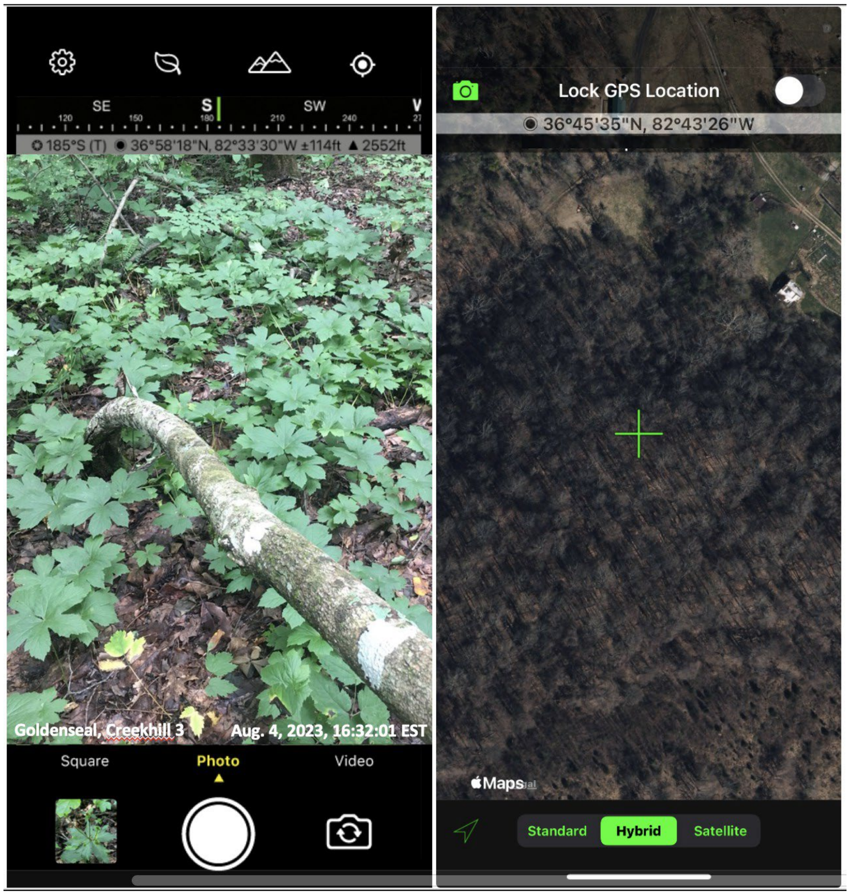


Figure 11. Example of a photo taken from the same location each year to assess change over time visually. The photo could be taken using a broader angle/view than what is depicted here. Notice how compass direction, GPS coordinates, and user-written notes are embedded in the photo on the left. Both photos were taken using the Solocator App. (For the purposes of these public instructions, GPS coordinates in these photos have been scrambled so as to not reveal the true location of the goldenseal depicted here). Panoramic videos can be taken from the same representative locations as well.

4. **Extrapolate numbers to the whole population.** Once data are collected from the previous three steps, the size/age category plot averages can be applied to the estimated DI percentages to extrapolate population size by using mathematical formulas that are embedded in an Excel spreadsheet created for this purpose (linked below). You will need to enter certain numbers obtained from the steps above into the spreadsheet (population area (step 1), data from the plot readings (step 2), and density intensity percentages (step 3), and it will automatically calculate the estimated Total Individuals in Population (TIP) and total individuals for each size/age category (Total Mature Reproducing (TMR), Total Mature Non-Reproducing (TMNR), Total Intermediate (TI), and

Total Young (TY). Figure 12 shows example output for a goldenseal case study applying these methods. These results can help inform decisions for responsible harvesting of these plants in this population. (For example, knowing that there is a very small percentage of reproducing individuals, you may choose not to harvest as many, knowing the population may not be replacing itself quickly. Furthermore, you may want to take more effort to collect and plant the resulting seeds.) If you want to understand the formulas behind it so you can adapt as necessary to different plant types and/or circumstances, see the Appendix, which explains the logic behind the calculations and provides definitions for the terms and acronyms. Click on the following link to download an Excel spreadsheet where you can enter your data to automatically calculate your results: Plant Population Data Analysis .xlsx

Size/Age Category	Estimated Total Indiviudals (TI) for Size/Age Categories
MR	722.3277409
MNR	9007.851827
I	2124.493355
Y	934.7770764

Total Populaiton Area (TPA) (m^2)	970
Estimated Total Individuals in Population (TIP)	12789.45

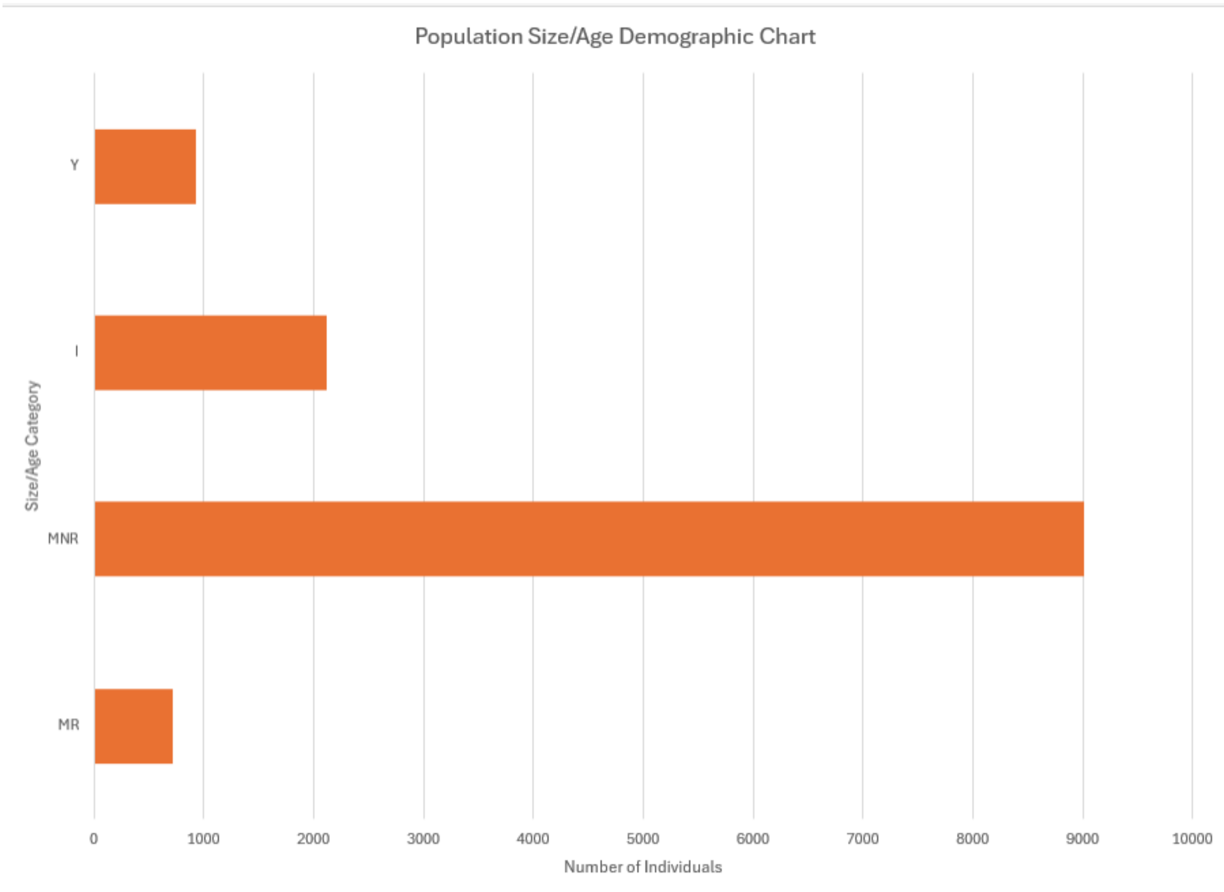


Figure 12. Example output and results of data collected on a goldenseal population using these methods.

Appendix. (Formulas used in the Excel spreadsheet Plant Population Data Analysis .xlsx).
*Note that below are the steps and mathematical equations used to extrapolate data about the entire local population of plants. However, for ease of use, it is recommended to follow the instructions in the Excel link above, which has the formulas already embedded into it. These formulas are provided below mainly for those who may want to change them to adapt to new methods for different types of plants and circumstances.

1. **Average up the varying size/age categories for each varying density intensity plot.**
    1.1. In step two, data was gathered about how many individuals for each size/age category were in each density intensity plot. There were three density intensity plots for each density intensity category.
        1.1.1. High-Density Intensity (HDI), Medium Density Intensity (MDI), Low-Density Intensity (LDI), and Very Low-Density Intensity (VLDI).
    1.2. To get the averages for each size/class category within each density intensity category, add up each plant for each size/class category within the separate density intensity categories. Then divide each sum by the number of plots present for each density intensity. This number should be three.
    1.3. Whenever the averages are gathered, there should be a total of sixteen values.
2. **How to get Density Intensity Averages (DI_{av}) for each Density Intensity (DI) category**
    2.1. Add up all of the plant averages for Mature-Reproducing (MR), Mature Non-reproducing (MNR), Intermediate (I), and Young (Y) to get the DI_{av} for the varying categories or rather to get the high DI_{av} (HDI_{av}), medium DI_{av} (MDI_{av}), low DI_{av} (LDI_{av}), and very low DI_{av} ($VLDI_{av}$).
    2.2. It is important to note that the plant averages described are the sums of the averages for the four different size/age categories for each DI category that were gathered from the circle plots described in step 2.4. This should result in a high-density intensity average (HDI_{av}), a medium-density intensity average (MDI_{av}), a low-density intensity average (LDI_{av}), and a very low-density intensity average ($VLDI_{av}$).
    2.3. Formulas:
        2.3.1. $HDI_{av}= MR_{HDI} + MNR_{HDI}+ I_{HDI}+ Y_{HDI}$
        2.3.2. $MDI_{av}=MR_{MDI} + MNR_{MDI}+ I_{MDI}+ Y_{MDI}$
        2.3.3. $LDI_{av}=MR_{LDI}+ MNR_{LDI}+ I_{LDI}+ Y_{LDI}$
        2.3.4. $VLDI_{av}=MR_{VLDI} + MNR_{VLDI} + I_{VDLI} + Y_{VLDI}$

2.3.5. DI_{av}=MR + MNR + I + Y

3. **How to get Density Intensity Ratio (DI_{ratio}):**
   3.1. Convert each Density Intensity Percentage (DIP) to a decimal form by dividing each DIP by 100.
      3.1.1. It is important to note that the DIP values are the percentages that were assigned to each DI category when looking at the smaller area or population.
      3.1.2. There will be a high DIP (HDIP), a medium DIP (MDIP), a low DIP (LDIP), and a very low DIP (VLDIP).
   3.2. Multiply each DI_{av} by each DIP.
   3.3. The product of DI_{av} and DIP for each DI category should result in four different Density Intensity Ratios (DI_{ratio}) of a high-density intensity ratio (HDI_{ratio}), a medium-density intensity ratio (MDI_{ratio}), a low-density intensity ratio (LDI_{ratio}), and a very low-density intensity ratio ($VLDI_{ratio}$).
   3.4. Formulas:
      3.4.1. HDI_{ratio}=HDIP*HDI_{av}
      3.4.2. MDI_{ratio}=MDIP*MDI_{av}
      3.4.3. LDI_{ratio}=LDIP*LDI_{av}
      3.4.4. $VLDI_{ratio}$=VLDIP*$VLDI_{av}$

4. **How to get Total Individuals in Population (TIP):**
   4.1. First one needs to get the Total Density Intensity Ratio (TDI_{ratio}) which is the sum of the HDI_{ratio}, the MDI_{ratio}, the LDI_{ratio}, and the $VLDI_{ratio}$.
   4.2. Take the TDI_{ratio} and multiply it by the total population area (TPA).
      4.2.1. Note that the TPA was gathered when walking around the total population using either a phone app that calculated it for you or by using measuring tapes in step 1.2.
      4.2.2. The TPA, if not in meters, should be converted to meters.
   4.3. The product of the TPA and the TDI_{ratio} is the total individuals in the population (TIP).
   4.4. Formulas:
      4.4.1. TDI_{ratio}= HDI_{ratio} + MDI_{ratio} + LDI_{ratio} + $VLDI_{ratio}$
      4.4.2. TIP= TDI_{ratio} * TPA

5. **How to get the averages for the size/age categories: mature reproducing average (MR_{av}), mature non-reproducing average (MNR_{av}), intermediate average (I_{av}), and young average (Y_{av}).**
   5.1. It is important to note that information for each size and age category number is calculated in step 2.5.

5.2. Add up all of the averages for each separate size/age class including MR. MNR, I, and Y.

5.3. This will get you the average for each size/age category ie. MR_{av}, MNR_{av}, I_{av}, and Y_{av}.

5.4. Formulas:

5.4.1. $MR_{av}=MR_{HDI}+MR_{MDI}+MR_{LDI}+MR_{VLDI}$

5.4.2. $MNR_{av}= MNR_{HDI}+MNR_{MDI}+MNR_{LDI}+MNR_{VLDI}$

5.4.3. $I_{av}= I_{HDI}+I_{MDI}+I_{LDI}+I_{VLDI}$

5.4.4. $Y_{av}=Y_{HDI}+Y_{MDI}+Y_{LDI}+Y_{VLDI}$

6. How to get the size/age category ratios: mature reproducing ratio (MR_{ratio}), mature non-reproducing ratio (MNR_{ratio}), intermediate ratio (I_{ratio}), and the young ratio (Y_{ratio}).

6.1. Add up MR_{av}, MNR_{av}, I_{av}, and Y_{av} to get the total size/age category average ($TSAC_{av}$).

6.2. Take each MR_{av}, MNR_{av}, I_{av}, and Y_{av}, and divide each of them by the $TSAC_{av}$ described above.

6.3. The quotients gathered from above are the different size/age category ratios (MR_{ratio} MNR_{ratio} I_{av} Y_{av}).

6.4. Formulas:

6.4.1. $TSAC_{av}= MR_{av}+MNR_{av}+I_{av}+Y_{av}$

6.4.2. $MR_{ratio}= MR_{av} / TSAC_{av}$

6.4.3. $MNR_{ratio}= MNR_{av} / TSAC_{av}$

6.4.4. $I_{ratio}= I_{av} / TSAC_{av}$

6.4.5. $Y_{ratio}= Y_{av} / TSAC_{av}$

7. How to get the total individuals for each size/age class.

7.1. Take MR_{ratio}, MNR_{ratio}, I_{ratio}, and Y_{ratio}, and multiply them all by the TIP.

7.2. The products of the MR_{ratio} and TIP will be the total mature reproducing, which is the estimated total number of mature reproducing plants (TMR) in the whole local population. This is also how the total number of mature non-reproducing plants (TMNR), total number of intermediate plants (TI), and the total number of young plants (TY) is gathered with respect to their various size/age categories.

7.3. Formulas:

7.3.1. $TMR = MR_{ratio} * TIP$

7.3.2. $TMNR = MNR_{ratio} * TIP$

7.3.3. $TI = I_{ratio} * TIP$

7.3.4. $TY = Y_{ratio} * TIP$

Glossary:

Note that these are the acronyms and their meanings that are used in Appendix A.

- Density Intensities (DI): The density intensity is the category of varying percentages of an area that is covered by the specific plant/fungi you are looking at.
  - **H**: DI High (60–100% cover)
  - **M**: DI Medium (25–60% cover)
  - **L**: DI Low (5–25% cover)
  - **VL**: DI Very Low (0–5% cover)
- Size/Age Categories
  - **MR**: Mature Reproducing
  - **MNR**: Mature Non-Reproducing
  - **I**: Intermediate
  - **Y**: Young
- Size/Age Classes within Density Intensities (DI):
  - $\mathbf{MR_{HDI}}$: Mature Reproducing within HDI plots
  - $\mathbf{MNR_{HDI}}$: Mature Non-Reproducing within HDI plots
  - $\mathbf{I_{HDI}}$: Intermediate within HDI plots
  - $\mathbf{Y_{HDI}}$: Young within HDI plots
  - $\mathbf{MR_{MDI}}$: Mature Reproducing within MDI plots
  - $\mathbf{MNR_{MDI}}$: Mature Non-Reproducing within MDI plots
  - $\mathbf{I_{MDI}}$: Intermediate within MDI plots
  - $\mathbf{Y_{MDI}}$: Young within MDI plots
  - $\mathbf{MR_{LDI}}$: Mature Reproducing within LDI plots
  - $\mathbf{MNR_{LDI}}$: Mature Non-Reproducing within LDI plots
  - $\mathbf{I_{LDI}}$: Intermediate within LDI plots
  - $\mathbf{Y_{LDI}}$: Young Within LDI plots
  - $\mathbf{MR_{VLDI}}$: Mature Reproducing within VLDI plots
  - $\mathbf{MNR_{VLDI}}$: Mature Non-Reproducing within VLDI plots
  - $\mathbf{I_{VLDI}}$: Intermediate within VLDI plots
  - $\mathbf{Y_{VLDI}}$: Young within VLDI plots
- Density Intensity Percentages (DIP): The percentages that are found in the subpopulation that can be applied to the whole population. They are used for the four different DI.
  - **HDIP**: High-Density Intensity Percentage
  - **MDIP**: Medium-Density Intensity Percentage
  - **LDIP**: Low-Density Intensity Percentage

- **VLDIP**: Very Low-Density Intensity Percentage

- T= Total
  - **TMR**: Total Mature Reproducing
  - **TMNR**: Total Mature Non-Reproducing
  - **TI:** Total Intermediate
  - **TY**: Total Young
  - **TIP**: Total Individuals in Population
  - **TPA**: Total Population Area
- Ratios
  - **MR_{ratio}**: The ratio of Mature Reproducing plants to the total number of plants recorded in the plots
  - **MNR_{ratio}**: The ratio of Mature Non-Reproducing plants to the total number of plants recorded in the plots
  - **I_{ratio}**: The ratio of Intermediate plants to the total number of plants recorded in the plots
  - **Y_{ratio}**: The ratio of Young plants to the total number of plants recorded in the plots
  - **HDI_{ratio}**: High-Density Intensity Ratio that is gathered by multiplying the High-Density Intensity Percentage (HDIP) by the HDI_{av}
  - **MDI_{ratio}**: Medium-Density Intensity Ratio that is gathered by multiplying the Medium-Density Intensity Percentage (MDIP) by the MDI_{av}
  - **LDI_{ratio}**: Low-Density Intensity Ratio that is gathered by multiplying the Low-Density Intensity Percentage (LDIP) by the LDI_{av}
  - **$VLDI_{ratio}$**: Very Low-Density Intensity Ratio that is gathered by multiplying the Very Low-Density Intensity Percentage (VLDIP) by the $VLDI_{av}$
  - **TDI_{ratio}**: The total or sum of HDI_{ratio} MDI_{ratio} LDI_{ratio} $VLDI_{ratio}$
- Averages
  - **HDI_{Av}**: The average number of total plants in the high DI (HDI) circle plots.
  - **MDI_{Av}**: The average number of total plants in the medium DI (MDI) circle plots.
  - **LDI_{Av}**: The average number of total plants in the low DI (LDI) circle plots.
  - **$VLDI_{Av}$**: The average number of total plants in the very low DI (VLDI) circle plots
  - **DI_{Av}**: The average number of total plants in a category of DI circle plots
  - **MR_{av}**: The sum of all of the average number of mature reproducing plants from the four density intensities, which was gathered from the circle plots and then averaged.
  - **MNR_{av}**: The sum of all of the average number of mature non-reproducing plants from the four density intensities, which was gathered from the circle plots and then averaged.

- **I_{av}**: The sum of all of the average number of intermediate plants from the four density intensities, which was gathered from the circle plots and then averaged.
- **Y_{av}**: The sum of all of the average number of young plants from the four density intensities, which was gathered from the circle plots and then averaged.
- **$TSAC_{av}$**: The total size/age category average that is gathered by adding up all of the averages for the size/age categories.