Alley Cropping

in Missouri

How Harvard can meet its climate goals while transforming US agricultural practice + improving livelihoods

Climate Solutions Living Lab | Harvard Law School | Spring 2018 | Team 4
Johan Arango-Quiroga, David Chan, Aubrey Germ, Heather Romero, Angela Shields, Charlotte Wagner

This Report and Implementation Plan are student work product completed to fulfill requirements of the Climate Solutions Living Lab, a 12-week course offered at Harvard Law School. This report and plan were researched and written under tight time constraints to answer specific questions posed to the students in their course assignment. Any opinions expressed in the report are those of the students and not of Harvard University or Harvard Law School. If you would like to learn more about Harvard Law School's Climate Solutions Living Lab, please contact Professor Wendy Jacobs at wjacobs@law.harvard.edu.

Acknowledgements

This project was completed during the Spring 2018 Climate Solutions Living Lab course at Harvard Law School. The course brought together students from diverse disciplines across various Harvard graduate programs to solve complex climate challenges. The focus of the course was to figure out how an unregulated entity, such as Harvard University, can continue to reduce its carbon footprint while creating positive social and environmental impacts off-campus. This course presented us with a fabulous learning opportunity and great experience.

Our team would like to thank the following people for providing their support, knowledge, time, and generosity throughout the spring semester. We learned so much and couldn't have done it without you!

Wendy Jacobs of the Harvard Law School Emmett Environmental Law & Policy Clinic

Debra Stump of the Harvard Law School Climate Solutions Living Lab

Drew Michanowicz DrPH at HSPH and our CSLL TA

Michael Gold of the University of Missouri Center for Agroforestry

Linda Tomasso of the Harvard T.H. Chan School of Public Health

Nathaniel Colbert-Sangree of Duke University's Carbon Offset Initiative

Ryan Smith of the Delta Institute

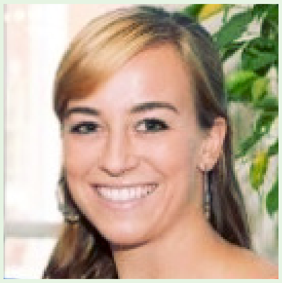
J.B. Daniel of the USDA-NRCS

Adam Downing of Virginia Tech Cooperative Extension School

Team

Johan Arango-Quiroga
HES ALM '19 | MIT IDSS

David Chan
HBS MBA '18



Aubrey Germ
GSD MUP'18

Heather Romero
HLS JD '19

Angela Shields
HSPH MPH '19

Charlotte Wagner
SEAS Ph.D. '20

Contents

Implementation Plan

> **Climate change is no longer a scientific problem. . . Climate change is a human problem."[2]**
>
> -Professor Mike Hulme
>
> *University of Cambridge*
> *Former IPCC Scientist*

Introduction

Goals

Professor Hulme, formerly of the IPCC, was once an avid supporter of global emissions reduction targets as the primary means of fighting climate change. Unfortunately, those efforts are continually hindered by the political logjam plaguing many national governments.

Now, Professor Hulme sees a different path forward: one focusing on mitigating climate change on the local scale. Transitioning the focal point of climate rhetoric from numbers like "limiting global warming to 2 degrees" to building coalitions of unlikely actors centered on realizing co-benefits, rather than preventing global warming. A focus on co-benefits, Professor Hulme argues, will bring disparate groups to the table, regardless of political ideology. Through the process of pursuing widely acceptable co-benefits, climate change can still be meaningfully addressed.

The goals of this project fit Professor Hulme's remarks astonishingly well. As a part of the Climate Solutions Living Lab at Harvard Law School, our team was tasked with the challenge of designing a project that can produce "quantifiable, verifiable, and monitorable social benefits including GHG emission reductions" by changing human behaviors in the agriculture sector.[1] Accordingly, our team created a project that brings together the work of disparate groups—rural farmers and universities—to create cognizable co-benefits such as reducing agricultural run-off and soil erosion, diversifying rural crop production, and improving health outcomes for surrounding localities. Through the process of achieving these co-benefits, our project also verifiably generates 100,000 tons of GHG emission reductions, and is scalable enough to generate far more.

This implementation study serves as a road map for any unregulated entity to achieve its own climate change mitigation goals by transforming the lives of rural farmers and producing a host of co-benefits that will benefit the not just the participating farmers, but also the surrounding communities for years to come.

---

1 Wendy B. Jacobs. Project Goals Memorandum. Climate Solutions Living Lab (Spring 2018).
2 Anna Salleh. Science can't solve climate change — better politics can, former IPCC scientist says. ABC News. Retrieved May 2, 2018 from http://www.abc.net.au/news/science/2018-05-02/why-science-cant-solve-climate-change/9711364.

Background

Our team considered many possible projects at the beginning of the Harvard Law School Climate Solutions Living Lab course. In our initial screening exercise, our team proposed eleven possible projects to develop in more detail throughout the semester.[1] To begin, each team member conducted independent research on each possibility to investigate its potentially effectiveness in meeting fourteen GHG reduction goals, co-benefits, and feasibility considerations.

After the research phase, each member numerically evaluated each proposal's ability to meet the project goals on a scale of zero to three, zero indicating little to no anticipated effectiveness, and three indicating a highly effective solution. The averages of the team's scores are recorded in Table 1. At this point, the team decided to eliminate the consumer side solution of reducing meat consumption, and focus solely on mitigating climate change from the supply side of agriculture. Thus, the team continued investigating the remaining top four proposals more in depth.

To continue our analysis, each team member investigated the proposals to make high-level feasibility determinations. Through this additional screening exercise, the team narrowed possible proposals to "reforestation of farm land" through agroforestry practices. Agroforestry, the "intentional integration of trees and shrubs into crop and animal farming systems"[2] to produce not only positive environmental change, but social and economic benefits as well, was particularly attractive to the team because of its ability to provide climate resilience to farms and additional profit streams to the farmers with whom we aimed to work.

Our decision to focus on agroforestry initiatives lead the team to investigate alley cropping and silvopasture, two subsets of agroforestry. Alley cropping integrates rows of trees with rows of conventional crop and silvopasture allows livestock to grazing among trees. Our team chose to focus our analysis of these options to application in Missouri and New York. Both states have established institutional support for agroforestry, but have still small-scale adoption rates.

The results of our Feasibility Study can be found starting on page 56. Though both projects showed promise, ultimately, the team determined that alley cropping in Missouri posed the best prospects for success for the purposes of the Climate Solutions Living Lab and this project. As such, our team prepared this implementation plan to assist interested parties in continuing to develop, and ultimately execute, this worthwhile project.

1 See Feasibility Report for additional details
2 U.S. Dep't Agric.. Agroforestry. Retrieved March 9, 2018 from https://www.usda.gov/topics/forestry/agroforestry.

Table 1. Summary of the Screening Exercise results. Bolded scores show the projects we investigated deeper. We ultimately took project 5 through our feasibilty study.

Project Ideas	Weighted Score
1. Carbon sequestration through regenerative organic agriculture (i.e. kernza)	**2.30**
2. Waste management of livestock (i.e. use for biofuels)	**2.29**
3. Reduced use of nitrogen fertilizers	**2.18**
4. Reducing meat consumption (at consumer level)	2.17
5. Reforestation of farmlands	**2.10**
6. Making livestock feed regenerative	2.02
7. Using crop residue for energy generation (i.e. biofuels)	2.00
8. Rice paddy flooding solutions	1.89
9. Reducing slash and burn farming practices (i.e. sugarcane)	1.86
10. Replacing slurry with compost	1.86
11. Supporting grassfed beef production	1.74

By transforming just **1,500 acres** of conventional Missouri farmland to alley cropped **chestnuts + hay**

Harvard will generate:

100,000
tons of CO_2 eq over 30 years

16.2%
interest on investment

$8,500
net profit per acre

$8 million
in co-benefits through air, water, and soil quality improvements

long-term farm resilience
through farmer education and crop diversification.

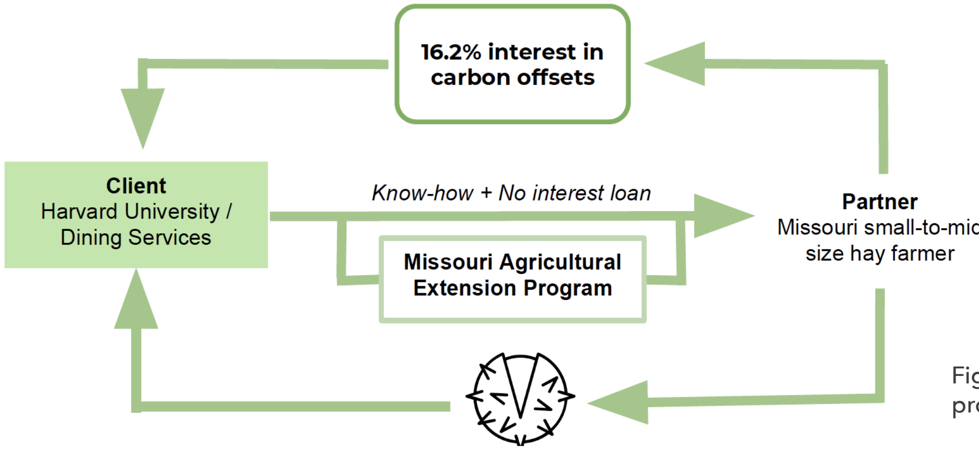


Figure 1. Alley cropping project framework

Project Summary

By adopting this project, Harvard[1] can help rural Missouri farmers transition their farms from conventional agricultural practices to alley cropping, a sustainable form of land use management. This project specifically focuses on converting traditionally farmed hay crop to an alley cropping scheme integrating Chinese Chestnuts. Transforming just 1,500 acres of conventional farmland to alley cropping will generate 100,000 tons of verifiable, quantifiable, and monitorable carbon offsets over the thirty year life of the project.

Additionally, these emissions reductions come with a host of co-benefits. This project is capable of producing 16.2% interest on investment for Harvard in the form of the carbon offsets produced by the alley cropping transition. It increases per acre profit by $8,500, creating a significant new source of income participating farmers. Furthermore, co-benefits in improved water, soil, and air quality improve the lives of those in surrounding communities by improving drinking water quality, increasing crop yields, and improving respiratory illness outcomes. This all comes with the added benefits of diversifying rural crops, increasing farm resilience to extreme weather, and creating educational opportunities for farmers and the university students called upon to help put this project into motion.

Our project achieves these results by reducing the barriers to farmers' adoption of sustainable practices. Currently, high monetary costs and financial risk discourage farmers from making transitions to climate-friendly land management techniques. Harvard, in our proposal Harvard University, reduces these barriers by offering a no interest loan and institutional know-how to the partner farmers in Missouri. The required know-how is already housed within Harvard's vast institutional resources: the Emmett Environmental Law Clinic, School of Engineering & Applied Sciences, Graduate School of Design, Business School, School of Public Health, Harvard Forestry to name a few. Our project has also generated interest from Duke University, who has offered institutional support as well. These education resources are put to work in developing this alley cropping projects beyond the bounds of the Climate Solutions Living Lab. After completing sufficient development, Harvard will work with on-the-ground resources in Missouri: namely, the University of Missouri Center for Agroforestry, and the University of Missouri Extension School.

By working with these local partners, Harvard will identify partner farmers (the first of which is referred to as the "pilot farm(er)"). Once the partner farmer is equipped to fully adopt alley cropping on their land, the farmer is able to begin producing benefits for Harvard (in the form of 16.2% interest on investment through carbon offset generation) and the surrounding community (in the form of social and ecological co-benefits). Additionally, the farmer will begin producing chestnuts, which can be purchased by Harvard, or by a third party. The duration of the project lasts thirty years, after which contractual obligations of the farmer and entity expire. However, after completing the transition to alley cropping, the partner farmers will have achieved a permanent transition to sustainable practices.

1 Though this project identifies Harvard as an ideal unregulated entity to adopt this project, another unregulated entity could participate. The education partnerships and suggested student work are not tied to financial contributions from the unregulated entity, making it possible for various parties to work in partnership with the educational institutions contemplated by this project while providing the financial support for the farmers and receiving the carbon offsets.

Net GHG sequestration (USDA)

3.42 tons

CO2 eq per acre per year

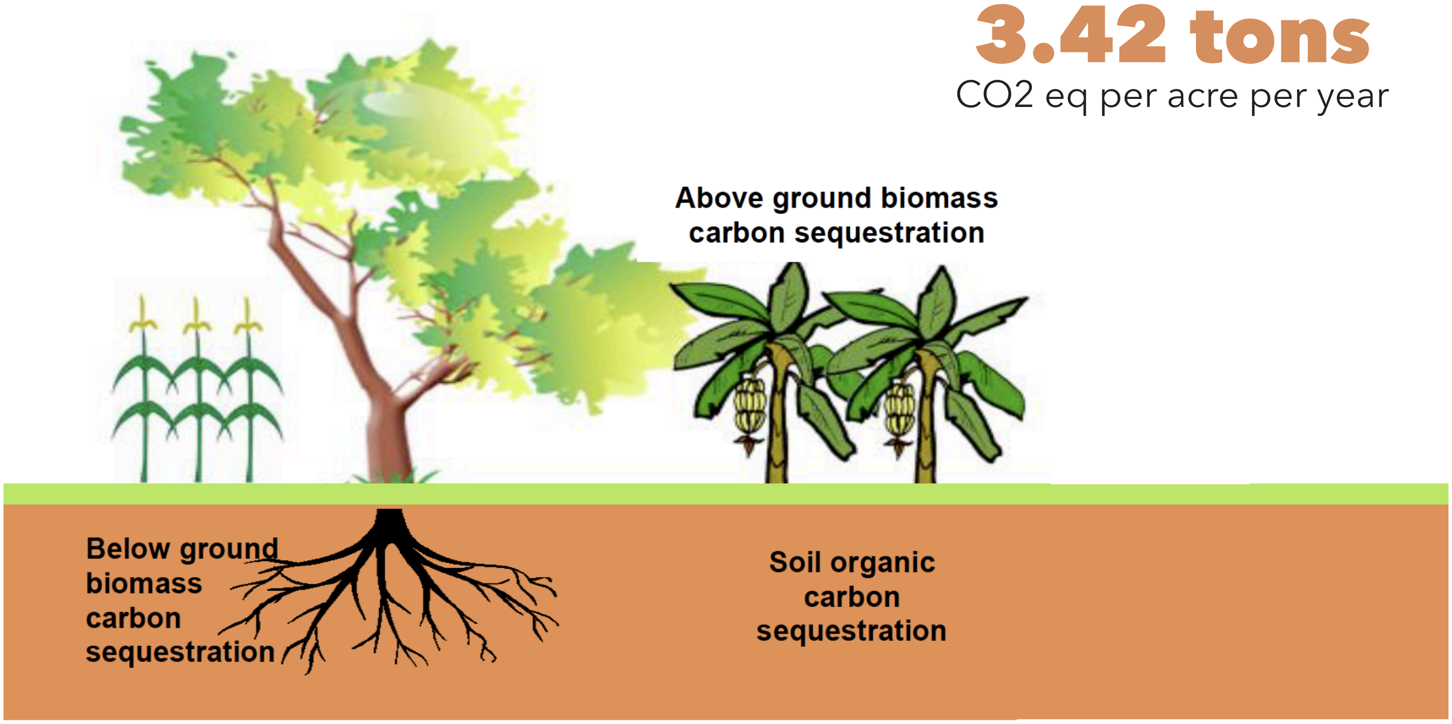


Figure 2. Sequestration of atmospheric CO_2 with terrestrial biomass

Adapted from Kim et al. 2016

Why Alley Cropping?

Climate change is caused by an imbalance between carbon sinks and carbon sources. For many centuries land was a net source of carbon as agricultural activities expanded, causing carbon loss from deforestation and increased erosion. Because of its intensive land use practices in addition to livestock emissions, agriculture contributes 24% to global GHG emissions.[1] Over the past fifty years however, net carbon storage in terrestrial biomass has increased as plant cover expanded towards more northern latitudes due to higher temperatures and carbon assimilation by plants increased as a consequence of increased atmospheric CO_2.[2]

Our project intends to increase the terrestrial biomass by transforming conventionally farmed land into agroforestry, thereby increasing the biomass above ground (i.e. in trees) and below ground (i.e. in root systems and soil carbon content). The amounts of carbon sequestered through agroforestry depends on the crop combination, total biomass, soil type and moisture content among other factors.

An important consideration for the success of carbon storage in an alley cropping system is the permanence of the carbon storage, as a transformation to conventional farming methods, or the death of trees can release the stored carbon back to the atmosphere. Trees can be charred to avoid carbon release from biomass degradation.

Carbon Sequestration

In our project, 40% of the farmed land will be transformed into a tree nut plantation, whereas the remaining 60% continues to be farmed with seasonal crops such as hay or alfalfa. According to the COMET-Planner tool developed by a cooperation of Natural Resources Conservation Service, the US Department of Agriculture and Colorado State University, 20% of an acre of humid Missouri farmland planted with treenuts can store an additional 1.17t CO_2 per acre per year over the first 20 years after implementation. This means that 3.42t CO_2 per acre per year could be sequestered if 40% of land are planted with treenuts. The carbon sequestration estimate by COMET-Planner is non-specific to the exact number of trees planted as well as the other factors mentioned above. However, the COMET-Farm tool, an extension of the COMET-Planner, allows the calculation of sequestered carbon based on spatially-explicit soil and climate data, such as plot size, crop type, soil type, yield, fertilizer application and date.[3] The COMET-Farm tool has been successfully used by other organizations dedicated to carbon farming such as the California-based Marin Carbon Project[4] and is consistent with the US national GHG inventory.[5]

With respect of the permanence of the carbon sequestration, it is important that trees are not cut and farmland is not returned back to conventional practices. We consider it unlikely that farmers will return to conventional farming practices after the 20-year completion of the project considering the high profitability compared to conventional practices (see Finance and Law sections). Further, we suggest that trees that reach the end of their productive life of 200-800 years (though peak productivity occurs in years 35-50) and have to be cut down should be charred to ensure that the sequestered carbon is not oxidised and released back to the atmosphere. Further research is needed to identify how long a farmer generally keeps trees working before replacement and determine what farmers typically do with their 'retired' chestnut trees.

1 EPA. Global Greenhouse Gas Emission data. Retrieved April 30, 2018 from https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

2 NOAA. Carbon Cycle Science. Retrieved April 30, 2018 from https://www.esrl.noaa.gov/research/themes/carbon/

3 Colorado State University. "What information do I need? Retrieved April 30, 2018 from http://cometfarm.nrel.colostate.edu

4 Marin Carbon Project. DRAFT Carbon Farm Plan — ABC Ranch. Retrieved April 30, 2018 from http://www.carboncycle.org/carbon-farming/draft-carbon-farm-plan/

5 Colorado State University. COMET-Planner (pdf). Retrieved April 30, 2018 from http://comet-planner.nrel.colostate.edu/COMET-Planner_Report_Final.pdf

Timeline

The project is designed in such way that initially a single test plot of ~5 acres is transformed to alley cropping yielding about 12t CO_2 per acre per year between 2020 and 2026. During this period another 29 farms are recruited into the project based on the success of the pilot farm, turning each ~5 acres of land into alley cropping and thereby increasing the annual offset yield to 342t CO_2 per acre per year. Finally, each of these farms will scale up their alley cropping practice to ~50 acres of land, thereby generating annual carbon offsets 5000t CO_2 per acre per year.

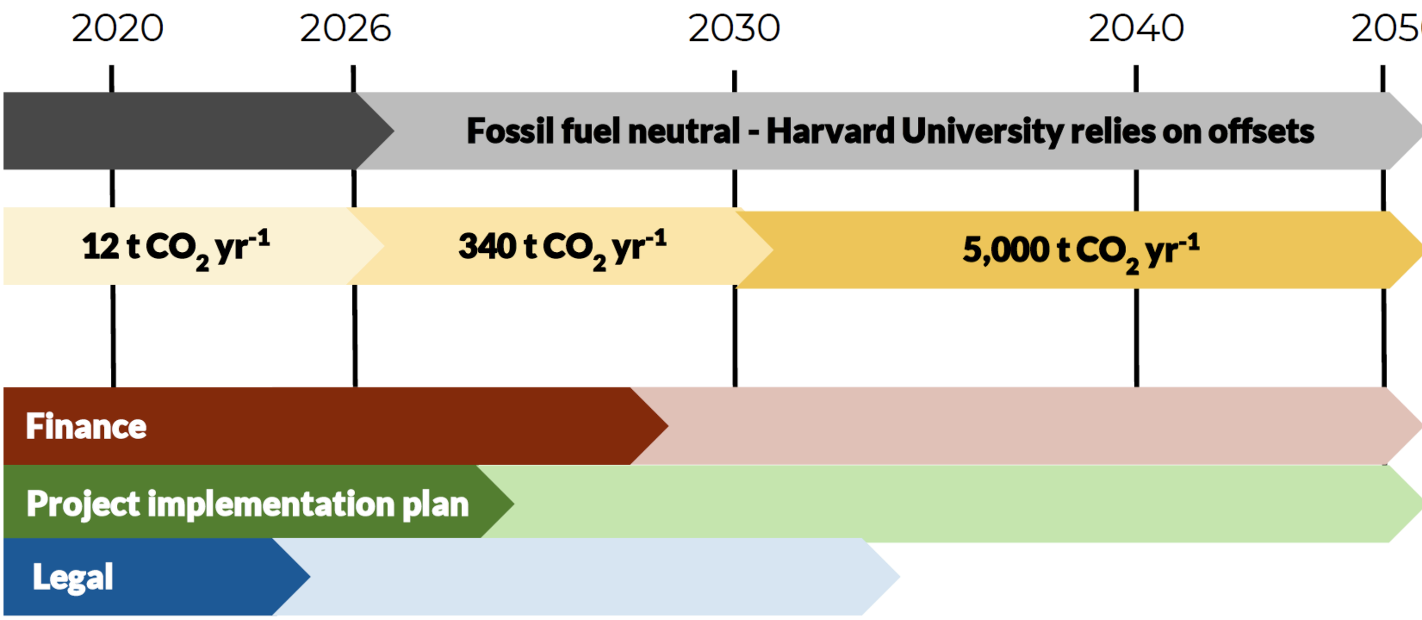


Figure 3. Alley cropping project timeline aligned with Harvard University's fossil fuel neutrality goals

Agroforestry Co-Benefits

Missouri suffers from a variety of water, air, and soil quality issues, many of which are exacerbated by climate change. In terms of water quality, around 67% of the state's lakes are considered eutrophic.[1] Eutrophic lakes are defined as those that are rich in excess nutrients and minerals, such as phosphorus and nitrogen, that promote the growth of algae and aquatic plants. This leads to a reduction in dissolved oxygen in the body of water, disrupting the health of local ecosystems and contaminating local drinking water sources.

Eutrophication in Missouri could be mainly due to agricultural runoff as the Glaciated and Ozark regions of the state, where agriculture is the most expansive, is where the majority of these eutrophic lakes reside. Missouri also ranks tenth in chronic lower respiratory illness mortality, with a rate of around 0.05%.[2] This is compared to the national of average of around 0.04%.

To put this into perspective, Missouri also ranks in the top 15 for most polluted states in the nation.[3] In terms of soil quality, Missouri soils have historically deficient concentrations of potassium, nitrogen and phosphorus[4] leading to decreased agricultural productivity in the state. These nutrients are the most important indicators of soil health as they are the basic macronutrients needed for optimal plant growth.

In order to account for these soil deficiencies, farmers are then forced to increase their use of fertilizer leading to potential agricultural runoff contaminating local water bodies. Across the board, there are a variety of quality issues that can be improved in Missouri and alley cropping is a potential intervention that can help with mitigation.

1 "Missouri Integrated Water Quality Report and Section 303(d) List, 2016." Missouri Department of Natural Resources Water Protection Program, http://www.centerforagroforestry.org/pubs/training/chap3_2015.pdf
2 "National Center for Health Statistics." Centers for Disease Control and Prevention, Centers for Disease Control and Prevention, 10 Jan. 2018, www.cdc.gov/nchs/pressroom/sosmap/lung_disease_mortality/lung_disease.htm.
3 Bizjournals.com, The Business Journals, www.bizjournals.com/stlouis/blog/2012/08/missouri-15th-worst-polluted-state-in.html.
4 "Potassium in Missouri Soils." University of Missouri Extension, extension2.missouri.edu/g9185.

Ecosystem Services

The public health co-benefits from alley cropping are derived from the domain of ecosystem services. Ecosystem services are the benefits that humans gain from the natural environment or properly-functioning ecosystems. By planting trees next to crops, this creates an above ground tree network that can act as a windbreak. This not only helps reduce wind erosion and protect crops but can also enhance the micro-climate of the ecosystem. Alley cropping helps reduce soil erosion and agricultural runoff by protecting fragile soils producing a network of roots from trees and companion crops. Water quality is also improved due to interception, sequestration, and decomposition of agricultural chemicals by tree and herbaceous root environments. Agricultural chemicals, such as nitrogen, that leech beyond the root zone of crops can be absorbed by the root systems of the trees therefore minimizing groundwater contamination and potentially improving water quality that enters local food and water systems.

Trees and shrubs can also improve crop yield by modifying the crop microclimate through slowing of wind speed and reduction of wind erosion. Crop evapotranspiration can be reduced by 15-30 percent and water content in the tillage layer can be increased by 5-15%.[1] Alley cropping further protects crops from damage by reducing crop visibility for pests and diluting pest hosts due to plant diversity. By protecting crops from damage, these systems can help improve crop yields which could then lead to more diversified income, utility of wood, and improved nutrition due to higher biodiversity. The entire system also benefits from enhanced nutrient cycling thus increasing the bioavailability of various nutrients essential for soil health and crop growth as well as improve carbon sequestration.

These actions work together to help improve upon the soil quality in the ecosystem thus potentially leading to a reduced need for fertilizer due to the enhanced nutrient cycling and for irrigation due to the increased water content storage capability. Healthy soils can also mitigate climate-related risks such as erosion, floods, and pest and disease outbreaks.

1 "Chapter 3: Alley Cropping." University of Missouri Extension, http://www.centerforagroforestry.org/pubs/training/chap3_2015.pdf.

Public Health

A study conducted at Greenley Memorial Research Center located in northeastern Missouri showed that, after only three years, agricultural runoff was reduced between 10 to 1%, total phosphorus loss was reduced by 18%, and total nitrogen loss was reduced by 21 to 20% based on calibration relationships.[1] These reductions lead to benefits in water and soil quality which can then lead to improved surface and drinking water and improved crop yields, respectively.

Research has shown that improving soil quality can also enhance the nutrient composition within the crops themselves thus leading to more nutritious food distributed to local communities.[2] Trees are also able to not only sequester carbon but remove harmful particulates and pollutants in the air. One study showed that pollution removal by trees was as high as 15% for ozone, 14% for sulfur dioxide, 13% for particulate matter, 8% for nitrogen dioxide, and 0.05% carbon monoxide.

Reduced pollution and particulates have been associated to contribute to improved respiratory illness in the local area.[3] By improving upon the existing water, soil, and air quality issues in Missouri, the local community can benefit from various positive health impacts through ecosystem services provided by alley cropping.

1 Udawatta, R. P., Krstansky, J. J., Henderson, G. S., & Garrett, H. E. (2002). Agroforestry practices, runoff, and nutrient loss. Journal of Environmental Quality, 31(4), 1214-1225.
2 Nowak, D. J. (2002). The effects of urban trees on air quality. USDA Forest Service, 96-102.
3 Laden, F., Schwartz, J., Speizer, F. E., & Dockery, D. W. (2006). Reduction in fine particulate air pollution and mortality: extended follow-up of the Harvard Six Cities study. American journal of respiratory and critical care medicine, 173(6), 667-672.

reduced particulate matter
15%

reduced irrigation runoff
10%

reduced nitrogen + phosphorous loss
20%

Financing

The Chestnut Opportunity

Among many potential crops that could have been planted under our alley-cropping architecture, our team selected Chinese chestnuts as we believe they offer the farmer the most potential while also bearing the least amount of risk for Harvard.

Chestnut production is only suitable in a handful of countries across the world, namely the United States, China, South Korea, and Italy. While the U.S. has thousands upon thousands of acres that would be suitable for chestnut farming, only a mere 3,700 acres were in production as of 2011. In fact, the U.S. has consistently imported chestnuts from the China, South Korea, and Italy over the past decade, demonstrating that even if domestic demand were to remain constant, there would be an opportunity to fill this demand from domestically-produced chestnuts.

Chestnuts are also highly nutritious and can be used in a number of ways. They are low in calories, fat, and cholesterol, and high in vitamin C, B-vitamins, and fiber. Just 100 grams of chestnuts will provide one with over 70 percent of his or her daily vitamin C requirement. Chestnuts are also gluten-free, and because they are high in carbohydrates, they can be easily ground into a Celiac-friendly flour that can then be used for bakery products that are often difficult to produce for this market.

As has been done with many other commodities in the U.S., such as avocados and blueberries, commodity marketing programs could quickly build domestic demand for this nutritious nut. The USDA and some state agricultural agencies are beginning to invest more in chestnut marketing, and there is already a greater retail presence emerging; for example, Trader Joe's already sells shelled boiled chestnuts, which would not have been seen in stores a few years ago.

Private Funding Sources

This project is financially extremely viable, as it provides a return of 13% over the course of 30 years. However, there is a high hurdle for farmers to adopt agroforestry, because during the initial 7 years the cash flow is negative with a cost of $5,107 per acre. We thus suggest to develop a financing plan for this cost, to increase adoption rates consisting of a combination a no interest loan. The client, Harvard University, would provide the debt capital for the loan through a trusted market intermediary, such as CoBank.

Public Funding Sources

In addition to sourcing debt capital from the client, we believe this project qualifies for a number of public funding resources, which improve the economic potential of the project and minimize the client's investment risk.

Among the public sources of funding are:

1. EQIP - Environmental Quality Initiatives Program[1]
    - Common Associated Practices Conservation Practice Standard (CPS)
    - Alley Cropping (Code 311) is commonly applied with Tree and Shrub Establishment (Code 612).
    - For alley cropping practices, EQIP will pay $50 per acre for first 3 years on land planted in trees and the grass strip adjacent to trees. No more than 50% of the cropland can be enrolled.
    - See Table 2. EQIP Standard Funding Figures[2] and Table 3. EQIP "Socially Disadvantaged" Status Funding Figures[3] (see Appendix D for more information about the 'socially disadvantaged" designation)
    - The HU Payment Rate refers to the higher rate that farmers who under the category of Socially Disadvantaged, Beginning, and Limited Resource Farmers/Ranchers, Veteran Farmers are entitled to.

2. Grants from SARE. See SARE - Farmer Rancher Grant Program - (Sustainable Agriculture Research and Education)
    - Farmers in Missouri are eligible to apply for grants through the North Central Region (NCR) SARE.
    - A review committee provides feedback to the NCR-SARE administrative council, which

1 EQIP funding figures are based on the 2014 Farm Bill, which is up for renewal in 2018. For more information see Appendix C
2 USDA, Natural Resource Conservation Service, Missouri, "Conservation Reserve Program", https://www.nrcs.usda.gov/wps/portal/nrcs/mo/programs/nrcs144p2_012374/
3 Ibid.

ultimately makes funding decisions. The farmer should get in contact with NCR-SARE, local agricultural groups, the NRCS, and extension agents to come up with a clear project proposal.
- Additionally, some of these people are members of the administrative council that make funding decisions.
- See Table 4. SARE Funding Summary

Public funding is a meaningful portion of the first year's financing (~20 percent), but plays a much smaller role in the rest of the project timeline. Of course, public funding is subject to grant limitations, scaling limits, and the risk of not being included in the next iteration of the Farm Bill.

Financing Structure + Profitability

Harvard would issue 10-year, no interest bonds to the farmers who agree to enter into contract to participate in alley cropping. The debt would be issued as needed in order to ensure the farmer is in compliance with the general framework and terms of the agreement before an issuance of additional capital for scaling. The loan disbursement schedule can be seen in Figure 4.

The total amount of debt that would be required from Harvard would be $7.5 million dispersed over a period of 12 years. In exchange for the credit, Harvard would receive the 100,000 tonnes of CO2-equivalent credits. At current offset market prices, this equates to roughly $1.2 million in value generated for the university, or an investment horizon yield of 16.2% (roughly 1% per annum).

Loan repayment would begin in 2028, when the first projects begin to generate positive cash flow as the chestnut trees mature and reach commercial yields. Repayments would continue through 2041, at which point Harvard's full $7.5 million principal investment would be repaid.

For the purposes of our financial model, we assumed farmers entering into the program had previously farmed hay and would continue to farm hay in the intercrop rows. We also used a chestnut price of $2.10 per pound, which is a conservative estimate as Missouri chestnuts have been fetching upwards of $3.25 per pound in the market. We assumed that through investment in training, farmers could learn how to graft so that participating farmers could save substantially on tree costs; pre-grafted trees sell for $25 per tree, while non-grafted trees sell for under $5. We assumed that the weighted average cost of a tree under this plan (since a handful of pre-grafted will be needed in order to secure the graftings) is $5.25. We also incorporated initial setup costs for labor and equipment, as well as ongoing costs for inputs (fertilizer, herbicides), maintenance labor, and monitoring via Farmers Edge satellite technology.

The farmer will also receive dual income from the hay production that comprises 40 percent of planned acres. We assumed farmers would grow 2 tonnes of hay per acre, and that farmers would receive $150 per tonne of hay.

The project is also highly profitable for farmers, as the expected profitability of the project exceeds the credit required to fund the project by a factor of 10x. This is also an additional reason for Harvard to consider the merit of the project, as the likelihood of the university recouping their principal loan is very high. Farmers will be economically incentivized to participate in the project as it offers a net profit of $8,500 per acre over the 30-year horizon, which is considerably higher than hay (<$1,000 per acre) and many other alternative crops. We believe the opportunity exists because of the steep upfront costs and eight-year period of negative cash flow, which is very often too much risk for a farmer to accept. By de-risking this upfront financing need, Harvard can help improve the socioeconomic livelihoods of rural American farmers while generating offsets at market rate.

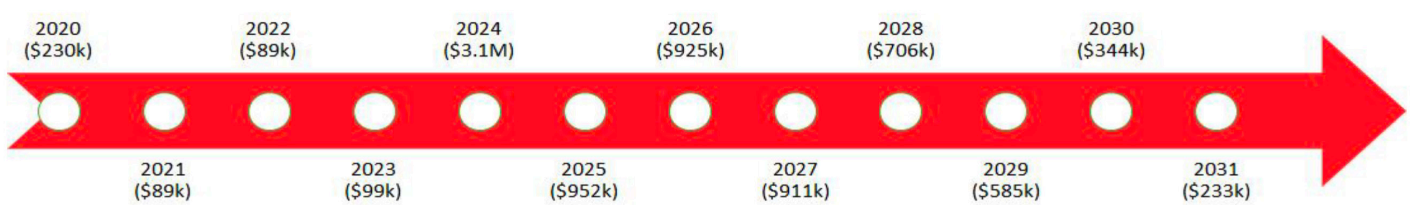


Figure 4. Full loan disbursement schedule by year

Table 2. EQIP Standard Funding Figures

Practice Code	Conservation Practice		Maximum Payment	HU Maximum Payment	Practice Unit/ Payment Unit	Payment Rate	HU Payment Rate 1/	Lifespan (Years)
311	Alley Cropping							
	Structural	Subaccount: AF			Acre			15
	Single row bareroot planting stock				Each	$1.52	$1.94	
	Single row bareroot planting stock with tree shelters				Each	$4.66	$5.71	
	Single row container planting stock, less than 2 gallons				Each	$5.57	$6.81	
	Single row container planting stock, less than 2 gallon with tree shelters				Each	$10.66	$12.90	
	Single row container planting stock, 2 gallon and larger				Each	$9.05	$10.98	
	Single row container planting stock, 2 gallon and larger with tree shelters				Each	$14.14	$17.08	

1 *Payment includes tree/shrub costs. Payment does not include site preparation.*
2 *Containers 1 quart and smaller will use the applicable bareroot payment rate.*
3 *Tree shelters are tubes made of light stabilized polypropylene or polyethylene material and come in various heights (2-6') determined by the need and intended function of the shelter.*
4 *See the (311) Alley Cropping conservation practice standard.*

Table 3. EQIP "Socially Disadvantaged" Status Funding Figures

Practice Code	Conservation Practice		Maximum Payment	HU Maximum Payment	Practice Unit/ Payment Unit	Payment Rate	HU Payment Rate 1/	Lifespan (Years)
612	Tree/Shrub Establishment							
	Structural	Subaccounts: C, PH, F, AW, W, AF			Acre			15
	Direct Seeding				Acre	$594.65	$755.80	
	Bareroot Trees and Shrubs, Each				Each	$0.57	$0.68	
	Bareroot Trees and Shrubs, with Tree Shelters, Each				Each	$2.59	$3.11	
	Container Trees and Shrubs, less than 2 gallon, Each				Each	$4.54	$5.45	
	Container Trees and Shrubs, less than 2 gallon with tree shelters, Each				Each	$9.80	$11.76	
	Container Trees and Shrubs, 2 gallon and larger, Each				Each	$8.02	$9.62	
	Container Trees and Shrubs, 2 gallon and larger with tree shelters, Each				Each	$13.28	$15.93	

1 *Within the Agroforestry subaccount, payment is only authorized for woody crop establishment.*
2 *Containers 1 quart and smaller will use the applicable bareroot payment rate.*
3 *Tree shelters are tubes made of light stabilized polypropylene or polyethylene material and come in various heights (2-6') determined by the need and intended function of the shelter.*
4 *See the (612) Tree/Shrub Establishment conservation practice standard.*

Table 4. SARE Funding Summary

Funding	Farmer Rancher grants are offered as individual ($7,500 maximum), team of two ($15,000 maximum), or group ($22,500 maximum) grants for ideas initiated by farmers and ranchers. About 40 projects are funded each year.
For how long?	Projects may last up to 24 months.
Strengths if our farmer applies for a SARE grant	SARE Grants support producers who are protecting natural resources, enhancing communities, and boosting profitability. SARE grants support Farmers and Ranchers exploring innovative marketing of sustainable agriculture projects, in addition to other project topics.

Implementation Summary: Steps A-Z

1. With an investment of roughly $160 per t CO2eq we will be able to create 50,000 tons of offset credits for your organization (realised over 30 years)

2. We will develop and certify an offset protocol that ensures that the offset credits generated by this project are legitimate and do in fact generate CO2 eq emission reductions of the expected magnitude

3. We have collaborated with the University of Missouri Center for Agroforestry to identify a farmer who will be an effective partner for the pilot program (~5 acres)

4. Farmer and the unregulated entity will enter negotiations to finalize a contract for the pilot project; the contract should serve as a model from which future contracts will be based

5. Contract provisions will need to be individualized to each farmer based on land characteristics, farmer crop experience/preferences, etc. Alley cropping provides a versatile template in which project goals can be met and farmers can personalize (to an extent) the project to insure personal success

6. Once proving the pilot program is showing to be successful (trees grafts are successful, and trees start producing fruit, farmer is able to adopt necessary behaviors & practices), the farm will expand the acreage dedicated to alley cropping

7. As farmers expand acreage and begin producing offsets, insurance policies will be applied for and offered plans purchased

8. Other farmers will be recruited to replicate the pilot's project design

9. Contract negotiations with new partner farmers will have to occur as farmers elect to enter the program until the target enrollment cap of 30 farms is reached

10. The farmer participates in the annual grafting training day at the Center for Agroforestry of Missouri to acquire the skill of grafting and nursing trees

11. The farmer will purchase a number of pre-grafted Chinese chestnut trees from a local nursery in Missouri. The expected cost of a pre-grafted Chinese chestnut tree is $25 per tree. We will likely need 4 pre-grafted Chinese chestnut trees per acre, and this assumes grafts from a pre-grafted tree can be utilized to graft 4.5 additional trees

12. Next, the farmer purchases 20 Chinese chestnut seedlings from a local nursery Missouri for each acre (s)he intends to plant

13. The farmer will plant double rows of chestnut trees in the prescribed spacing arrangement detailed in the Farming Design and Calculations section (adaptations as required by the specific land layout are possible)

14. In between the rows of chestnut trees, the farmer will continue growing the cash/row crop he or she has previously been farming (be it corn, soy, wheat, alfalfa, etc.) for the first 6 years

15. Using satellite imaging (Farmer's Edge), we will start monitoring the number of trees and health of those trees to ensure the project is being maintained and properly managed through the 30 year period (as detailed in our offset protocol)

16. After 6 years, chestnut trees begin to bear meaningful quantities of fruit which will require a change in the intermediary row crop to allow for harvest of the tree nut

17. The farmer will cease farming heartier row crops like corn or soy and will switchover to a grass crop, such as alfalfa or bluegrass

18. At year 12 the trees reach maturity and start providing ~30-40 lbs/tree, the cash crop now starts to be a much smaller income source than the tree crop

19. At year 15, each tree produces anywhere between 60-100 lbs depending on the quality of the land and the farmer's management practices

20. As a university, we believe there may be ways in which we could build a circular economy in this model

21. If you believe your dining halls can find use for Chinese chestnuts, we can have the farmer agree to sell a portion of the chestnuts to you for an agreed period of time

22. If you do not believe you will have use for chestnuts, the farmer can easily sell to a coop or other distribution network

Design

Implementation

A key aspect of our project design and implementation involves creating a flexible alley cropping scheme that minimizes costs, is adaptable for specific farms and farmer needs, and maximizes outputs.

To enable this agroforestry project to achieve maximum success, it is critical that a pilot farm be established first. It is envisioned that this pilot farm and the associated farmer will serve as an example for future adopters. Through our research, it became clear that that most farmers are initially reluctant to adopt new practices due to perceived risks and unknowns. This pilot farm scheme allows farmers to see the alley-cropping project successfully implemented on another farm and presents them with a chance to test out their own success on an initial 5 acres. If successful, the adopting farmer can scale up from there. Overall, this pilot and testing strategy lowers the risk of farmer drop-out for the client, and increases confidence of the farmer.

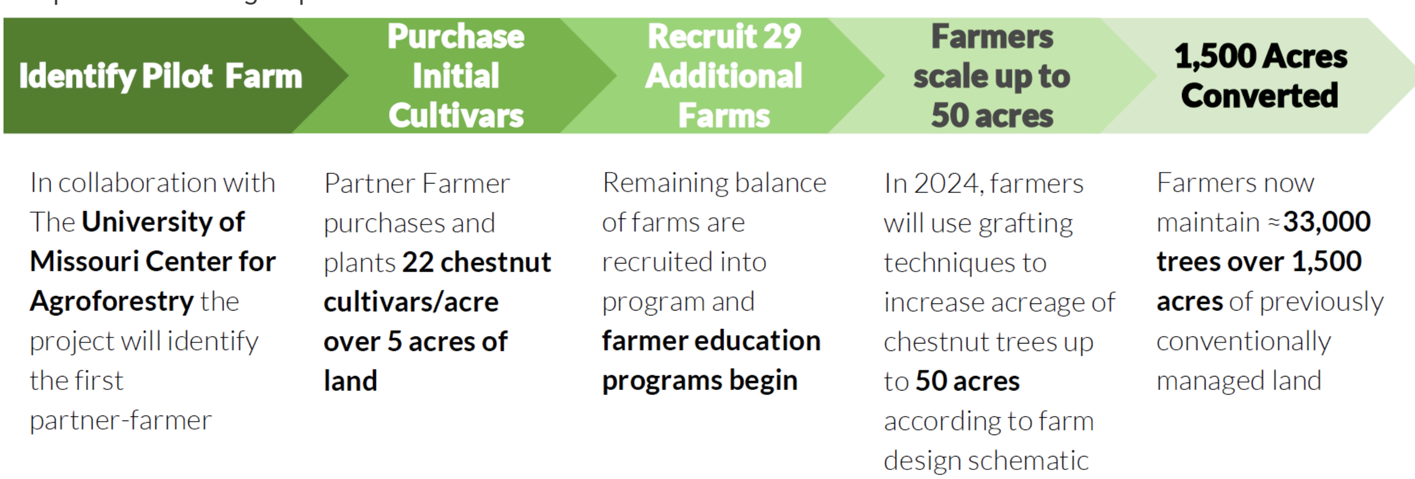
To get the pilot off the ground, we propose working closely with the University of Missouri center for Agroforestry to identify the first partner-farmer. Michael Gold, the Director of the Center for Agroforestry, is well-versed in the Missouri farm community and has served as a great resource for this aspect of the project. We envision working with him to identify an ideal pilot farmer.

In the first phase of project implementation, the pilot farmer will purchase Chinese Chestnut seeds from local nurseries and plant over 5 acres according to the design on the next page. Chinese Chestnut seedlings are widely available in nurseries across the Midwest. However, seedling tree yield cannot be predicted, and establishing an entire orchard of chestnuts with seedling trees will make nut harvest more complicated and unpredictable.

Thus, the farmer will also purchase grafted cultivar trees from the nursery or another chestnut farmer to create a cutting bank for future grafting. Cultivars are essentially pre-cultivated and grafted immature trees that are proven to demonstrate the traits and characteristics of successful chestnut trees. To ensure that all the trees reach maturity and maximum productivity, a consistent graft stock on all of the trees is necessary. Therefore, after the farmer seeds an initial 5 acres, they can graft the seedling trees a year later with cuttings from the cultivar trees. This grafting method is much cheaper than purchasing an entire farms worth of cultivars, and Missouri nurseries generally do not have enough Chinese Chestnut cultivars in stock to supply an entire farm. We also based all of our financial calculations on this planting model.

The first partner-farmer will work closely with University of Missouri to get this pilot farm functioning as well as possible. After the pilot is up and running, additional farmers will be recruited and educated on alley cropping and grafting through the Center for Agroforestry. They will go through a similar process, first starting with 5 acres to test success and learn techniques, and will ultimately scale up to 50 acres

Figure 5. Implementation snapshot and chestnut tree purchase + scaling sequence



Alley Cropping with Chinese Chestnuts + Hay

// Optimal design for low-input management 40 ft vertical spacing (high input management = 30 ft)
// Scale: 1 acre [43,560 square feet or 208 ft x 208 ft]
// Potential Intercrops: alfalfa, corn, or wheat
// Yield: ~22 trees/acre [assumed cultivar planting]
Year 6-9: 15 lbs of chestnuts/tree= 330 lbs/acre/yr
Year 12-15: 40 lbs chestnuts/tree = 880 lbs/acre/yr

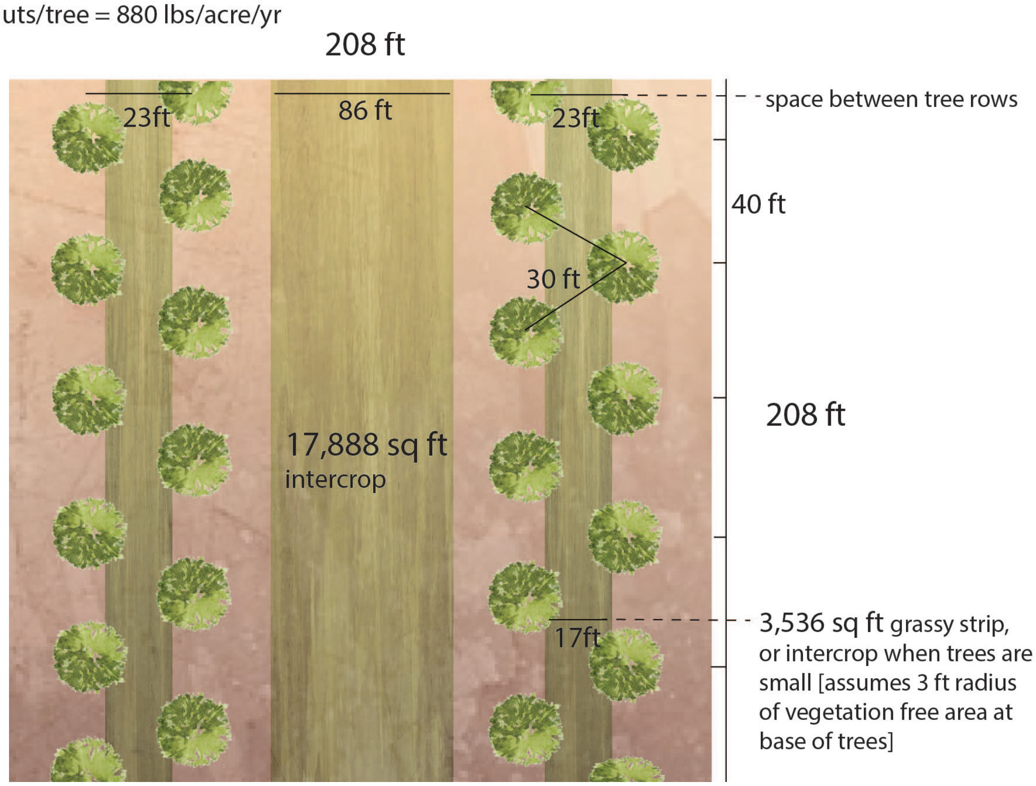


Figure 6. Hypo Acre depicting proposed scalable acre schematic

using grafting techniques. It is possible they will be able to purchase their graft trees from the pilot farm. Ultimately, there will be 1,500 acres converted, and this will produce our goal of 100,000 tons of carbon offsets.

Farm Design

The optimal farm design at a scalable 'hypo-acre' can be seen above. This design is based off of The Missouri Center for Agroforestry research for best practices. This crop placement and spacing is meant to be managed at a low-input level and is flexible based on the amount of land an individual farmer wants to convert from conventional farming. A double-row system with 40 ft vertical spacing between trees, and 30 ft diagonal spacing is ideal for many reasons. The design maximizes efficiency, maximizes 360 degree sunlight, minimizes root competition, and reduces the need for tree trimming throughout growth.[1]

For the row crop, it is recommend to use hay, which provides an ideal surface for harvesting chestnuts.[2]After hay is harvested, it provides a smooth flat surface from which chestnuts can easily be gathered. But it is possible that another crop, such as corn or wheat, can be used for the first 1-5 years when trees are small, sunlight is plentiful, and yields are minimal. This could help ease farmer's transitions into alley cropping, if they previously farmed corn or wheat. However, for the purposes of our calculations and contracts, we assumed hay would be planted in the alleys for the duration of the project.

Chestnut trees will start producing decent yields around year 6-9, and will reach maturity at year 12-15 with the recommended cultivar planting scheme.

1 Van Sambeek, Jerry; Reid, William. 2017. A double row alley-cropping system for establishing nut orchards. MNGA (Missouri Nut Growers Association) Newsletter. 17(4): 11-14

2 Based on our phone call with Mike Gold, April 2018.

Project Partners

Though our team has identified an established network of experts in Missouri, agroforestry adoption rates are currently low. The current network includes the Center for Agroforestry, the Natural Resources Conservation Services, and the farmers who are practicing alley cropping and growing chestnuts (see Figure 8).

The Center for Agroforestry at the University of Missouri has expertise in agroforestry practices and chestnut cultivation and marketing in the state. Our team has also developed a close relationship with the Director of the Center for Agroforestry - Dr. Michael Gold. The second partner is the Natural Resources Conservation Services (NRCS). The NRCS has a designated Conservation Specialist in each county who is familiar with the local context and farmers in the area. These specialists also have expertise in agricultural practices that provide environmental benefits, as well as public funding options available to farmers (i.e. EQIP). The third partner is local farmers who have successfully adopted alley cropping and who are already growing chestnuts. Farmers are encouraged to adopt new practices if they have clear examples of success stories.

Although this network exists, there are not a lot of farmers who have already adopted alley cropping in Missouri, which our team has discovered is largely due to farmers' tendency towards risk-aversion. They don't want to risk changing their current practices and potentially lose profit on their lands and tackle an unfamiliar way of farming and market. Farmers want financial stability and security year to year.

This is where Harvard can have an impact.

How Does Harvard Fit In?

Harvard can help decrease the risk that is preventing farmers from switching from conventional practices to alley cropping (see Figure 7). Harvard can do this by providing a debt interest free loan to the farmer. In addition to loan provision, several of Harvard's schools and students are in a unique position to contribute to this partnership. The School of Engineering and the Emmett Environmental Law Clinic could work together to help our team develop an agroforestry protocol. The Business School could help seize the emerging opportunity for the expansion of the domestic chestnut market through the adoption of alley cropping. A potential platform for this is the Agribusiness Seminar Program. The Center for Health and the Global Environment at Harvard School of Public Health could work on developing user-friendly and accessible tools to monitor and quantify the public health co-benefits generated by alley cropping and other agroforestry practices.

Harvard's involvement in this partnership would align with Harvard's Sustainability commitment to cultivate and lead external partnerships, in higher education and beyond, as outlined in the Harvard Sustainability plan.

Our proposal also presents a real opportunity for Harvard (see Figure 9).

Figure 7. Current agroforestry network in Missouri

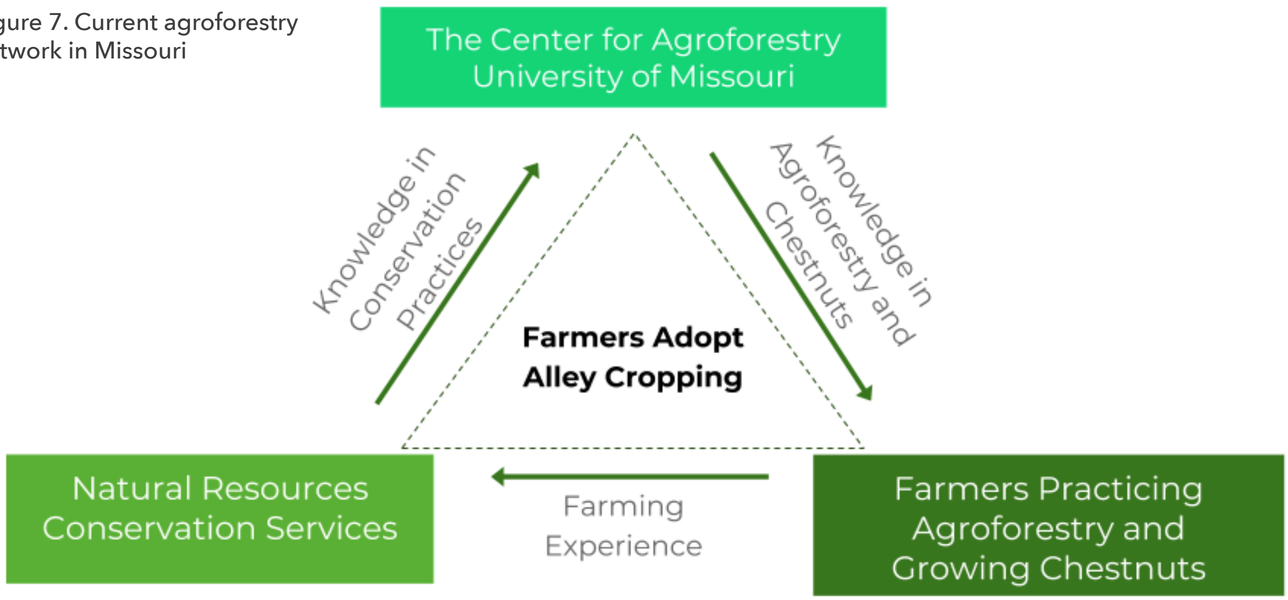
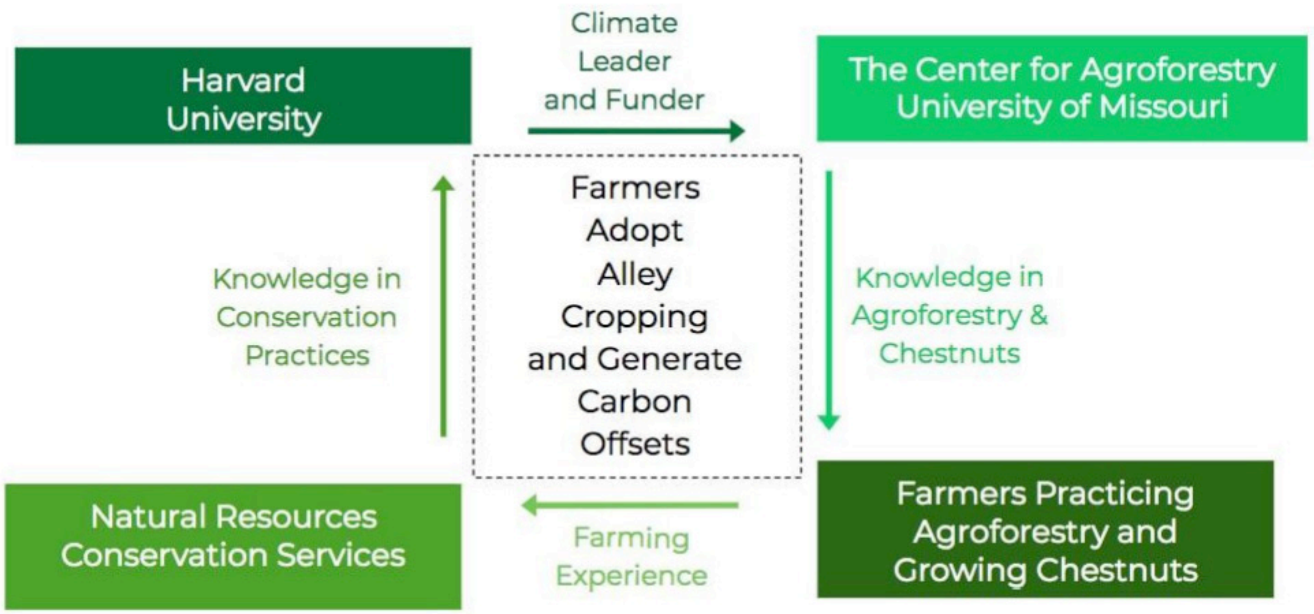


Figure 8. Proposed Missouri agroforestry framework including Harvard University

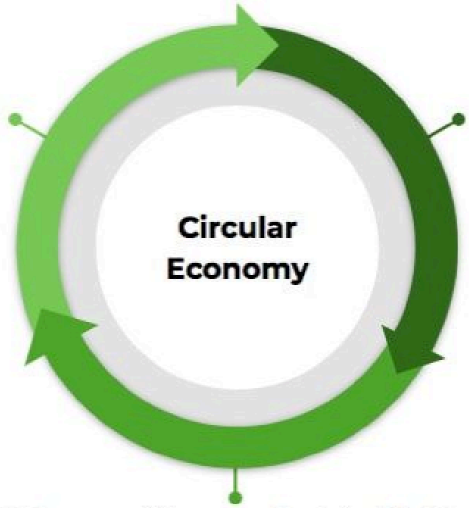


Why Should Harvard Be Involved?

The loans will be repaid by the farmers, and Harvard can then use the repayments to reinvest in Harvard's other climate initiatives or to scale up this program. This loan will also be repaid in the long term with 100,000 tons of CO_2 equivalent in carbon offsets effectively taking the role of interest. At current carbon credit prices, this works out to an Effective Annual interest rate of 16.2%.

An additional benefit is that Harvard would be improving the lives of farmers and become a catalyst for a new wave of sustainable farming and credit carbon financing. This partnership will also help amplify Harvard's local and global impact. Harvard would also have an opportunity to secure long-term purchase agreements for the project's chestnuts, which could be used in the Harvard Dining Services.

Figure 9. Circular economy resulting from alley cropping project implementation



Full Loan Repayment
Harvard would receive full loan repayment available for reinvestment such as kickstarting similar sustainable farming projects elsewhere

Carbon Credits
In lieu of debt interest, Harvard would receive 100,000 tons of CO2 equivalent in carbon credits

At current carbon credit prices, this works out to an EAR interest rate of 16.2%

Improving Rural Communities
Harvard would be improving the lives of farmers and become a catalyst for a new wave of sustainable farming and credit carbon financing.

Sustainably Produced Chestnut Supply
Harvard would have an opportunity to secure long-term purchase agreements for the project's chestnuts, which could be used in HUDS

Development of a Protocol for Agroforestry

This methodology is an early attempt to build a framework which could help the development of a more detailed and elaborate Protocol for Agroforestry. Our team acknowledges that developing a methodology that can be approved and adopted by a Carbon Registry would require more time, research, know-how, and financial support. This proposal expects to spark interest among students, future Climate Solution Living Lab students, researchers, and professionals in the field of sustainability to explore agroforestry as a tool to address climate change.

The American Carbon Registry (ACR), the Climate Action Reserve (CAR), and the Verified Carbon Standard (VCS now called Verra) currently lack a specific methodology for issuing carbon credits for agroforestry projects. For this project, we suggest creating and having a Protocol for Agroforestry adopted by the ACR or Verra. The main reason why we propose the creation of a protocol is because this would increase the likelihood of obtaining an insurance policy for the generated offsets. Additionally, the decision to attempt to have the protocol adopted by ACR and Verra is because CAR requires forestry projects to have a permanence of 100 years with mandatory land easements.[1] In this project, our team has avoided the use of easements because they represent a potential barrier to farmers adopting alley cropping practices.

The methodologies provided by the protocols are based on similar frameworks.

---

1 Climate Action Reserve. Forest Project Protocol Version 3.1. http://www.climateactionreserve.org/wp-content/uploads/2011/04/FPP_V3.1_with_Errata-06-08-2010-Announc.pdf

Applicability

Every protocol defines some eligibility conditions that every Project Proponent (PP) must meet, which include, but are not limited to:

- The Project includes one or more Project Areas that are practicing conventional farming at the start of the Project and adopt alley cropping for the duration of the project.
- Agroforestry practices attributable to the project activity are in accordance with Agroforestry Practices defined by the USDA and NRCS.[1]
- The annual, minimum, maximum stocking rate shall be determined via consultation with a qualified expert (NRCS Soil Conservationist, Qualified Extension Agent, a Certified Agroforestry Manager).
- The PP shall exclude land that is prone to regular flooding.
- Best Management Practices or Conservation Practices shall follow the guidelines provided by the Natural Resources Conservation Services.[2]
- PP must demonstrate ownership of land or control over the project area at the project start date.

1 USDA - National Agroforestry Center. https://www.fs.usda.gov/nac/index.shtml

2 USDA. Natural Conservation Resource Service. Conservation Practices. https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/cp/ncps/?cid=nrcs143_026849

Boundaries

Every project must define geographic, temporal, and greenhouse gas boundaries.

Geographic boundaries:
The project should delineate geographic boundaries using the United States Geographic Survey topographic map, a general location map, and a property parcel map. The project shall contain the following information:

- Name of the project area
- Unique ID for each discrete parcel of land
- Geographic coordinates (accuracy < 30 m)
- Total land area
- Land rights holder and user rights

The Methodology shall include a clause that allows the addition of new parcels after the start of the crediting period.

Temporal boundaries
Under the ACR, the Crediting Period is defined by the ACR Standard as the finite length of time for which a GHG project plan is valid, and during which a project can generate offsets against its baseline scenario.[1] In other words, the Crediting Period is determined when the portion of soil carbon from alley cropping that will remain in the stable pool is likely to be greater than the portion that would be stabilized under baseline conditions. Defining this period would be a major hurdle

1 American Carbon Registry. Technical Standard. Crediting Period Definition. http://americancarbonregistry.org/carbon-accounting/standards-methodologies/american-carbon-registry-standard

in the development of a Protocol for Agroforestry. The research stage to determine the crediting period could be the result of one of the partnerships that Harvard University and the Center for Agroforestry might be able to cultivate.

The Protocol shall provide a clause to allow the revision of the baseline in order to renew the Crediting Period. This revision can occur every 10 years and it can be done sooner if there is a major reversal (i.e. extreme weather events). Baseline projections shall be annual and data on reductions of greenhouse gases and carbon sequestration shall be included in the GHG project plan.

Some protocols require a crediting period of 40 years and a 100-year period of permanence. For the development of a Protocol for Agroforestry, our team suggests providing more flexibility to the PP. An example of a solution proposed by Nathaniel Colbert-Sangree would be to create a shorter crediting period and a shorter permanence (i.e. 20 years each).[2] In order to make sure the offsets generated from these type of projects are permanent, this protocol must be complemented with a reassessment at the end of the project where the PP has the option to make a reassessment to decide to pursue one of the following two options. First, the PP adopts agroforestry somewhere else with the same GHG offset result. Second, the PP has a buyout option where the purchase of GHG offsets is possible. This part of the development of the Protocol for Agroforestry calls for a partner with expertise in carbon markets to provide innovative solutions that will not only guarantee permanence but also adoption, and scaling-up, of agroforestry practices.

Another issue to keep in mind is dead wood. This type of wood can become a source of GHG, which will need to be prevented by charring the trees. The PP shall determine if this carbon pool represents a significant amount of emissions, which can be tested with the Tool for Testing Significance of GHG emissions.[3] This tool will be further explained in the carbon pools section.

Greenhouse gas boundaries + baseline scenario

Due to the fact that the GHG emissions or reductions calculated for one year might not be representative of the typical farming operation, the PP shall use the average of at least 3 years of the last 5 years prior to the project start date to determine the baseline. The PP shall use 3 years that appropriately represent their farming operations and provide a justification that can be verified in the GHG plan.

In order to account for greenhouse reductions, a baseline scenario must be established which is based on historical and current practices implemented on the farm. There are several models available for the PP to quantify changes in SOC and GHG emissions. These models shall be used on the condition that the PP demonstrates that the selected model is sufficiently accurate for their study area and a suitable uncertainty analysis is performed.

The PP might use a well-established resource like the COMET-Farm tool[4] developed by Colorado State University to provide a full farm-level greenhouse gas accounting. Some of the reasons why we suggest, but not mandate, this tool is because it is easy to use; it can be accessed for free online; it allows the PP to estimate GHG at the farm-scale; it provides the creation of scenarios with different management practices; and it uses state-of-the-art methods/models based on USDA Guidelines that are consistent with the US national GHG inventory. [5]

COMET-Farm is a robust tool that requires the PP to input data on field operations, livestock, and fossil fuel consumption to fully account GHG emissions and removals. The soil-related GHG emissions are estimated using the DayCent dynamic model - a daily time-step version of the CENTURY biogeochemical model.[6] Emissions from livestock operations are based on USDA and university research, mostly consistent with models used in the U.S. National GHG Inventory. The calculation of energy-related GHG emissions is based on the models used in the USDA/NRCS Energy Tool that is complemented by peer-reviewed research. All of these methods used by the COMET-Farm implement the peer-reviewed, USDA-sanctioned entity-level entity methods. Furthermore, empirical models and the Monte-Carlo simulation are used to calculate uncertainty (see Figure 10).[7]

2 Colbert-Sangree, Nathaniel (Program Coordinator at the Duke Offsets Initiative). May 1st, 2018. Conference call.

3 UNFCC. Tool for testing significance of GHG emissions in A/R CDM project activities. https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-04-v1.pdf/history_view

4 USDA-NRCS. COMET-Farm. http://cometfarm.nrel.colostate.edu/

5 Easter, M. et al. (2016). Leveraging COMET tools for Offset Projects: Challenges and Opportunities. C-AGG Workshop. https://www.c-agg.org/wp-content/uploads/C-AGG_Presentation_Easter.pdf

6 Natural Resource Ecology Laboratory. DayCent: Daily Century Model. https://www2.nrel.colostate.edu/projects/daycent/

7 Easter, M. et al. (2017). COMET-Farm and COMET-Planner Updates. C-AGG Chicago. https://www.c-agg.org/wp-content/uploads/2017_C-AGG_Chicago_Paustian_Presentation.pdf

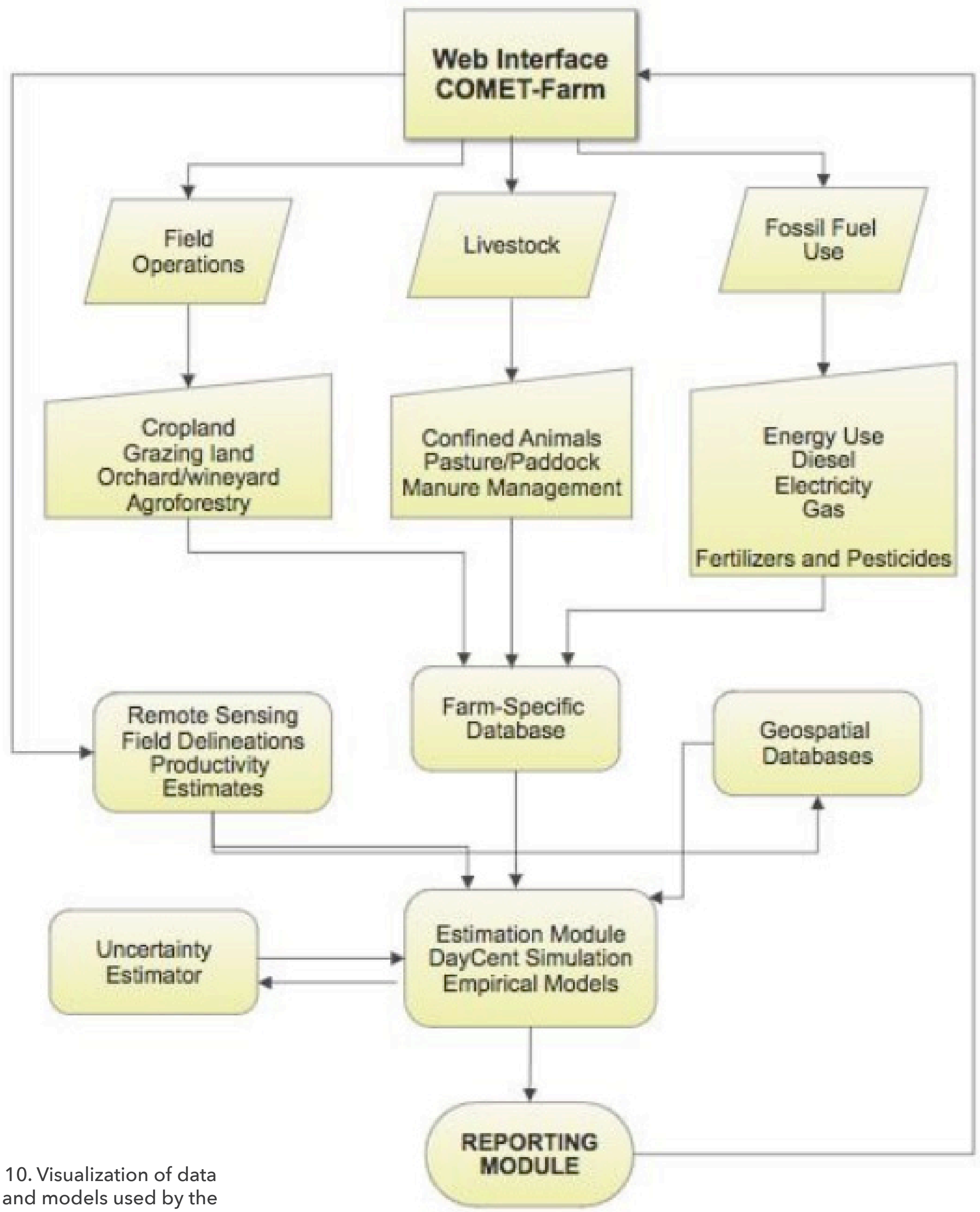


Figure 10. Visualization of data inputs and models used by the COMET-Farm tool (Easter et al, 2016)

Project Scenario

This methodology requires the use of a model to predict direct and indirect changes in Soil Organic Carbon and Biomass Carbon under the baseline and project scenarios. Several models may be used for carbon accounting. A process-based biogeochemical model (PBM) can be used to account for one variable (i.e. soil organic carbon), and use a Tier-2 Emission Factor for N2O emissions. This methodology does not prescribe a specific model but project proponents may:

- Use a process-based biogeochemical model (i.e. Century, EPIC, DAYCENT, Denitrification-Decomposition models, Roth-C)
- Develop Tier-2 Empirical Model
- Analyze historic trends through remote sensing technologies for location specific variables. For instance, forest cover can be assessed with satellite imagery or aerial photographs
- Analyze historic trends partly assessable through remote sensing using a proxy. For instance, soil carbon is not directly assessable through remote sensing, but it might be correlated with vegetation cover types

Though, some of the process-based modeling might have limitations, they are "likely to provide the most robust framework for estimating soil C stock and GHG flux changes in" sustainable agriculture programs.[1]

1 Smith, P. et al. Towards an integrated global framework to assess the impacts of land use and management change on soil carbon: current capability and future vision. Glob. Change Biol. 18, 2089–2101 (2012).

This section also includes all sources, sinks, and reservoirs that are quantified in this scenario:

- Emissions and/or sinks resulting from the adoption of alley cropping as defined by the Natural Conservation Resource Services guidelines on best management practices
- Emissions and/or sinks from supporting activities like tree/shrub establishment, site preparation, mulching, among others, as defined by the Natural Conservation Resource Services guidelines on best management practices[2]
- Emissions and/or sinks related to other conservation practices that shall be implemented by the project owner in adherence with the guidelines provided by the Natural Conservation Resource Services guidelines on best management practices[3]
- Fossil fuel use from the transport and use of agricultural machinery to implement and maintain the agroforestry practice
- Other emissions related to the land where the agroforestry shall be implemented
- This section might be expanded as the Protocol for Agroforestry gets refined

2 USDA. Natural Conservation Resource Service. Conservation Practices. https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/technical/cp/ncps/?cid=nrcs143_026849
3 Ibid.

Validation Requirements for Scenarios

Although the PBM model and the Tier-2 approach would present a highly valid method to estimate changes in soil organic carbon (SOC) pools, soil samples and field measurements are required to validate the models for use in specific project areas. The amount of samples and the frequency should be determined when the Protocol for Agroforestry is developed and should consider the impacts on costs and address the question of who would bear the cost of the validation procedures.

An important factor to consider is the current state of the science in soil carbon and biomass sequestration. If the scientific literature is already at an advanced stage where accounting and forecasts are highly accurate, a sampling and experimentation stage might not be required, which would lead to a less costly and faster development of a Protocol for Agroforestry. If the science is reliable and robust, a large fraction of the cost associated with the development of the protocol is likely to be used to cover staff time.[1]

The Protocol shall include a clause that guarantees that the scientific literature is not only peer-reviewed, but that it has also had positive reviews (i.e. highly accurate, used by highly-specialized institutions, etc.).

1 Colbert-Sangree, Nathaniel (Program Coordinator at the Duke Offsets Initiative). May 1st, 2018. Conference call.

Legitimacy and Credibility of the Offsets

Although the use of a Tier-2 approach or a PBM model have not been approved for agroforestry projects, ACR and Verra have approved these methodologies as eligible protocols for other types of projects. As mentioned above, this methodology requires the PP to demonstrate that the model is sufficiently accurate for the project and that appropriate uncertainty factors are provided. These requirements guarantee that the generation of offsets are legitimate and credible.

Carbon Pools

The PP shall determine the carbon pools included in the GHG project plan by justifying carbon pools inclusion, or exclusion, from the GHG assessment boundary as displayed in Table 5. The PP shall also account for any significant decrease in carbon stocks that has a reasonable attribution to project activities. "The tool for testing significance of GHG emissions in A/R CDM project activities"[1] shall be used by the project owner to determine which carbon pools are included in the GHG assessment.

Additionality

The Project Proponent shall demonstrate additionality consistent with ACR's three-prong test.[2] First, the Project must demonstrate that the adoption of the project or the reduction of GHG is not mandated by a regulatory framework. Secondly, the Project shall not be a practice that is widely employed and deployed within the industry. Third, the Project must prove that it is feasible from at least one of the following criteria: financial, technological, and institutional. Valid evidence that can be used to demonstrate additionality includes economic analyses, reports, peer-reviewed literature, industry group publications, surveys, etc.

1 UNFCC. Tool for testing significance of GHG emissions in A/R CDM project activities. https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-04-v1.pdf/history_view

2 American Carbon Registry. A Hybrid Approach to Additionality. https://americancarbonregistry.org/carbon-accounting/old/carbon-accounting/documents/Additionality%20Criteria.pdf

Table 5. Detailed explanation of protocol carbon pools

Carbon pools	Included/Optional/Excluded	Explanation of choice
Aboveground	Included	Significant carbon pool source subjected to the project activity.
Belowground	Included	Significant carbon pool source. Omission would represent a conservative scenario.
Dead wood	Included/Optional	Shall be included if it represents a major source or sink of carbon.
Harvested wood products	Included	Shall be included if it represents a major source or sink of carbon.
Litter/forest floor	Optional	Generally considered an insignificant source or sink of carbon.
Soil organic carbon	Included	Significant carbon pool source subject to the project activity.

Project Emissions General Equations

The equations included here are meant to guide the creation of this section in a future Protocol for Agroforestry. The emissions or removals generated by the project are the sum of the changes in carbon stocks in the selected carbon pools within the project boundary. Therefore, the project net emissions shall be calculated for each project parcel separately using the following equations:

[Equation 1] Annual Project Emissions or Removals

$$PE\,(y,i) = PE_{\Delta SOC}\,(y,i) + PE\,N_2O\,(y,i) + PE\,fuel\,(y,i) + PE\,other$$

[Equation 2] Annual Changes in the Project's Carbon Emissions from the Changes in Soil Organic Carbon

$$PE_{\Delta SOC}\,(y,i) = A(i) \cdot \frac{44}{12} \cdot \sum_{t=1} \Delta C_t$$

[Equation 3] Annual Project Nitrous Oxide Emissions from Soils

$$PE_{N_2O}\,(y,i) = A(i).CE_{N_2O}\,(y,i)$$

$PE(y, i)$ = The total sum of the project emissions during year y. [MT CO2-eq yr-1]

$PE_{\Delta SOC}(y, i)$ = Annual CO_2 emissions or removal from the change in soil organic C for project parcel i during year y of the project. The sign of this component is determined by the baseline trends in SOC, which can be either positive when soil is a net source of CO_2 or negative when it is net sink of CO_2. [MT CO_2-eq yr^{-1}]

$A(i)$ · = Size of project parcel i. [ha]

44/12 = Factor to convert the mass of C to CO2.

ΔCt = Change in carbon stock in all selected carbon pools, in year t. [MT CO_2-eq yr^{-1}]

$PE\Delta SOC(y, i)$ = Annual CO_2 emissions from the change in soil organic C for project parcel i during year y of the project. The sign of this component is determined by the baseline trends in SOC, which can be either positive when soil is a net source of CO_2 or negative when it is net sink of CO_2. [MT CO_2-eq yr^{-1}]

$CE_{N_2O}(y, i)$ = Cumulative Nitrous Oxide emissions from soils of the project parcel i during year y of the project, expressed in CO2-eq. [MT CO_2-eq yr^{-1}]

$PEN_2O(y, i)$ = Annual N_2O emissions rate from soils of project parcel i during year y of the project. [MT CO_2-eq yr^{-1}]

$PEfuel(y, i)$ = Fuel emissions from transportation to the project parcel and application of the organic material on the land during year y. [MT CO_2-eq yr^{-1}]

PE other = This equation should also include emissions and removals from aboveground biomass as it is established in afforestation and reforestation methodologies. Additionally, there might be unique significant emission sources identified by a PP in a particular farming operation.

Monitoring

Implementing and continuing the practice of best management practices have been identified as major major challenges in this project. The way to surmount this barrier seems to be partially by using a combination of contract clauses, financial incentives, and the creation of a more resilient farming system (from both an environmental and economic standpoint). Furthermore, advances in Information Communication and Technologies (ICT) driven by lower costs, adaptable and more affordable tools, improvements in data storage and exchange, innovative business models and partnerships, and the access to open shared data,[1] are providing effective monitoring resources for agricultural projects.

Our project has identified a few examples of monitoring services for agricultural activities that make use of technologies like satellite imagery, software modeling tools, sensors, and drones, among others. These services are:

- FarmersEdge:[2] They collect data from on-farm weather stations, telematics devices, satellite imagery, and soil samples. This information is integrated with on-site farm data.

- FarmShots:[3] This company analyzes satellite and drone imagery of farms.

- American Robotics:[4] It has created a fully-automated drone that provides high-resolution data. It generates health reports of the crop on a daily basis.

- IBM:[5] This company analyzes drone aerial imagery and sensor data, which provides information on plant health, soil moisture, CO_2, sunlight, rainfall, air, and humidity.

These tools shall provide quantification of carbon stocks, monitoring for permanence, reporting and verification services. The monitoring/reporting/verification (MRV) service shall provide transparent verification services through an online system that can be audited and is open to questioning all the methodologies used for quantification and projections. The service shall provide calibration and validation data used for the remote sensing analysis.

1 World Bank Group. (2017). ICT in Agriculture - Updated Edition. http://documents.worldbank.org/curated/en/522141499680975973/pdf/117319-PUB-Date-6-27-2017-PUBLIC.pdf
2 FarmersEdge. https://www.farmersedge.ca/smart-solutions/
3 FarmShots http://farmshots.com/
4 American Robotics. http://www.american-robotics.com/
5 Huang, A. (2016). Transforming the Agricultural Industry. https://www.ibm.com/blogs/internet-of-things/agricultural-industry/

The GHG project report should also include the following information:

- Inventory of crops

- Soil- When soil sampling is required follow the Soil Science Society Methods of Soil Analysis (Sparks et al. 1996) including: total soil carbon, soil texture, soil bulk density, soil pH.

- Historical and project weather- The following parameters shall be provided and collected during the duration of the project: rainfall, daily temperatures, and pan-open evaporation rates from the nearest meteorological station.

- Historical management- In the development of the Protocol for Agroforestry, it should be determined how far the historical records must be collected for. Protocols vary from 5 to 10 years prior to the project start.

- Project management

- Ecology- Plants and plant community

Data Collection + Privacy

Given the vast data collection requirements in developing a protocol, farmer concerns about data privacy should also be addressed.[1] The data collected for the protocol—crop inventories, soil nutrients, weather patterns, etc.—provide an intimate look at the farmers' most valuable possession: their land. Therefore, several steps should be taken to help alleviate farmer concerns about the use of their data.

First, in developing the protocol, it is vital to identify what information can be kept confidential and what information must be made public for steps such as peer review. The protocol in general should specify that the personal and property information provided by the farmer is sensitive information that directly impacts the farmer partners' livelihoods. This explanation should accompany any redactions as well.

Second, a clear outline of information required should be presented to the partner farmer during the contract negotiation & planning phase of the project. Students working on the project from SEAS and the Emmett Environmental Law Clinic can prepare this outline for distribution to prospective farmers, and farmers should consult with local partners to understand what data will be collected and how the data will be used. The local partners should help the farmer understand why the data is being collected as well, and how it will be stored, and who will have access to it. Though these topics will likely be concerning for farmers, it is also vital that they understand the significance of the information they are agreeing to share. Information that must remain public for verification purposes should be noted for the farmers' benefit. After consultation, the farmer should be allowed to designate information to be marked confidential according to their personal preferences and verification confidentiality limitations.

Third, after acquiring farmer approval to collect the necessary data, it is important to then share that information with the farmer as well. The information should be presented to the farmer in an accessible format so that they can make use of the information if they so choose.[2] This may require the data to be processed in a format different than that used in the protocol, so a student from SEAS may be needed to write a program to process the data in a new format. This information sharing can be extremely beneficial to the farmer because it will enable the farmer to make management decisions based on this scientific data. More complete knowledge of the health of the farmers' land will also provide them with the benefit of having an accurate assessment of the value of their land. Additionally, this works to the benefit of the unregulated entity as well, because the farmer will be able to see co-benefits affecting their land as the project progresses. This will act as a positive feedback mechanism, and can help increase subscription to the project, as evidence that the adopting the alley cropping program actually benefits the land in quantifiable ways.

1 This section relies heavily on a Telephone Interview with Nathaniel Colbert-Sangree, Program Coordinator, Duke Offsets Initiative (May 1, 2018).

2 This may require a student programer to develop software to analyze the verification data and then compile into a farmer-friendly format; this project can be integrated into the protocol verification work that will be done by students at Harvard and Duke.

Additional Resources Needed for the Protocol

This section includes a list of suggested protocols and/or methodologies that have either been approved by some registries or developed by renowned institutions working in the field of sustainable farming.

- A Protocol for Modeling, Measurement and Monitoring Soil Carbon Stocks in Agricultural Landscapes developed by the World Agroforestry Centre (ICRAF) and The Earth Institute at Columbia University (EI). [1]
- Afforestation and Reforestation Protocols such as, but not limited to, the Methodology for the Quantification, Monitoring, Reporting, and Verification of Greenhouse Gas Emissions Reductions and Removals From Afforestation and Reforestation of Degraded Land.[2]
- The Protocol created by the Asian-Pacific Network titled "Developing Small-holder Agroforestry Carbon Offset Protocols for Carbon Financial Markets - Twinning Sustainable Livelihoods and Climate Mitigation."[3]
- The approved Verra methodology for Soil Carbon Quantification Methodology.
- Protocols addressing nitrogen reduction and nutrients like, but not restricted to, the approved ACR methodology for N2O Emissions Reduction from Changes in Fertilizer Management.[4]

Additionally, Duke University, Oberlin College, and the University of Florida have developed the Offset Network. This network aims to provide protocols, guidance on how to implement new protocols, and case studies to help institutions create offset projects. The Offset Network is currently working with Second Nature in a partnership that will "decrease the cost of offset projects, and encourage research and development by leveraging the academic expertise that exists within institutions."[5]

1 ICRAF and EI. (2011). A protocol for modeling, measurement and monitoring soil carbon stocks in agricultural landscapes.http://www.worldagroforestry.org/publication/protocol-modeling-measurement-and-monitoring-soil-carbon-stocks-agricultural-landscapes

2 ACR. (2017). Methodology for the Quantification, Monitoring, Reporting, and Verification of Greenhouse Gas Emissions Reductions and Removals From Afforestation and Reforestation of Degraded Land https://americancarbonregistry.org/carbon-accounting/standards-methodologies/restoration-of-california-deltaic-and-coastal-wetlands/ca-wetland-methodology-v1.1-November-2017.pdf

3 Asian-Pacific Network. (2009). Developing Small-holder Agroforestry Carbon Offset Protocols for Carbon Financial Markets - Twinning Sustainable Livelihoods and Climate Mitigation. www.apn-gcr.org/resources/items/show/1560

4 Verra. (2012). Methodology for N2O Emissions Reduction from Changes in Fertilizer Management. https://americancarbonregistry.org/carbon-accounting/standards-methodologies/emissions-reductions-through-changes-in-fertilizer-management

5 The Offset Network. http://offsetnetwork.org/

Potential Partners to Create the Protocol

Our team identified different types of expertise needed for the creation of a Protocol for Agroforestry. A person who is knowledgeable in carbon markets would make a contribution in addressing challenges related to crediting period and permanence. Researchers or Professors with expertise in biogeochemistry would ensure that the science needed to validate and make projections of carbon stock is robust and up-to-date. Additionally, professionals with experience with implementing programs to promote agricultural practices and working directly with farmers (farmers with agroforestry experience and agricultural extension agents) would provide a valuable insight that would help to create a protocol that includes the perspective of someone who is familiar with daily farming operations. The input from farmers would allow the creation of a protocol that has a higher likelihood of being adopted by other farmers.

The following is a list of experts that our team has identified as potential partners, experts who could lead to potential partners, or experts who can provide support:

- Nathaniel Colbert-Sangree, Program Coordinator at Duke Offsets Initiative, has offered to provide support in structuring the team's approach and his expertise in offset market/program/protocol.

- Terra Global Capital[1]

- The Environmental Defense Fund

- Second Nature

- Soil Experts: Professor Whendee Silver's Lab[2] at Berkeley University works on ecosystem ecology and biogeochemistry. Professor Keith Paustian[3] is an expert on soil organic dynamics and he has been working closely with the development of the COMET-Farm tool. There is also a network of researchers called Ameriflux.[4] This community has the purpose of measuring ecosystem CO_2, water and energy fluxes in The Americas.

1 http://www.terraglobalcapital.com/

2 https://nature.berkeley.edu/silverlab/

3 http://soilcrop.agsci.colostate.edu/faculty-2/keith-paustian/

4 Ameriflux Network. http://ameriflux.lbl.gov/about/about-ameriflux/

Legal Considerations

Contracts

This project will utilize a mandatory carbon offset program contract and an option purchase agreement. First, the partner farmers will contract with Harvard to participate in the carbon offsets program. Second, the partner farmer has the option to contract with Harvard as a purchaser of a percentage of the partner farmer's nut yield.

Two important considerations to keep in mind in designing the contracts are the project's intended risk management strategies: mitigate investor risk and preserve farmer integrity. The Carbon Offset Contract should be drafted in a way that realizes these two goals. Mitigating investor risk will involve structuring payments, farm design, and offset generation in a way that spreads the financial risk to the investor over the life of the project; preserving farmer integrity requires that farmer maintain substantial control over on-site discretion to react to the realities of farming in a changing climate. These two guiding principles will manage the risk that both Harvard and the farmer face in adopting the project, and insures that both parties realize the maximum benefits of project participation.

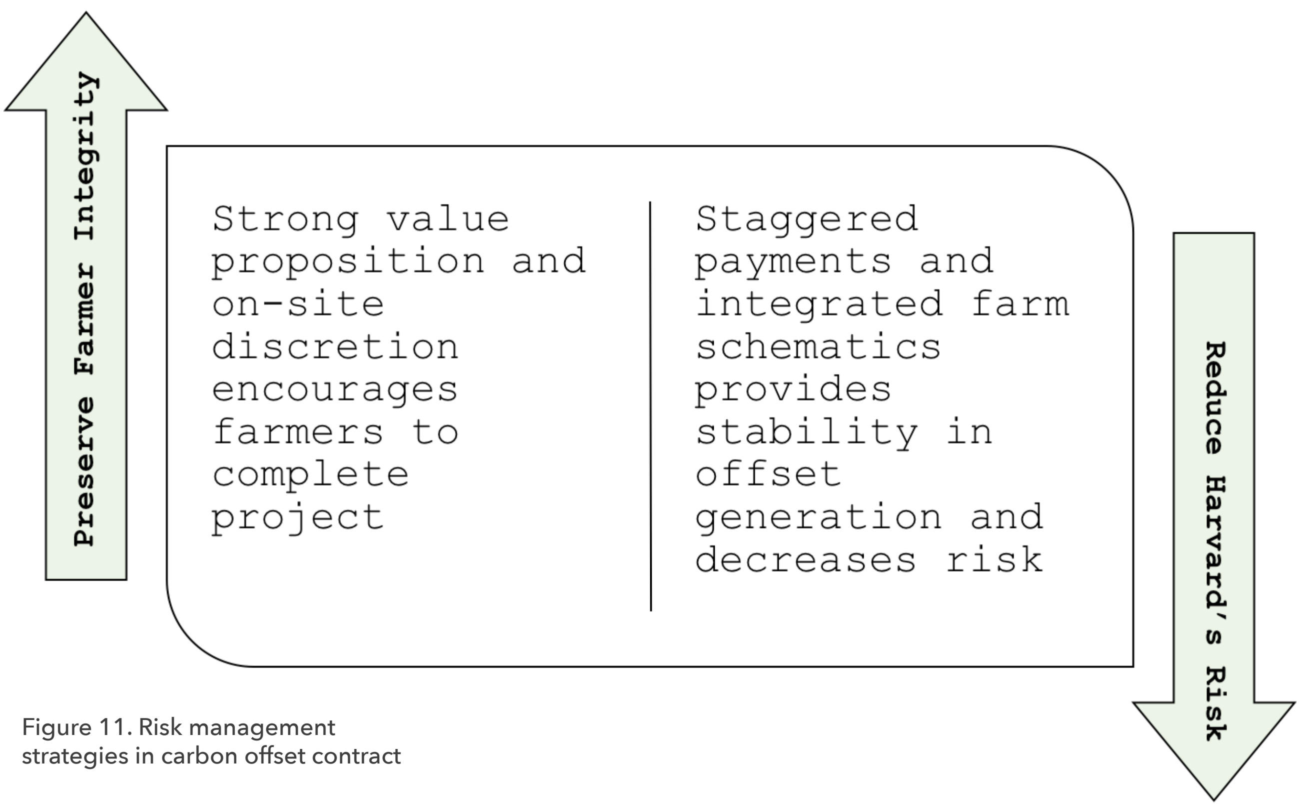


Figure 11. Risk management strategies in carbon offset contract

The Carbon Offset Contract

The carbon offset contracts should contain all provisions relevant to each party's performance in the alley cropping program insofar as the production and maintenance of the carbon offsets. At a further stage of development for this project, a draft hypothetical contract should be created that captures Harvard's anticipated role in the project and lays out the expectations of the partner farmer. The draft can be based on the hypothetical acre[1] in the early stages of development (and will be referred to as the "hypo contract" herein). As part of the educational mission of the project, initial drafting of the hypo contract can be done by law students in the Emmett Environmental Law and Policy Clinic, as part of the student work already required by this project. Law students drafting the hypo contract should work closely with students from other disciplines contributing the project (i.e. SEAS students) so that they understand the realities of farmers on the ground and the scientific data required for the protocol verification portion of the project. A series of recommended contract provisions can be referenced in Appendix A.

The hypo contract is intended to be a starting point for negotiations and farm planning: it is not intended to act as a standard form contract for all partner-farmers. Additionally, the hypo contract can also be included in materials for prospective partner-farmers who want more information about the program and what their obligations could look like.

From the hypo contract, partner-farmers can work with Harvard to customize the alley cropping project to fit their land's specific topography, nutrient profiles, etc. This designing and negotiation phase will require input from various project partners: the University of Missouri Center for Agroforestry and/or the University of Missouri Extension School should be tapped to contribute institutional knowledge in transitioning conventional farmland to alley cropping; partner-farmers already in the program should be consulted for support as the project scales up; the local NRCS[2] offices should also be contacted in the process of planning and applying for federal funding programs. It is important to include local project partners in planning and negotiation phase to ensure that the farmer sees a viable support network and is comfortable working with the project team for the long-term prospects of the project.

This consideration of the farmer during the negotiation and planning phase should extend throughout the life of the contract as well. Maintaining respect for the farmer's authority to make decisions for the project on the ground is key to keeping farmers in the project for the full thirty year term. Though significant planning will take place before the first chestnut tree is planted, the farmer will have to respond to the needs of the trees on the ground and in real time.

As discussed earlier, Missouri is suffering from the effects of climate change, which presents challenging situations for farmers. Though the alley cropping scheme is more climate-resilient than conventional farming practices, major weather events, crop disease, and pests can pose challenges for any farming operation. Harvard must therefore be prepared that a farmer will be unlikely to adopt and maintain the project if they do not feel satisfied that they can manage their farm without having to renegotiate the contract over and over.

Naturally, this presents a less comfortable situation for Harvard. However, the Carbon Offset Contract anticipates that the discretion of the farmer must be balanced with the financial risk to Harvard. To do this, the Contract enshrines staggered payments to the farmer from Harvard and gradual on-farm alley cropping adoption to reduce financial exposure over the life of the project. Collaborative planning before the Contract is signed also gives Harvard the ability to verify that the underlying alley cropping plans align with their expectations. Though farmer discretion is important, the farmer does not have unlimited license to stray from the initial design parameters.

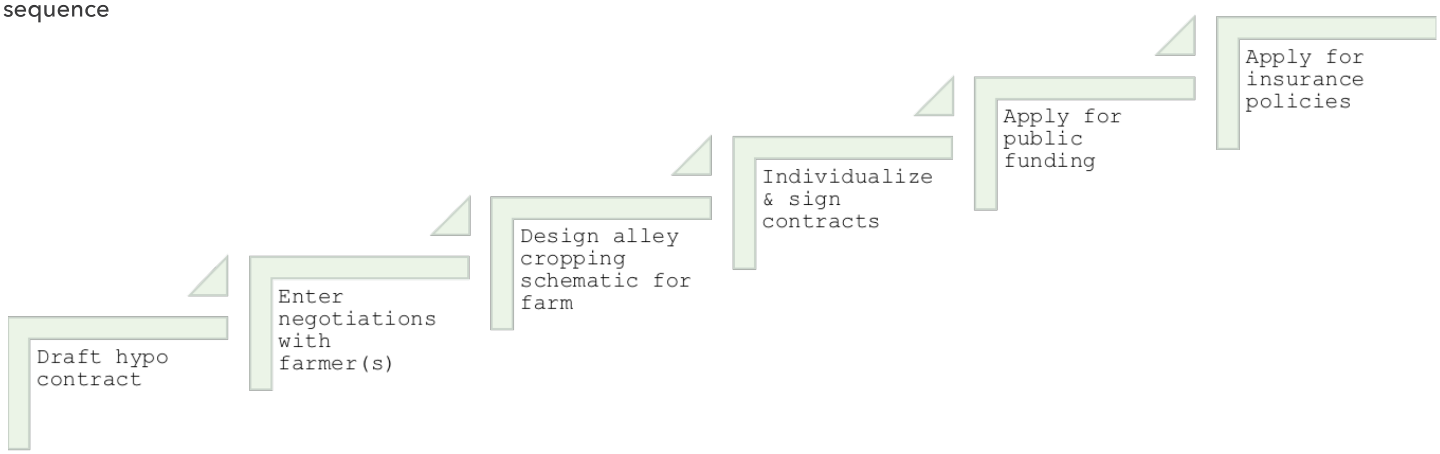
Finally, in the event of a total breach of contract by either party, the Carbon Offset Contract anticipates remedial steps for the non-breaching party to pursue. If Harvard breaches the contract, it will likely have the financial resources to pay damages to the partner-farmer.

1 See Figure 6 of the Design section on previous pages.
2 See Finance, Public Funding discussion on previous pages..

However, if the partner-farmer breaches the contract, they are unlikely to have the financial resources to pay damages to Harvard (making them "judgment proof"). In recognition of this fact, and the necessity of creating an attractive project for which farmer interest is feasible, the contract should not impose onerous obligations on the farmer.

Instead, presenting a strong value proposition to the farmer in adopting and maintaining the project long-term is the best deterrence possible. The partner-farmers electing to stay in the project for the full duration will accrue numerous benefits—strengthened crop resilience to extreme weather, increased profit per acre, and improved soil health—all subsidized by Harvard. The benefits afforded to the farmer outweigh any associated costs of entering and maintaining the program. Therefore, in the Contract should include farmer breach provisions requiring the farmer to notify Harvard of intent to leave the program, and a consultation with local partners to attempt to work out any obstacles the farmer perceives in staying in the program. If after consultation the farmer cannot be convinced to stay in the program, the farmer should be allowed to leave voluntarily. Imposing onerous remedial burdens on a farmer leaving the program will likely lead to a net financial loss for Harvard pursuing those remedies and negative PR for future scaling efforts.

Figure 12. Contract and application sequence



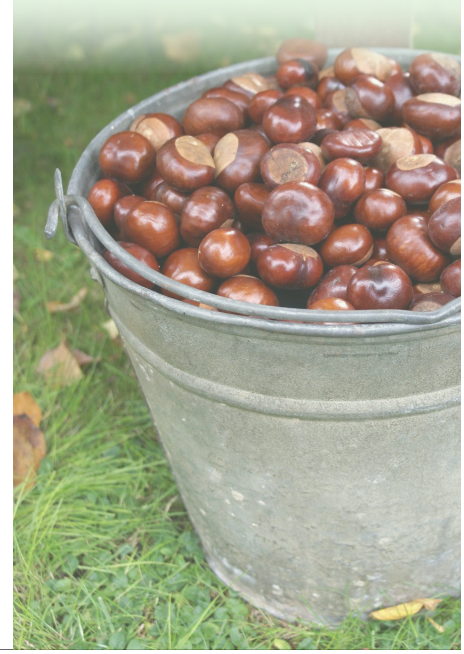
The Purchase Agreement

The Purchase Agreement (the "Agreement") is an optional contract in the alley cropping program. The Agreement is intended to provide both Harvard and the farmer with the opportunity to purchase/sell the chestnuts produced during the project. The parties may agree to contract for the purchase of a portion or all of the farmer's chestnut yield for the duration of the project or for the first few years the chestnut trees begin yielding chestnuts.

The Purchase Agreement should be negotiated at the same time as the Carbon Offset Contract to reduce administration costs as opposed to negotiating the purchase agreement several years into the project nearer when the trees start yielding nuts. Harvard will want to consider the carbon emissions associated with transporting the farmers' chestnuts to Harvard's dining halls. If the cost is appropriate though, Harvard should consider purchasing chestnuts from the partner farmers.

The farmer should consider whether or not the Purchase Agreement is right for them as well. The farmer may elect to sell a portion of their yield initially to give the farmer time to learn the chestnut market and find additional purchasers. Or, the farmer may instead decide it benefits them to sell their entire yield to the interest unregulated entity. The farmer should make these determinations in consultation with local partners, especially the University of Missouri Center for Agroforestry and the University of Missouri Extension School, who will have stronger knowledge of available markets and prices.

Should the farmer and Harvard decide that they want to enter a Purchase Agreement, it should determine an acceptable price point and quantity for the duration of the Purchase Agreement. The Purchase Agreement can be drafted by students in the Emmett Environmental Law and Policy Clinic as part of their work on the alley cropping project in general.



Insurance

The alley cropping project also includes an additional layer of risk management: a two-prong insurance scheme protecting both Harvard and the farmer. To protect the farmer, crop insurance should be acquired to insure both the intercrop and the chestnut trees. Harvard will be protected by acquiring insurance for the carbon offsets produced by the farmer. Both parties will covenant in the Carbon Offset Contract to apply for and purchase available insurance policies.

Farmer Protection: Crop Insurance

The farmer should acquire crop insurance on both the chestnut trees and the hay intercrop. Each crop will need to be insured under a different federal crop insurance regime.

Chestnut trees are insurable under the federal Noninsured Crop Disaster Assistance ("NAP") program, though traditional crop insurance policies are not available for chestnuts. NAP provides financial assistance to producers of non-insurable crops when low yields, loss of inventory or prevented planting occur due to natural disasters. NAP insurance can be acquired through consultation with the farmer's county Farm Service Agency ("FSA") office.

The farmer will be responsible for applying for and purchasing the NAP insurance policy. To do this, the farmer will have to personally contact the local FSA identified by the project partners, and then work with the FSA to complete the application process. The farmer will be required to pay $250 fee per crop/commodity and $750 fee for the farmer's administrative costs if the farmer does not qualify as socially disadvantaged. (See Appendix D for a description of the socially disadvantaged designation) These fees will be covered by Harvard's initial payments to the farmer to keep the cost of adopting the project low. As part of the application, the farmer will be required to provide information about their farm, including but not limited to total acreage insurable and irrigation information.

The intercrop between the rows of chestnuts should be eligible for traditional crop insurance policies. Traditional insurance can be obtained in the same way as the NAP insurance described above, by consulting with the local FSA office. Crop insurance policies offered vary by crop and county, though there are generally four types of crop insurance available (more information provided in Appendix B). Premiums for traditional insurance will vary based on crops covered, farm location, plan type, coverage level, and unit classification (the way a farm is counted in the insurance plan). To help offset these costs, government subsidies are available for crop insurance, increasing in rate to match the coverage level selected by the farmer, and the farmer should work with the local FSA to learn more about subsidies for which they may qualify. Based on analysis of wheat (which is generally very similar to hay), this project recommends that farmers acquire Revenue Protection insurance for the hay crop, though this recommendation is subject to the farmer's consultation with the local FSA.

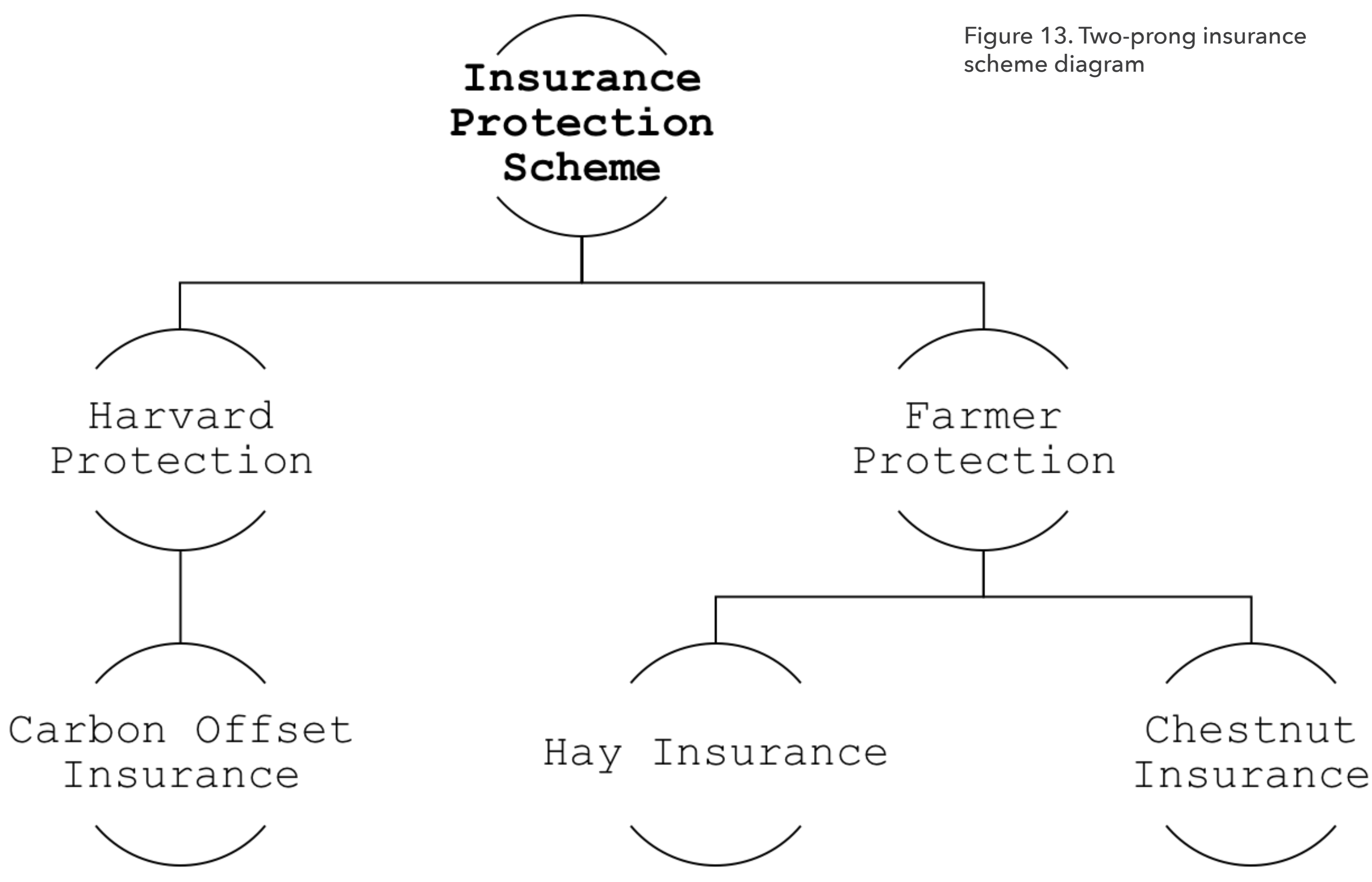


Figure 13. Two-prong insurance scheme diagram

Unregulated Entity Protection: Carbon Offset Insurance

Carbon offset insurance is a fairly nascent field of insurance, but appears to be rapidly growing. Purchase of carbon offset insurance transfers the risk of invalidation of the carbon offsets from the parties (of which the risk would primarily sit with Harvard due to financial constraints felt by the farmer) to the insurer. The cost of insurance would nominally increase the cost of the project, by $0.30 to $1.00 per carbon offset insured.

As of May 2018, Parhelion was expanding its carbon offset insurance offerings. With "ISU Environmental Insurance acting as retail broker and Parhelion Underwriting the facility underwriting manager, the globally recognized insurance market, Lloyd's of London, provid[es] the security" for carbon offset purchasers seeking protection in the (unlikely) event of invalidation. In the event that an insured carbon offset is invalidated, the policy replaces that offset with a costlier California Compliance Allowances instead.

Since the market for offset insurance is relatively new, there are limited offerings at this time. Parhelion is currently accepting applications for any ARB approved protocols (including forestry protocols) and will also consider future protocols when they are approved. The protocol verification offered by the alley cropping project should be submitted to Parhelion when it is approved. To be considered for underwriting, the application should include "Full project information, Verification reports, Registry listing details Details of the insured legal entity, Off-take agreement, [and] Details of Offsets to be insured including volumes, reporting periods, anticipated issuance dates and required limit per Offset." Thus, as the alley cropping project progresses, these application requirements should be considered and information gathered when appropriate. This task would be assigned to students working on developing this alley cropping project at the Environmental Law Clinic, Harvard Kennedy School, and Harvard Business School as a joint task. Additionally, students working on further developing this project should continue monitoring Parhelion offerings as time progresses with special attention to any offerings expanding beyond ARB approved protocols.

Appendices

Appendix A

Contracting Details for the Carbon Offset Contract

This implementation study includes a series of recommended warranties, representations, and covenants for the Carbon Offset Contract. These example provisions are based on the team's anticipated risk mitigation strategies, monitoring & verification needs, and consideration for farmer expertise and discretion in carrying out the alley cropping project in real conditions impacted by climate change (i.e. severe drought and/or flooding).

As a threshold matter, the Carbon Offset Contract should also aim to…

- Clearly define all terms at the outset of the project;
- Identify all relevant stakeholders (including but not limited to the parties to the contract, educational partners, and local project partners). Examples of potential stakeholders and partners include the partner farmer, Harvard, Harvard University, Duke University, University of Missouri Center for Agroforestry, University of Missouri Extension School, local Farm Service Agency and National Resource Conservation Service offices, and (after scaling) partner farmers already in the program.
- Express the general purpose of the contract: to create carbon offsets through the transition of conventional farm lands to climate-resilient alley cropping farms;
- Identify the duration of the the project as 30 years;
- Set the price of the carbon offsets produced and the anticipated number of offsets produced (subject to change within a mutually agreed upon margin);
- Set forth other useful standard terms.

Example warranties

- The Farmer will abide by the alley cropping project designed to fit their particular plots of land (see Figure X for an example of how each design plan will be structured);
- The Farmer will allow access (as necessary) to their property to allow for monitoring and verification activities on a regular basis;
- The Client will notify the farmer in advance when they anticipate entering the property to carry out monitoring activities;
- The Farmer will continuously maintain the alley cropping trees for 30 years from the date of planting.
- The Farmer will apply for and acquire NAP insurance on the chestnut trees. The Client will identify the county FSA office through which the farmer will apply for insurance. The farmer will then be responsible for contacting the office's insurance agent and provide the necessary information for the insurance purchase. The Client will pay the application fees for the insurance.
- The farmer warrants that they own [X] acres of land, [Y] of which are for growing [crop] and warrants that [Z] of said acres will be available for and will be dedicated to planting and growth of chestnut trees.

Example Representations

- A mutually agreed upon margin of error (the "haircut") in farmer compliance with project design plans to allow farmers time and flexibility to respond to unforeseen challenges (such as large-scale storms, plant disease, etc.);
- The farmer and client are willing renegotiate the underlying project parameters in the interest of allowing the farmer to adapt to on-site challenges (such as competition between crops and trees);
- The farmer is the full legal owner of the land to be used for the alley cropping project.

Example Covenants

- The partner-farmer will verify ownership of the land to be used for the alley cropping project;
- The farmer will purchase the chestnut cultivars
- The farmer will plant and manage the growth of the trees
- The farmer will acquire crop insurance to cover the chestnut trees for the project. The farmer should also acquire insurance for the intercrop and keep that insurance up to date if the intercrop changes as the trees mature.The cost of insurance should be considered in setting the price of the carbon offsets so that the farmer receives sufficient payments to cover the cost of insurance.
- The client will pay all costs incurred by monitoring and verification, including but not limited to hiring a firm to capture satellite images for verification and consultation with an agricultural specialist to analyze images

Appendix B

Traditional Insurance Policies for Hay Intercrop

Outlined below are four potential insurance policies available to protect the hay intercrop contemplated by this project. Actual coverage and policy provisions will likely vary from farm to farm, and this appendix should only be used for generally planning purposes. Contact with a local FSA office is critical to identifying actual policy provisions.

Revenue protection (RP)

- Protects against yield reductions and price fluxuations
- Farmer selects amount of yield to insure (between 50-80%)
- “The coverage price is based on the greater of the new crop projected price during February (December futures contract for corn, and November futures contract for soybeans) or the harvest price (during October)”
- If the farmer’s yield is lower, indemnity covers the difference

Revenue protection with harvest price exclusion (RP-HPE)

- Like RP, but does not add extra protection for increased yields at harvest

Yield protection (YP)

- Protects against production loss
- Farmer selections portion of projected average new crop future prices during the month of February to insure
- Lower yield = indemnity for the difference

Area risk protection insurance (ARPI)

- it is recommended that farmers use this plan only if their yields move in the same direction as their county's averages.

Appendix C

Farm Bill 2018 Renewal Considerations

Additional research will be required after the passage of the 2018 Farm Bill. As of May 2018, the Farm Bill renewal had not yet been finalized. Given the inherent uncertainty surrounding the final form of the 2018 Farm Bill, this implementation makes reference to the 2014 Farm Bill instead. Thus, some potential changes to the Farm Bill are outlined for reference purposes below. These should provide a starting point for future research to ensure that all references to the 2014 Farm Bill programs continue to be accurate, as this project will be implemented, at the earliest, under the 2018 Farm Bill.

Strengthening Our Investment in Land Stewardship Act 2018 (SOIL Act)

- Improves coordination in applications and contracting between EQIP and CSP
- Establishes a soil health & carbon storage initiative within EQIP and CSP
- Potentially very beneficial to agroforestry in general, and our alley cropping project in particular
- Creates a "graduation program" in which farmers who reach stewardship goals can move from the EQIP program to CSP
- Allows for addition of acreage mid-contract to compensate farmers adopting conversation practices on additional land and increase the overall conservation award of the contract
- Reduced EQIP contract life to 5 years instead of 10 years

Give Our Resources the Opportunity to Work Act (GROW Act)

- Reiterates many of the SOIL acts provisions of increasing cooperation between EQIP and CSP

The Healthy Fields and Farm Economies Act

- Increases USDA reporting and research on environmentally beneficial practices which could lead to better compensation for those practices in USDA programs

Crop Insurance Modernization Act

- Section 2(c) proposes to improve research and data gathering by the Risk Management Association (RMA) to account for soil health and other natural resources and the use of conversation practices. Accounting for these factors would probably bring down the cost of insurance for alley croppers, as agroforestry practices improve soil health and qualify as conservation practices under NRCS
- Section 2(e) increases small-scale farm access to crop insurance by lower the paperwork load associated with acquiring Whole Farm Revenue Protection. Though not immediately applicable, should the chestnut market continue to grow and eventually get insurance coverage this could be an important consideration for partner-farmers

Appendix D

NRCS Socially Disadvantaged Designation

Based on our conversation with Michael Gold from the Center for Agroforestry, a lot of farmers who might be interested in adopting alley cropping are new farmers and could fall under the category of Socially Disadvantaged, Beginning, and Limited Resource Farmers/Ranchers, Veteran Farmers. NRCS verifies Beginning Farmer, Limited Resource Farmer, and/or Veteran Farmer status prior to contract obligation. There is no verification process for participants who self certify as Socially Disadvantaged.

Socially Disadvantaged, Beginning, and Limited Resource Farmers/ Ranchers, Veteran Farmers are eligible for:	Not more than 90 percent of the costs associated with planning, design, materials, equipment, installation, labor, management, maintenance, or training;
	Not less than 25 percent above the applicable rate.
	Advance Payments: Not more than 50 percent of the costs for the purpose of purchasing materials or contracting.

Feasibility Study

Introduction

Harvard University is currently pursuing an aggressive sustainability goal: fossil fuel free by 2050, fossil fuel neutral by 2026. As an unregulated entity, Harvard will meet its sustainability goals through voluntary means. One mechanism for achieving fossil fuel neutrality will be the purchase of carbon offsets. However, electing to purchase carbon offsets leads to the question: which offsets should be bought?

The projects discussed herein provide an answer to this question. Agricultural sustainability projects have huge potential for climate change mitigation in the future. These projects purposefully target behavioral change in the agriculture sector to achieve at least 100,000 tons of CO_2 eq reduction per year. Additionally, adoption of these agriculture focused projects will create positive co-benefits for partner farmers and their communities. Both projects proposed are agroforestry initiatives.

Agroforestry is the "intentional integration of trees and shrubs into crop and animal farming systems" to produce not only positive environmental change, but social and economic benefits as well. Though agroforestry is applicable to many different types of farms, habitats, and climates, the projects suggested in this report focus on alley cropping (planting rows of crops between rows of trees) and silvopasture (planting trees and forage for livestock grazing on the same plot of land). Through these projects, Harvard has the opportunity to achieve its goals of becoming fossil fuel neutral, and ultimately fossil fuel free, while also supporting rural farmers who adopt sustainable long-term practices producing co-benefits.

Executive Summary

One. Alley cropping and silvopasture adoption can cause significant carbon sequestration effects eligible to produce carbon offset credits.

Alley cropping and silvopasture are both viable paths to producing carbon offsets through agriculture. Increases in biomass from planting trees and establishing roots systems demonstrates a quantifiable method of carbon reduction. Additionally, GHG credits can easily be calculated by participating farmers using online tools.

Two. Farmers feel more comfortable employing new practices (such as agroforestry) when they have a sufficient support system on which to rely.

Farmers are naturally wary of adopting new systems for which they do not have adequate support. Connecting farmers with local agroforestry resources is critical to ensuring farmer confidence in implementation of new practices. Sufficient market research must be conducted before initiating agroforestry projects to guarantee a buyer for new specialty commodities.

Three. Success in alley cropping and silvopasture practices are attainable—as long as everyone involved does their homework.

Every participant in a project needs to do their due diligence before making commitments to adopt a new practice. The right tree must be planted for the right purpose on the right plot of land. Farms need to be able to adapt as the trees grow and change the status quo of light, chemical, and root interactions between plants.

Unregulated entities need to understand that farmers need flexibility to respond to the land management challenges inherent in alley cropping and silvopasture. However, if everyone involved is fulling informed and understands the long-term goals of the project, each participant can achieve their personal objectives.

Project Overview

As previously mentioned, both of the projects discussed herein are agroforestry initiatives. Project 1, Alley Cropping in Missouri, investigates the feasibility of partnering with local farmers in rural Missouri areas to help spur the adoption of alley cropping practices. Project 2, Silvopasture in New York, discusses the feasibility of partnering with local farmers in New York to encourage the adoption of silvopasture practices. Both projects will target three separate entities: an unregulated entity, a commodity purchaser, and a farmer. Each project strives to create at least 100,000 tons of CO2e reduction per year.

The unregulated entity contemplated by both projects is Harvard University. Harvard's stated goal of fossil fuel neutral by 2026 makes it an excellent unregulated entity to purchase the carbon credits produced by either project.

The commodity purchaser is a to-be-identified purchaser of specialty commodity products local to the farmer-partner. The commodity purchaser will preferably be able to purchase the entire yield produced by the farmer. The purchaser will gain the benefit of supporting local agriculture and the opportunity to popularize a specialty commodity. The purchaser will also have a dedicated source of the commodity for the duration of a purchase agreement with the farmer.

Each project targets as "ideal" farmer—one who meets a series of predetermined criteria to maximize benefits to all stakeholders. The ideal farmer would personally own a small to mid-sized farm. Family farmers and individuals are preferable to large farming organizations. The ideal farmer would be one who is seeking off-farm income to make ends meet and has been affected hardships caused by climate change, such as drought or increasingly severe storms.

These criteria are important because farmers can seek premiums for the specialty commodities they can produce in agroforestry, bettering their quality of life, and agroforestry practices are climate resilient so as to protect the farmer from future loss. The ideal farmer would also be able to access local university extension resources. Access to these resources would help the farmer feel secure in their decision to adopt new practices as they would have a solid support system available when needed. Identifying ideal farmers will help ensure that these agroforestry project produce the most benefit to all parties.

Feasibility Findings Summary

	Criteria	Alley Cropping Missouri	Silvopasture New York
Overarching Objectives	*CO_2 Reduction*	Favorable	Favorable
	Public Health Co-Benefits	Acceptable	Acceptable
	Ecosystem Co-Benefits	Acceptable	Acceptable
	Social Co-Benefits	Favorable	Favorable
	Scalability	Favorable	Acceptable
	Innovative Qualities	Acceptable	Acceptable
Initial Adoption	*Statutory/Regulatory Frameworks*	Favorable	Favorable
	Farm Bill Incentives	Favorable	Acceptable
	Upfront Costs	Acceptable	Acceptable
	Profitability	Acceptable	Acceptable
	Additionality	Favorable	Favorable
	Behavioral Adoption Barriers	Concerning	Acceptable
Long Term Implementation	*Ease of GHG Quantification*	Acceptable	Acceptable
	Ease of Monitoring	Acceptable	Acceptable
	Contract Considerations	Acceptable	Acceptable
	Behavioral Implementation Barriers	Acceptable	Acceptable
	Local Experts to Provide Continuing Support	Favorable	Acceptable

Favorable Acceptable Concerning

Project 1: Alley Cropping in Missouri

Introduction

Alley cropping is a form of agroforestry practice where single or double rows of trees are planted in alternation with a companion crop planted in the alleyways. Agronomic, horticultural or forage crops may be combined with a woody plant selected for its value for wood, nut or fruit crops. Through the increase of biomass above the soil (trees) and the permanent root system in the soil the carbon content per unit of land is increased, thereby resulting in net greenhouse gas capture.

The not-for-profit Drawdown estimates that 17.2 Gt CO2 eq could be saved through alley cropping with 571 million acres of adoption globally. In addition to the climate benefits, alley cropping increases production, reduces water run-off and erosion and diversifies farm income. Alley cropping thus promises to have a significant positive impact on farmer's livelihoods where climate-related pressures are high, and farmers rely on secondary income to supplement their on-farm income. Lack of peer education is considered the main obstacle to establishing alley cropping practices.

In the US, Missouri ranks 2nd in the number of farms, with over 100,000 small to mid-sized farms. Overall, 68% of state territory is dedicated to farmland, with corn and soybean being the primary crops. Almost all are farms family owned, suggesting that there is a strong relationship with the land, and an interest in engaging in agricultural practices that increase the long-term value of the land. In addition, Missouri has been experiencing frequent drought conditions, with currently ~99% of the state under some level of drought. As such, Missouri provides great opportunity for creating large-scale change in the agricultural sector and will benefit significantly from increasing resilience to climate-related pressures.

Finally, Missouri is home to The University of Missouri Center for Agroforestry, "one of the world's leading centers in agroforestry," providing a local resource for interested farmers through regular outreach programs and trainings. Though the Center for Agroforestry is a valuable tool for local farmers, alley cropping adoption in Missouri is low and opportunities for expansion are likely.

This project proposes to partner with 30 farmers in Missouri each agreeing to transform at least 50 acres of their conventionally farmed land into alley cropping, combining either walnut or pecan trees with the current main commodity produced by the farmer (f.e. soybean, corn, alfalfa or hay) to save 100,000t CO2 eq.

Planning + Process Design

In assessing the feasibility of this project, it is important to understand potential barriers to adoption and understand the reasons alley cropping has not been adopted at a wide scale in many regions of the US. With the knowledge of these barriers comes the opportunity to creatively design ways to overcome them in the implementation phase of our project.

Design and Behavioral Considerations

A Missouri study found that overall, many farm landowners had little knowledge of agroforestry practices yet they had interest in learning more about agroforestry practices such as alley cropping. A study of woodland owners and farmers in Pennsylvania found that some barriers to agroforestry adoption included "lack of ability to experiment, expenses of additional management, and unknown markets for products" as well as perceived and real complexities associated with more crops, and thus more complex management and harvesting regimes. This could certainly apply to Missouri as well.

According to another study, four of the top five ways farmers prefer to learn about new practices are demonstration, farm visits, field days, and discussions. Thus it is critical to have established and thriving reference farms set up as well as educational programming. Additionally, land tenure has been found to be positively correlated with the adoption of agroforestry practices, which has implications for the type of farmer we choose to work with for our project.

Clearly, it is important for farmers to see a return on their investment and how the benefits will outweigh the costs if they adopt alley cropping. According to a study on crop diversification, “Missouri farmers have grown accustomed to being paid, either on cost share basis or on a land rental basis to provide environmental services or to address their environmental concerns. This has been a very effective mechanism to incorporate windbreaks and riparian buffers in Missouri’s landscape, with lower transaction costs due to the existence of public institutions.” Another study mentions that there are many economic incentives and policies that promote monoculture, making it hard for farmers to see the benefits of diversified systems.

One study that assessed carbon offset trading as an added incentive to adopt alley cropping in Missouri concluded that the “current context [of] carbon trading does not provide an added incentive value for Missouri landowners to adopt either silvopasture or alley cropping practices because of the low magnitude of annual return.” Therefore, we must make sure to design other incentives structures to work around this.

These behavioral barriers to adoption don’t seem insurmountable, but a creative approach to developing our implementation plan must be taken.

Greenhouse gas reductions

During the first few years of an alley cropping project greenhouse gas savings are 0 or negative due to the initial investment and slow growth process of woody plants. Greenhouse gas capture is highest during the period where the increase in biomass on the land is highest and eventually levels out as trees gain their maximum size. According to COMET, a greenhouse gas accounting system developed by the United States Department of Agriculture and Colorado State University, alley cropping in Missouri will capture an average of 1.71t CO2 eq acre-1 yr-1 over the course of 20 years when converting 20% of farmland to tree plantations. As we strive to convert 40% of farmland to tree plantations, a total of 1,461 acres of conventionally farmed land would need to be converted to alley cropping in order to capture 100,000t CO2 eq. At an average farm size of 269 acres, we would need to recruit six farms, or twelve farms who agree to convert half their land to alley cropping, into the program.

Detailed carbon accounting for alley cropping that is specific to the farmland in question can be established in cooperation with the farmer using the COMET-Farm tool, and will form the basis for the partnering agreement.

Monitoring

To make sure that the greenhouse gas emission reductions agreed upon in the partnering agreement are actually achieved, a thorough monitoring of the stock, growth and health of trees on our project sites over the 20 year period is necessary.

Tree growth and health is dependent on the tree type, but can be evaluated through monitoring the size and rate of change of the tree crown from aerial images.

One option is retrieve high scale images (~1m x 1m) with drones, which have been widely employed in agriculture for crop evaluation such as crop health, moisture content and growth. Drones have also been employed to supervise reforestation. Drone pilots can be hired to take these images.

A more inexpensive alternative may be to use existing aerial images from google earth or satellites, such as those provided by the smart agriculture provider Farmer’s Edge. Using Farmer’s Edge satellite images have the advantage that they come with an evaluation report on soil properties and plant growth that would allow farmers to improve their yields. However, these reports would likely not include sufficient information to evaluate the tree health on their own and will require additional expert evaluation by tree (forestry) experts, which may be recruited from local extension schools.

Generally, monitoring is a major hurdle for generating carbon offsets, and should thus be made a inexpensive and straightforward as possible. The final monitoring strategy will have to be defined in a certification protocol, that ensures the high quality, reliability and replicability of the generated carbon offsets.

Public Health

Key Considerations

Light competition: Small leaves and light shade trees are preferable to heavy shade in order to minimize light competition. By increasing the distance between rows of trees, the years an alleyway can be cropped with minimal competition from the trees is also increased. An east-west orientation of tree rows will optimize the sunlight received by alleyways. Trees with small leaves will allow more light to enter the system. Pruning basal branches before they reach 1" in diameter improves future wood quality and thins the depth of the canopy permitting more sunlight to reach companion crops.

Root Competition: Competition for water and nutrients between crops and trees increases as distance between crops decreases. This can be reduced by understanding which species are deep-rooted or shallow-rooted (deep-rooted species minimize competition with adjacent crops due to a lack of surface roots). Root competition is the major reason for reduced crop yields.

Chemical Interactions: Defined as the negative biochemical influence exerted by one plant on the growth of nearby plants. Pine needles may produce acids that inhibit growth of plants on the forest floor. Chemical interactions can be controlled by selecting plant combinations that work together.

Proper management of Alley Cropping Systems

If properly managed, meaning light competition, root competition, chemical interactions are optimized, alley cropping systems have positive benefits on public health. Intercropping systems help diversify farm products and supplement income by providing short-term cash flow from annual crops while also providing a medium to long-term products from wood. Also, timber, nut, and fruit-bearing trees take time to mature, therefore farmers can plants other crops in between rows that may require more sun while the trees are reaching their full maturation.

Alley cropping helps reduce soil erosion and agricultural runoff by protecting fragile soils producing a network of roots from trees and companion crops.

Water quality is also improved due to interception, sequestration, and decomposition of agricultural chemicals by tree and herbaceous root environments. Agricultural chemicals, such as nitrogen, that leech beyond the root zone of crops can be absorbed by the root systems of the trees therefore minimizing groundwater contamination and potentially improving water quality that enters local food and water systems. Trees and shrubs can also improve crop yield by modifying the crop microclimate through slowing of wind speed and reduction of wind erosion. Crop evapotranspiration can be reduced by 15-30 percent and water content in the tillage layer can be increased by 5-15 percent.

Alley cropping further protects crops from damage by reducing crop visibility for pests and diluting pest hosts due to plant diversity. By protecting crops from damage, these systems can help improve crop yields which could then lead to more diversified income, utility of wood, and improved nutrition due to higher biodiversity.

A huge limitation of alley cropping is that it requires a more intensive management system including specialized equipment for the tree management and additional managerial skills. If the system is not properly managed, alley cropping can have negative repercussions on public health. If trees are not planted at an optimal distance from each other, this can lead to a shortage of light for crops or competition for water and nutrients between crops and trees. This would then lead to a reduction in crop yield due to a deficiency in adequate nutrients which could have a profound impact on human nutrition and economic security. If the trees and crops chosen to be grown together are not compatible this could lead to various chemical interactions that could also reduce crop yields.

Figure 1. Alley Cropping Management Outcomes

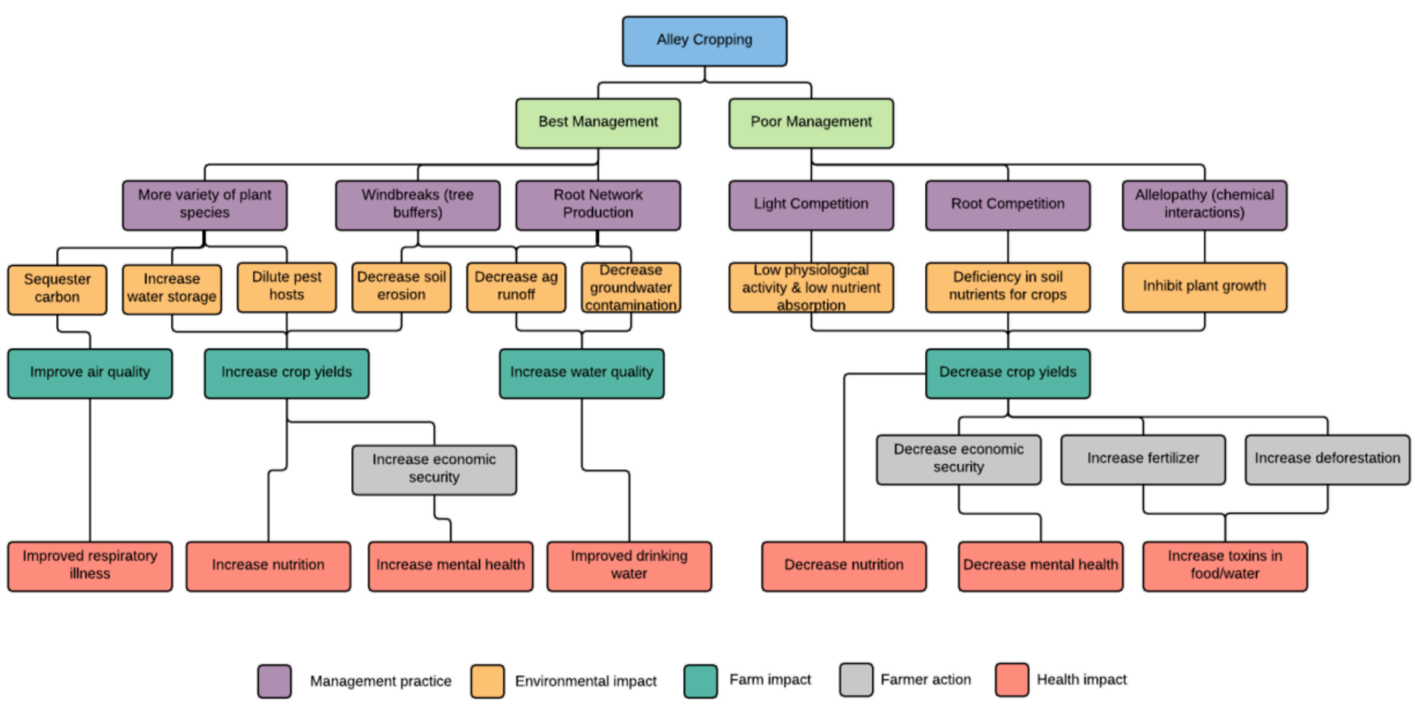


Figure 1. Alley Cropping Management Outcomes

Legal Analysis

There are no national or Missouri state laws that pose significant barriers for farmers interested in adopting alley cropping practices. Similarly, there are few significant legal concerns in the implementation of a drone monitoring program. Instead, the primary legal concerns for alley cropping projects will involve careful crafting of contracts to ensure that project partners and clients are entering agreements with equal understandings of project obligations and assurances that risks can be mitigated.

Contract Considerations: Alley Cropping

A set of contracts between the participating entities will be necessary to ensure the success of the alley cropping project. Participating farmers will contract with two clients: a carbon-offset purchaser and a commodity purchaser. The carbon-offset purchaser will be the primary client for the project and this contract will cover the obligations necessary to ensure the production of sufficient carbon offsets. A second client, the commodity purchaser, will be a local entity that will agree to purchase the commodity produced by the trees introduced to the farmer's land as a result of the alley cropping project. The participation of the commodity purchaser will help encourage farmers to adopt the alley cropping project by guaranteeing that the commodity produced by the added trees will produce an additional source of income to the farmer.

Though contracts will need to be individually drafted for each participating farmer reflecting the unique parameters set to meet the design needs specific to each parcel of land, a series of high level provisions are necessary to ensure the feasibility of all potential alley cropping projects.

Carbon-Offset Contract

The feasibility of the Carbon Offset Contract will require a series of provisions outlining the expectations of both parties that are required to make the project a success. Sample provisions are listed below, and while the project anticipates that these provisions are necessary for the success of the project, they alone may not be sufficient and should be fleshed out in greater detail upon implementation:

- A guarantee from the farmer that they will abide by the alley cropping project designed to fit their particular plots of land;
- A guarantee from the farmer that they will allow access to their property to allow for monitoring and verification activities on a regular basis;
- A guarantee from the client that they will notify the farmer in advance when they anticipate entering the property to carry out monitoring activities;
- A mutually agreed upon margin of error in farmer compliance with project parameters to allow farmers time and flexibility to respond to unforeseen challenges (such as large-scale storms, plant disease, etc.);
- Documentation from the farmer to verify ownership of the land to be used for the alley cropping project;
- A guarantee from the farmer that they will acquire insurance to compensate the client in the event of breach of contract by the farmer;
- Representations from the farmer and client of a willingness to revisit the underlying project parameters in the interest of allowing the farmer to adapt to on-site challenges (such as competition between crops and trees);
- An assurance from the client that they will be responsible for costs incurred by monitoring and verification.

The greatest risk posed by this project's heavy reliance on contract mechanism is the risk of a total breach of contract by the farmer. In the event that the farmer desires to reallocate their land for non-agroforestry uses, or suffers some other unforeseen event resulting in a major loss of trees, the client would lose the carbon offsets promised by the project. To mitigate this risk, the the client can obtain insurance on the carbon offsets which would substitute the lost carbon offsets with substitute California Carbon Allowances. Procurement of insurance is particularly important because there is a high likelihood that participating farmers may be judgment proof if the client pursued recovery of damages in court. Though the carbon offset insurance market is a relatively new innovation in the insurance industry, policies are available to cover carbon offsets sold through eligible protocols (decided upon submittal of application to the insurer).

Additionally, the contract will bind the farmer to following a pre-determined implementation plan outlining the project parameters individualized to their land. This is in lieu of binding the farmer to produce a specific number of carbon credits annually. Given the variables inherent in agriculture, binding the farmer to a set of parameters instead of a carbon outcome will encourage farmer participation. The project's parameters will include an underlying calculation demonstrating the anticipated number of carbon offsets produced by the farmer based on compliance with the project parameters.

However, the team anticipates that this project will present a strong value proposition to the farmer that will serve as a deterrent from breaching the contract. The contracts will respect the discretion of the farmer to make on-site decisions in response to challenges that arise (and will arise, as farming in the midst of climate change will inevitably will). Additionally, the farmer's ability to diversify their crops and generate additional profit per acre extends the strong financial value the farmer stands to gain by remaining a part of the program. It is also likely that if a farmer decided to return to conventional practices, they would incur some cost in transitioning back. This would stand as a barrier to exit, as the project will not compensate farmers who return to conventional practices. The benefits that accrue from staying in the program, as well as the costs that accrue from leaving, demonstrate that reliance on the contracting mechanism is feasible, though the contracts will have to be carefully crafted to strike this balance.

Commodity Purchase Agreement

The Purchase Agreement is an optional contract contemplated by the project. The partner farmer and unregulated entity may elect to enter into the purchase agreement, or the partner farmer may find alternate purchasers for the chestnut yields.The following provisions will be included in the commodity purchase agreement:

- A guarantee from the purchaser that they will purchase the entire yield of the added trees;
- A guarantee that the purchaser will pay the farmer at least market rate for the commodity;
- The farmer will be responsible for the transportation and delivery of the commodity to the purchaser.

The purchase agreement will have a delayed effect. After planting the saplings for the alley cropping project, the farmer will not be able to deliver a commodity to the purchaser until the sapling trees reach maturity and begin producing fruit. The purchase agreement will also have to consider the increasing production of the trees as they grow. Also, the carbon offset contract will cover all planting and compliance costs: the purchase agreement will only be used to secure purchasing rights to the commodity crop produced by the alley cropping trees.

The main intent behind the Agreement is affording the partner farmer the opportunity to have a reliable purchaser while they learn the chestnut markets. Ideally, the partner farmer will be comfortable enough with the market at the end of the purchase agreement that they can fetch the highest price possible for the chestnuts. However, if the partner farmer wants to go straight to the market with their yield, this is also permissible. The purchase agreement acts as an additional incentive to attract farmers to the project.

2014 Farm Bill: Alley Cropping

The 2014 Farm Bill is not a source of statutory barriers to the adoption of alley cropping projects. The Farm Bill does, however, authorize several programs which could provide funding for alley cropping adoption efforts. Though the Farm Bill is currently awaiting renewal by Congress, these programs are likely to survive in whole or in part in the 2018 iteration of the Farm Bill. The final form of the 2018 Farm Bill has not been released yet, though. Therefore, this feasibility study considers the Farm Bill in its current, 2014 form. Information about potential changes in the 2018 Farm Bill are listed in Appendix B. These changes should not fatally impact the feasibility of either the alley cropping or silvopasture projects. It will be important, after the passage of the 2018 Farm Bill, to follow up on changes to the relevant provisions discussed in this feasibility study. Further research should be conducted on the provisions listed below, and those outlined in Appendix B.

Conservation Stewardship Program: Alley Cropping

The Conservation Stewardship Program (CSP) is a part of USDA's Natural Resource Conservation Service (NRCS) and offers technical and financial support for conservation efforts on working lands. The CSP offers up to five-year long funding contracts to eligible farmers. Farmers and their farms must meet a series of eligibility criteria to be considered for the program, listed in Figure 2, below.

Farmer Eligibility	Farm Eligibility
• Proof of decision making power over eligible farm (i.e. proof of ownership)	• Produces at least $1,000 in sales annually
• Operator listed in Farm Service Agency records	• Privately owned land
• Individual adjusted gross income under $900,000	• Land not currently enrolled in other USDA conservation programs
• Activities must incur costs or forgone income	

Figure 2. Conservation Stewardship Program Eligibility Criteria

CSP is available in all fifty states and applications are accepted year-round. Alley cropping projects should be eligible for CSP contracts as long as the partner farmer and farm meet the above criteria.

Program enrollment is limited to ten million acres annually, and no funding may be awarded to acres already enrolled in other USDA conservation programs. Funding per farm is also limited to $40,000 in payments per year, with a $200,000 maximum for a five-year contract. The amount of funding awarded to each farm is based on a calculation factoring in the number of acres on the farm, and the conservation activities in use. The conservation activities eligible are pre-determined by NRCS—alley cropping qualifies under several of the criteria, such as "[a]dding food-producing trees and shrubs to existing plantings."

Environmental Quality Incentives Program: Alley Cropping

The Environmental Quality Incentives Program (EQIP) provides up to ten-year contracts with farmers in order to share the costs associated with implementing environmental improvements and compliance with clean air and clean water regulations. Alley cropping is listed as a qualifying practice for EQIP funding, with a series of technical guidance documents available from NRCS to help guide farmers through the process of adopting alley cropping on their lands.

The amount of funding available for alley cropping projects is calculated based on the number of rows of qualifying activities multiplied by an associated per-row cost. Consultation with a local NRCS office is required to advance an application.

Agricultural Conservation Easement Program: Alley Cropping

The Agricultural Conservation Easement Program (ACEP) offers farmers the opportunity to preserve the working use of their land in exchange for the grant of an easement to a state or local governmental partner. Easements are permanent land-use restrictions that attach to the land, not the owner of the land. In an alley cropping project, the partner farmer would agree to designate a portion of their land that would permanently be used for alley cropping practices. ACEP is divided into two regimes: Agricultural Land Easements (relevant to alley cropping) and Wetland Reserve Easements (irrelevant to alley cropping). Applications are filed in consultation with regional NCRS offices.

Payments to farmers in exchange for the Agricultural Land Easements is conditioned upon acceptance of the application to NRCS, number of acres enrolled in the program, and the environmental significance of the land. Up to seventy-five percent of the fair market value of the easement will be funded for "grasslands of special environmental significance" whereas up to fifty percent of the fair market value will be funded for other land. However, alley cropping partners in Missouri may face significant difficulties in applying to ACEP: no Agricultural Land Easements were granted in Missouri between 2014 and 2016. However, several Wetland Reserve Easements were granted each year between 2014 and 2016. The reason for this absence of agricultural easements is unclear and a possible topic for follow-up research.

Business + Economic Analysis

General Considerations

Generally speaking, financing of these projects is not expected to be a major hindrance. We are targeting smaller farms with few acres of land, and so any initial capital expenditure on trees, shrubs, or alley crops will not be prohibitively expensive. Furthermore, through the numerous Federal grant-giving organizations described above, along with others at both the state level and through private organizations, we believe we will be able to secure finance. Please find more detail below on the total addressable markets (TAM) and specific financing sources unique to each project idea.

An area of slightly more concern is profitability. Profitability can vary greatly in both alley cropping and silvopasture as a result of which supplementary crops are grown and how these crops are marketed and sold. One study from Cornell University highlighted the economic outcomes of a three-year SARE-funded grant program for a shiitake mushroom agroforestry project in New England. 250 farmers were educated on the process and potential benefits of participating in an agroforestry project like growing log-inoculated shiitake mushrooms; of those 250, 55 submitted 5-year business plans, and 27 of those 55 farmers were approved for funding. 15 of the 27 farmers went ahead and engaged in the agroforestry project, and of those 15, 10 reported net profit after expenses. The average net profit at the end of the 5-year investment horizon for an average-sized operation was $9,000, proving the economic viability of this model. However, we imagine that profitability figures may be less promising for other commodities, or may be achieved at lower frequencies of success. Therefore, commodity selection is a critical component of the implementation strategy.

Missouri & Alley Cropping

Missouri is promising from a financial standpoint. There are many sources of funding, be it federal grants, state grants, and private grants. The TAM in Missouri is sizable with an estimated 40,000 college students in the state who are dependent on campus dining services. This means universities could be a great partner in Missouri. As mentioned earlier, the federal grant programs through NRCS, EQIP, ACEP, CSP, and SARE are all available in Missouri. Furthermore, the state offers grant and credit financing programs, which is a unique source of funds that many other states do not offer. The Alternative Loan Program provides credit financing for up to $20,000 with a 5-year maturity, 7.5% interest rate, and semi-annual payments for any entrepreneurial or innovative agricultural investment.

The Missouri Department of Conservation is another source of funding. The Department offers technical advice and guidance to farmers who are practicing sustainable growing methods, such as agroforestry. The Department also compliments the CRP program through a cash-per-acre incentive for a period of up to 10 years. However, it is important to note that in the past this option has run dry, so we will need to verify whether this program is accepting applications for grant funding. The Department also offers two areas of the Cost Share Program that can be applied to agroforestry. The first is a tree and shrub establishment program and the second is a woodland improvement program, both of which offer a 75 percent cost share on all approved practices, unless a flat fee has been established for the practice.

Lastly, there may be private organizations, such as The Nature Conservancy, that have unique investment mandates and are able to take on low return projects like this one. This could be an interesting option to explore.

Greenhouse Gas Protocols and Public Policy

In this section, an identification of the potential challenges, obstacles, uncertainties, and opportunities that the establishment of alley cropping in Missouri are addressed from the perspective of the requirements set by the greenhouse gas protocols and from a public policy standpoint.

One of the protocols does not allow the use of synthetic fertilizer. Therefore, it is important to target farmers who have made a transition to organic fertilizers, who are in the process of shifting towards the complete use of organic fertilizers, or farmers who are willing to stop using synthetic fertilizers but have not been able to do so. Therefore, this project should keep in mind that farmers can be presented with an incentive if there is a potential cost-benefit from moving towards organic fertilizers where productivity yields are not sacrificed. This potential limitation would be applicable to the silvopasture project in New York.

Protocols require sink-based projects like alley cropping and silvopasture to have a long-term vision. For instance, one of the protocols allow projects to generate credits up to 40 or 50 years, but require the carbon to be stored for at least 100 years after the issuance of CRTs (Climate Reserve Tonnes). This long-term contracting requirements raise two challenging situations that are mentioned in other sections of this feasibility report (including engineering, legal, financial). First, the question of monitoring, verification, and a robust documentation process must be in place for 100 years. The monitoring program should be a simple and cheap process that does not require too much effort from the farmer. In order to have a robust monitoring system, farmers should be familiar with Standard Operating Procedures (SOP) and QA/QC standards for field data collection and data management. This could be an additional cost and time-consuming step that should be considered for the successful implementation of the project. Secondly, the concern about the future. In the future, farmers might stop implementing practices, they might decide to sell the farm, or land is inherited. These issues should be addressed through contracts and insurance.

In order to have an inexpensive way to record data, the following recommendations have been identified. Including time and date-stamped photographs in the monitoring program. Consulting with the town or county since some of them take aerial photos for free. Another option is to tour the site and take pictures with a digital camera or smartphones. This project has also brought up the potential use of unmanned-aerial vehicles to improve monitoring which has raised concerns from a legal standpoint and economic feasibility.

For both the alley cropping and silvopasture projects, it is necessary to define whether the project is only targeting to enhance biotic sequestration or if it is also including reductions in enteric, manure, fertilizer, or fossil fuel emissions. This is important because it will determine the crediting period and the minimum project term. Under one of the protocols, for biotic sequestration both the crediting period and the minimum project term is 40 years. For other emission reductions, there is a 10-year crediting period and no minimum project term. These differences will be crucial to create an effective and comprehensive monitoring program.

Both projects, alley cropping and silvopasture, should target project partners that have good documentation (at least for the last 10 years) in order to ensure eligibility to a protocol. Under some protocols, strong documentation is required. This would make it easier to calculate the potential greenhouse gas reductions, the implementation of an effective monitoring program, and prove reliability when applying to a protocol.

A financial challenge was identified regarding proving additionality and avoiding leakage. Under one of the protocols, if a project activity lead to a decrease greater than 3% in product output, relative to the baseline case, the potential for activity shifting and market-effects leakage emissions must be accounted for. This principle applies for both alley cropping and silvopasture. Both projects should take into consideration a baseline scenario with productivity values.

Protocols require projects to demonstrate additionality through a performance and legal test. The performance test must prove that projects achieve greenhouse gas reductions or removals are above and beyond business as usual activities (determined through a standardized baseline assessment). The legal test must prove that there is not any federal, state or local laws, statutes, rules, regulations or ordinances, court orders or other legally binding mandates that are a barrier for the projects.

A potential limitation to consider in the implementation phase is that some protocols do not allow projects that are receiving payment stacking and credit stacking for ecosystem services. Some exceptions are made but need to be consulted with the Protocol specialist depending on the farm context. There are also several opportunities identified in this research. Farmers from different U.S. states are eligible to earn credits through the California carbon market. California is the only state in the U.S. with a cap-and-trade program where the current value of one carbon credit is around $15.

Another potential limitation is that farmers may feel apprehensive about the level of data they are required to provide for the protocol verification. This level of data provides a detailed picture of the farmers' most valuable asset: their land. Therefore, the design of the protocol should be built with respect to the data that the farmer is being asked to donate to the project. Careful consideration in the protocol of the farmers' data concerns should mitigate the risks farmers will anticipate in giving their data to the protocol. The implementation plan will provide more detail on appropriate steps to take, but as long as the protocol follows these steps and remains respectful of farmers' privacy, the feasibility of protocol verification should not be negatively impacted.

Unlike farmers in New York that have access to the Agriculture Management Assistance Program (AMA), farmer in Missouri have access to the Conservation Technical Assistance Program (CTA). Missouri farmers that choose to be involved with CTA have higher chances to have funding from EQIP financial assistance.

For both alley cropping and silvopasture, there are several opportunities that can address social benefits. If one component of the project is designed to support local/regional food, efforts to increase consumption of such products and develop, improve, or expand local/regional markets, then there is a possibility to obtain grants from the Local Food Promotion Program (LFPP) and the Farmers Market Promotion Program (FMPP). If an alley cropping project includes a Specialty Crop, there are potential source of additional funding through the Specialty Crop Research Initiative. This program gives priority to projects that are multi-institutional or trans-disciplinary and include clear mechanisms to communicate results to producers and the public. This Initiative has five legislative focus area priorities. From these priorities the most relevant to our program is that our project is an effort to improve production efficiency, productivity, and long-term profitability (including specialty crop and marketing).

This research also took a look at potential ways to calculate the social impact of either alley cropping or silvopasture. The first tool that was considered was a Social Life Cycle Assessment. There is a software called SimaPro that can help identify hotspots or social impacts. The limitations of this program is that is not free, it requires training (know-how), and it requires time that would lead to higher costs. This tool could be really helpful for project that are addressing supply chains and helping private companies (potential clients) estimate social impacts. Another methodology that was found was to calculate the Social Cost of Carbon as the EPA used to do it before January 20th, 2017. EPA and other federal agencies use estimates of the social cost of carbon is a measure, in dollars, of the long-term damage done by a ton of carbon dioxide (CO2) emissions in a given year. Some of the limitations of this methodology is that the current modeling and data do not include all important damages leaving room for uncertainty.

Project 2: Silvopasture in New York

Introduction

Silvopasture is an agroforestry practice where trees selected for their value for wood, nut or fruit crops are integrated with pasture. Through the increase of biomass above the soil (trees) and the permanent root system in the soil the carbon content per unit of land is increased, thereby resulting in net greenhouse gas capture. The not-for-profit Drawdown ranks silvopasture #9 of Climate Change solutions suggesting that 31.19Gt CO_2 eq could be saved globally by converting 203 million acres of conventional pastures to silvopasture. In addition to the climate benefits, silvopasture increases farmer's resilience through generating additional income from forestry products that become available at different time horizons and improves the health and productivity of animals and land.

New York state is the #3 producer of dairy products in the US, with over 36,000 small to mid-sized farms. Over half of New York farms have less that 100 farmed acres. Similar to Missouri, New York state has a strong Agricultural Extension program based at Cornell University that could be tapped into to overcome adoption obstacles.

This project proposes to partner with dairy farmers in New York state to transform (part of) their pastures into silvopastures with walnut or maple trees overall aiming to save 100,000t CO_2 eq.

Planning + Process Design

In assessing the feasibility of this project, it is important to understand potential obstacles to silvopasture adoption and understand the reasons silvopasture has not been implemented at a wide scale across New York. With the knowledge of these barriers comes the opportunity to creatively design ways to overcome them in the implementation phase of our project.

Design and Behavioral Considerations

As a practice, silvopasture is underrepresented in New York and the rest of New England when compared to other regions of the US. A study that assessed silvopasture practices and perspectives in the Northeast found that a key barrier to adoption was the fact there are few publicly known local examples of silvopasture in the region. This lack of established and successful reference farms for farmers to visit makes it risky for a farmer to adopt a new system without a clear understanding benefits and tradeoffs. The same study also summarized that a common concern is the lack of understanding of what qualifies as silvopasture. Apparently, many farmers make the mistake of thinking silvopasture is anything that involves livestock grazing around trees and other vegetation and that it does not involve much management of tree health. Further studies have shown that in other areas of the world, "adoption of agroforestry practices has been slow due to farmer bias against trees and limited knowledge of landowners on agroforestry practices." Table 1 summarizes key findings in silvopasture adoption in New York and New England, or lack thereof.

One of the biggest barriers to adoption appears to be the lack of knowledge and understanding of silvopasture practices, as well as practice management and fencing construction and maintenance over the long-term. One of the most interesting findings is that many practicing farmers seem to use silvopasture, or general 'shade paddock' areas of their farms as part of their rotational grazing practice during the hottest months and during droughts because of greater amounts of shade and better foraging opportunities for their livestock. Therefore, it seems that some farmers look to silvopasture as having a seasonal advantage, rather than as a year-round practice they can employ. This might be attributed to their lack of understanding of silvopasture and lack of incorporation of commodity-producing trees.

According to the study, the acreage dedicated to silvopasture varied on farms and "ranged from less than 1 ha to 73 ha, with a median of 5 ha per farm." This is something to keep in mind, so we don't just consider total farm size in our calculations moving forward.

The study also found that creating silvopasture by converting forests to rows of trees was the main strategy of conversion, as opposed to planting new trees. This could certainly be a barrier to getting farmers to adopt commodity trees, such as nut and fruit trees, if they are used to the convenience of using pre-existing woody trees. It is also a problem if they are deforesting parts of their land and assuming it is silvopasture without the proper maintenance and use of trees that makes it most beneficial.

A key issue and potential opportunity seems to lie in the fact that many farmers ultimately use their silvopasture trees for sawtimber or firewood. Clearly, this does not follow our primary goal of carbon sequestration, so figuring out how to incentivize farmers to deliberately plant fruit and nut trees and maintain them in the long-term will be crucial. The ability to diversify income through better tree choice and management would be a valuable incentive to adopt.

Many types of livestock can be used in silvopasture, but the study found that foraging pigs created the most tree distress, as pigs can interfere with root systems creating more long-term maintenance and growth issues. Cattle, sheep, and chickens appeared to cause less distress.

Overall, the study concluded that, "An opportunity exists for agricultural extension professionals and foresters to aid farmers in managing and optimizing these complex systems. Resources need to be developed to assist farmers in managing silvopastures. Best management practices regarding livestock, trees, and forages coupled with case studies and silvopasture demonstration areas would go a long way in ensuring that farmers are integrating functional silvopastures into the regional landscape." It

Reasons for silvopasture utilization	Number of farmers
Shade for livestock	16
Expanding pasture acreage and diversity	14
Increased utilization of existing farm woodland	12
Increased forage availability during mid-summer and droughts	12
Diversified livestock diet	8
Overall animal welfare	6
Management of undesired vegetation	5
Winter shelter for livestock	4
Tree health/fertilization	3
Increased farm aesthetics	2
Challenges of silvopasture utilization	–
Fencing establishment and maintenance	9
Lack of knowledge toward silvopasture management	6
Lack of time for silvopasture management	5
Unknown forage quality and management techniques	5
Reduced mobility of machinery	3
Lack of support from agricultural extension organizations	3
Undesirable vegetation	2
Fleece contamination in fiber animals	1
Epicormic branching on trees	1
Monitoring livestock	1

Table 1. Reasons for, and challenges of, silvopasture utilization by 20 farmers practicing silvopasture in New York and New England. Farmers were interviewed in 2014 and may have provided more than

also claimed that, "The path to ensure the sustainable management of regional silvopasture systems starts by providing land managers with documented experiences of others to learn from and consider." Nonetheless, a positive finding in this study was that most farmers had a positive attitude toward silvopasture. "19 of the [practicing] farmers interviewed were pleased with the practice, and 14 of these farmers intended to increase the amount of land on their farm in silvopasture."

Many of these behavioral obstacles to silvopasture adoption in NY appear to be surmountable. With a creative implementation plan, the development of a positive relationship with an extension school, and the provision of educational opportunities, it seems farmers can learn how to adopt and practice silvopasture in a way that is more beneficial to both themselves and the earth.

Greenhouse gas reductions

Similar to alley cropping, greenhouse gas reductions achieved by silvopastures follow a sigmoid curve and reach their peak after ~10 years. A healthy tree stocking range for silvopasture establishment is typically between 200 to 400 trees per acre. According to COMET, implementing silvopasture will capture an average of 1.34t CO_2 eq acre-1 yr-1 over the course of 20 years. To meet our 100,000t CO_2 eq reduction goal, a total of 3,732 acres of conventional NY pastures would need to be converted to silvopasture. At an average farm size of 202 acres, we would need to recruit ten farms, or nineteen farms with a farm size of 100 acres, into the project.

Detailed carbon accounting for silvopasture that is specific to the farmland in question can be established in cooperation with the farmer using the COMET-Farm tool, and will form the basis for the partnering agreement.

Monitoring

To make sure that the greenhouse gas emission reductions agreed upon in the partnering agreement are actually achieved, a thorough monitoring of the stock, growth and health of trees on our project sites over the 20 year period is necessary. In order to achieve this we intend to use high scale images (>1m x 1m) taken by drones, which will need to be taken on a biannual basis. Drones have been widely employed in agriculture for crop evaluation such as crop health, moisture content and growth. Drones have also been employed to supervise reforestation. Drone pilots can be hired to take these images. To ensure that the project is continuing and progressing adequately, the images will be evaluated for a charge by tree (forestry) experts, which may be recruited from local extension schools.

Public Health

Optimal management practices

1. Tree management
   - Proper matching of tree crop to soil type in pasture
   - Control of the grass growth around young trees (necessary for early tree development)
   - Proper management of tree densities (necessary for light management and forage long-term production).

2. Forage management
   - Proper forage selection
   - Necessary light for forage growth and response
   - Proper rotational grazing

3. Livestock managment
   - Timing livestock access to forage area by planting an obstacle row which creates a 'fence' that steers animals on pasture pathways between and around tree seedlings.
   - Providing the right kind of forage to optimize livestock health.

Similar to alley cropping, silvopasture systems also need to be properly managed in order to reap the positive public health benefits shown in chart 2f. Silvopasture systems also gain many of the same benefits as alley cropping systems mentioned above such as diversified farm income through increasing biodiversity and improved micro-climate for livestock.

Compared to conventional pasture or range, radiant heat can have a profound negative impact on livestock. By establishing trees into existing pastures, the shade and wind protection offered will reduce animal stress and enhance livestock performance. Research has shown that compared to unshaded pastures, uniform shade results in maximum cattle grazing time. With regard to New York, protection from cold is especially important for livestock in northern climates. Established trees can reduce wind speed which then lowers animal stress, improves animal health and increases feeding efficiency of livestock. Some research has also shown that trees' ability to modify the climate and change light levels can enhance growth of some forages, including cool-season grasses and legumes, and thus leading greater yields, quality, and digestibility. This then translates to greater economic security for farmers, and as a result, improved mental health and nutrition.

Poor management practices

1. Tree management
   - Trees are not spaced at optimal distance leading to light competition, and forage and tree competition.
   - Trees are not matched properly with soil type in pasture leading to a worsened livestock operation and a decrease in timber and forest products.
   - Lack of control of forage growth around young saplings leading forage and tree competition

2. Forage management
   - Improper forage selection leading to tree and forage competition
   - Inadequate light for forage growth and response
   - Lack of proper rotational grazing

3. Livestock management
   - "Dumping" livestock on an area and leaving for extended periods of time, causing overgrazing of forages and damage to trees.
   - Improper forage feed leading to a decrease in livestock health

Poorly managed livestock can damage trees and prevent saplings from growing. Browsing of terminal shoots by livestock will result in loss of tree growth. Trampling, the damage livestock does by stepping on a seedling, is the number one cause of sapling death. Trees less than 16 inches tall are the most susceptible. Trampling not only causes deformation and weakening of the stem but may also provide an entry point for pests. Less trees could lead to a decrease in system productivity which could have negative health repercussions, such as added mental stress. The additional pests added into the system may lead to an increase in fertilizer use which could increase the amount of toxins in nearby food and water. The farmers must also provide the right kind of forage for particular livestock. If not provided the correct forage, this could be detrimental to livestock health.

Table 2 outlines additional management practices needed to establish either an alley cropping or silvopasture system.

Figure 1. Silvopasture Management Outcomes
Best management practices seem to define whether the system will produce positive or negative public health benefits. Comparing the two agroforestry systems, it seems as if alley cropping is easier to implement and maintain as the initial set-up seems the most important best management practice.

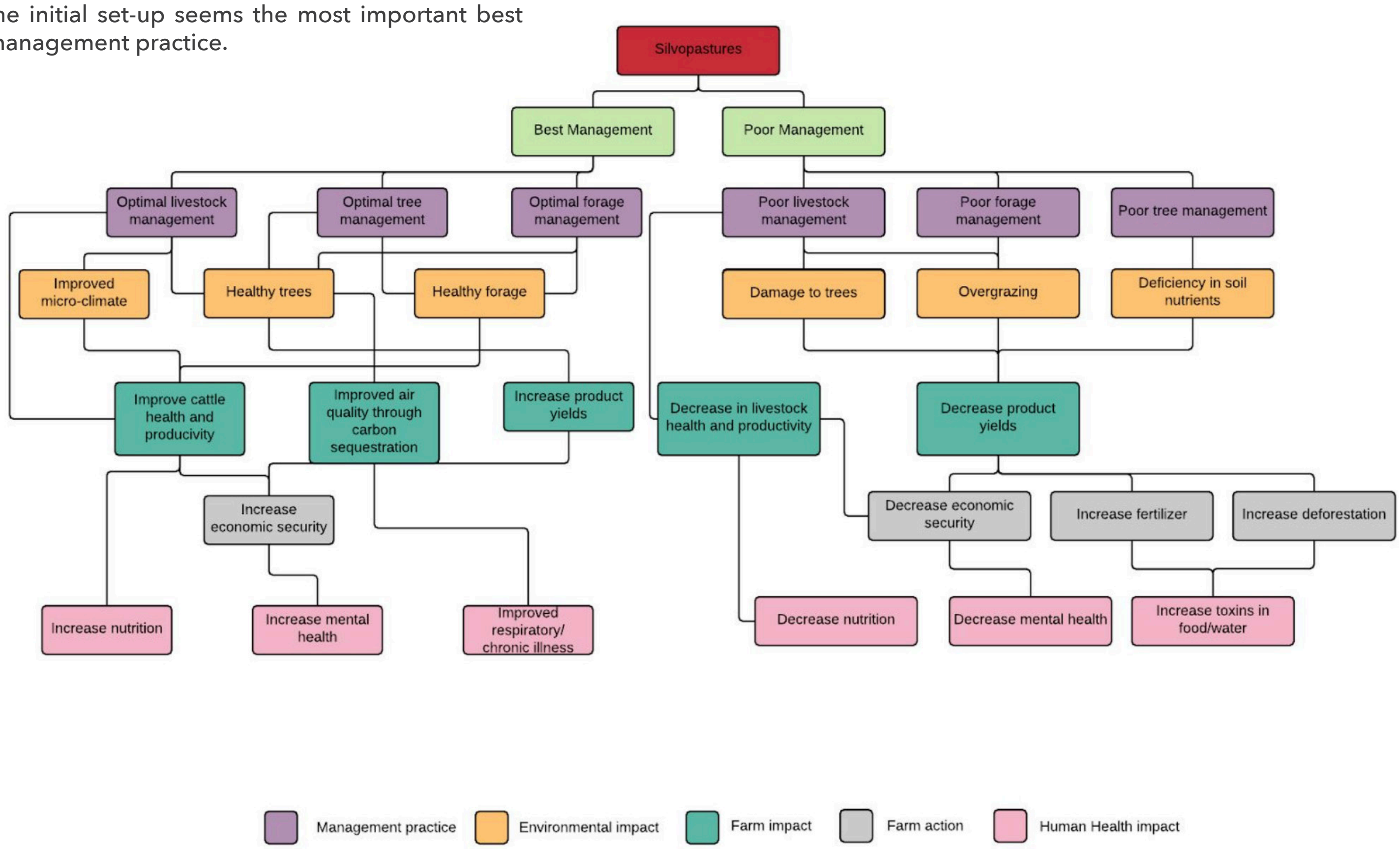


Table 2. Alley Cropping vs. Silvopasture Best Management Practices

Alley Cropping Best Management	Silvopasture Best Management
1. Initial tree arrangement 2. Initial tree and crop arrangement 3. Initial tree and crop companion selection 4. Continual pest management 5. Continual fertilizer and nutrient management 6. Continual tree management (pruning, replanting, etc.) 7. Continual weed control 8. Periodic root training	1. Initial tree arrangement 2. Initial tree and forage arrangement 3. Initial tree and forage selection 4. Initial water installation 5. Continual pest management 6. Continual fertilizer and nutrient management 7. Continual tree management (pruning, replanting, etc.) 8. Continual weed control 9. Periodic root training 10. Continual pasture management 11. Continual livestock management (fencing, etc.) 12. Continual livestock grazing management

Much like Missouri, there are no national or state statutes or regulation that create explicit barriers to the adoption of silvopasture in New York. The legal concerns of drone monitoring are slightly more complex than in Missouri, but only because virtually all state-level legislation regulating drones is currently pending and will need to be tracked in the future to insure project compliance with changing state laws. As with alley cropping, contracts will be the primarily legal concern for the implementation of a silvopasture project in New York.

Contract Considerations

Contract considerations for silvopasture in New York will be the same as in alley cropping in Missouri, and the outline of contract provisions for the carbon offset contract and the purchase agreement above can be referenced.

2014 Farm Bill

As with alley cropping, the 2014 Farm Bill poses no explicitly statutory or regulatory barriers to implementation for silvopasture in New York. Many of the funding programs available to alley cropping projects in the Farm Bill are similarly available to silvopasture projects, with differences discussed in greater detail by program below. Additionally, given that dairy is a major agricultural commodity for New York, additional production incentive programs in the Farm Bill are implicated by the proposed silvopasture project. Overall, the incentives and funding available for silvopasture in New York provide less clear and easily accessible support than for alley cropping in Missouri.

Conservation Stewardship Program: Silvopasture

There are no outstanding differences in farmer eligibility for CSP funding between silvopasture in New York and alley cropping in Missouri. Both projects are subject to the same eligibility criteria described in Figure 2 and the same application process. Silvopasture would also qualify for some of the same conservation criteria as alley cropping ("[a]dding food-producing trees and shrubs to existing plantings") and could qualify for criteria that alley cropping does not ("Silvopasture for wildlife habitat (cover and shelter)"). Qualification under any criteria will depend on the specific parameters of the project design.

Environmental Quality Incentives Program: Silvopasture

Silvopasture eligibility for EQIP is more questionable than alley cropping. Funding for silvopasture establishment is not an explicitly named practice in New York's EQIP payment schedule, and so silvopasture projects in New York would have to qualify under another designation. Depending on the parameters of a silvopasture project in New York, qualification may still be possible. Additionally, sixty percent of EQIP funding is allocated for the livestock industry, and at least five percent must target "restoration, development, protection, and improvement of wildlife habitat." These allocation goals indicate that silvopasture practices fit within the intent of EQIP, and efforts should be made to match project parameters to New York's EQIP practices.

Agricultural Conservation Easement Program: Silvopasture

Silvopasture is also eligible for ACEP consideration. Silvopasture and alley cropping have similar considerations in terms of eligibility for ACEP and the types of easements that would be created. One key difference is that New York does have a recorded Agricultural Land Easements between 2015 and 2016—unlike Missouri. Though information is not available on the specific land-use practice approved for these easements, it does indicate that the path to granting an Agricultural Land Easement for funding could be easier in New York than in Missouri.

Dairy Margin Protection Program

Several commodity programs authorized by the farm bill provide income insurance to New York farmers who could potentially be targeted to adopt silvopasture. One such program, the Dairy Margin Protection Program (DMPP), is designed to supplement the income of dairy farmers when the margin between the price of feed and the price of milk falls too low. These types of programs are designed to bolster the dairy industry and insure milk production even in the face of falling prices, thus encouraging dairy farmers to produce as much milk as possible.

These incentives in the Farm Bill have had controversial effectiveness but are popular among farmers and the senators who support them. Therefore, it is likely that the 2018 Farm Bill will have some version of the Dairy Margin Protection Program. Incentive programs like the DMPP could dissuade farmers in New York (and across the country) from adopting silvopasture practices: though it is likely that silvopasture would increase the yield per head on dairy farms, the absolute number of dairy cows silvopasture can support will inevitably be lower than farmers could support using non-silvopasture practices. This decrease in total yield possible per acre of land could be a perceived barrier to entry for New York dairy farmers.

Given the prominence of dairy production in New York, this is a significant consideration for project partner selection. This obstacle could be addressed through increased education: having an outreach program in which silvopasture farmers speak with prospective silvopasture adopters about the benefits of silvopasture, such as increased animal health leading to larger dairy yields. However, there would likely need to be some form of monetary compensation to convince farmers to take the risk on lowering their head per acre.

Business + Economic Analysis

There are clearly grants and financing options available in New York (such as aforementioned EQIP), yet at the state level, these funding options are less centralized than those of Missouri, and so we are less certain of the likelihood of identifying grant funding that could support our project. That being said, the absence of a grant may not make the project unfeasible, as there are many private sources of funds in New York that could potentially fill this gap.

The TAM is New York is much higher than that of Missouri, with an estimated 200,000 residential college students who are routinely in-demand of dining services. The proximity to New England also makes New York a feasible "bundled" option for Harvard, where the client of the offset project is also the client of whatever commodity is grown as part of the commodity-selling program.

The current barrier in New York is funding. Unlike Missouri, we have yet to identify state-specific grants for New York, though we think that the private investment arena for New York may be more accessible than Missouri by virtue of geographic proximity. Additionally, New York offers excellent end-markets to products, as there are a vast number of high-end restaurants and farmers markets in a reasonable delivery area. For these reasons, we believe New York may still be economically feasible. Unlike Missouri, the bulk of the value will likely come from the tail-end of the value chain at the point of sale with the commodity buyer, rather than at the beginning with affordable implementation due to strong grant incentive programs.

Greenhouse Gas Protocols and Public Policy

Some of the conclusions in this section are based on personal communication with silvopasture experts from Agricultural Extension Service agencies specialized in silvopasture, research on policy opportunities, and greenhouse gas protocol methodologies.

Livestock operations, and their productivity, are impacted by climate change. As cattle is raised in grasslands or concentrated animal feeding operation without shelter, livestock are impacted by heat stress. This stress makes the animals lethargic, they eat less, and their performance lowers as well. This is a very important problem that has been identified since yields and economic gains can play an important role to convince grassland farmers to establish a silvopasture system.

This project identified three different ways to establish a silvopasture project including thinning forests, converting forest to grassland, and establishing silvopasture in already established grasslands. When a farmer thins forests, they can make an economic gains from selling timber. If a farmer decides to thin only 5 acres of land, they might not make any economic gain and just break even. Based on the fact that the silvopasture project is aiming to sink a significant amount of carbon, thinning a forest would mean a loss of biomass, and therefore more carbon that does not get captured. This type of silvopasture is not the type of establishment this project would aim for.
The following option is to convert forest to grassland. This practice implies a really high financial investment.

Preparing the land, the purchase of seeds, planning, machinery use, and other steps that would make it a very complex operation. A USDA-NRCS specialist told us about an palm plantation forest that was converted to silvopasture. The 16 year-old palms were harvested, and the subsequent costs of seeds, planting, and time was very large. In this operation a big commercial grinder that prepares seeds and planting accounted for a cost of $17,000 per acre. Most farmers cannot afford to make these type of investment, therefore a silvopasture project of this nature would be very difficult to implement.

That leaves us with the third option of ranchers with establish grasslands that want to incorporate trees into their system. This would be the desirable farmer to have a silvopasture project with higher chance to be feasible because of different reasons. First, the ranchers are already familiar with the livestock management operations. Secondly, they are affected by the livestock low performance caused by heat-stress. However, not all farmers would necessarily take the initiative to transition their operations to silvopasture that easily. Therefore, it is important to recognize farmers who are the first adopters type of farmer. Another opportunity here is to try to understand what could attract those farmers who are not first adopters.

In order to identify these types of farmers, the Local Conservationist would be a valuable resource for the implementation part of this project. Every county has a designated Local Conservationist who can connect the project with the community. They know where farmers can get familiar with silvopasture practices. It has been identified from the protocol reading and conversations with Agricultural Extension agents about the importance of demonstration sites. Farmers need to see how it gets done and that it gives results. Additionally, Local Conservationists are aware of the challenges and opportunities in a specific place. About productivity and animal performance.

Under some protocols, some projects are not eligible because of their location based on two reasons. First, the location may not have a baseline emission reduction from belowground organic carbon in the first 10-year emission factor period. Secondly, the location may not have reliable and robust data. Under one of the protocols, some parts of New York State are not eligible and they are defined by Major Land Resource Area (MLRA) as 144A-New England and Eastern New York Upland Southern Part and 144B - New England and Eastern New York Upland Northern Part. Unlike New York, greenhouse gas protocols do not provide geographical restrictions for alley cropping in Missouri.

As previously mentioned, protocols require sink-based projects like silvopasture to have a long-term vision. Long-term contracting is an important issue that needs to be addressed by all disciplines. For grassland projects, it is important to keep in mind that if a project commits to keep a given number of acres as grasslands, those acres cannot be converted to croplands for a period of 100 years after credits are issued.

The long-term viability of the project relies on effective long-term monitoring. In silvopasture, there is a strong correlation between animal performance and heat stress. Therefore, the economic benefits can be easily introduced in this correlation. One recommendation identified during this feasibility stage, it is the inclusion of creating a temperature recording protocol on-site. If silvopasture is reducing the heat stress that livestock are currently going through, it is important to make the economic case for it. Additionally, if the monitoring system relies on climate data from databases, these values might not reflect the microclimate created by the establishment of silvopasture.

In addition to the recommendations inspired by the protocols on monitoring programs and that have been included in the alley cropping section, livestock could be used to collect data on-site. Considering the impact that global warming will have on livestock living under heat-stress, a silvopasture project could think of an additional monitoring program that learns more about the cattle under this type of system. There is an example of USAID working with the Peruvian Government to track waste by training vultures. This project had two components. First, to track trash with GoPro cameras. Secondly, to learn more about vultures with sensors that worked with solar energy. Something similar could be implemented in the monitoring program to connect animal welfare, productivity yields, and economic gains. One project of this nature could be done in alliance with local Extension Service programs.

For the silvopasture project, it will be important to know the percentage of tree canopy in the land. This information will help the project know what type of methodology (under certain protocols) can be used for the project. A farm with tree canopy that does not exceed 10% the land area on a per-acre basis qualifies as grassland but over 10% is eligible to be under a forest protocol.

There are also some challenges related to uncertainty on how certain practices can be included under incentive programs. For instance, New York State does not have practices that address silvopasture establishment directly – unlike Missouri. It would be important to understand if silvopasture is a practice that can be included in Prescribed Grazing (code 528). There are cost-share mechanisms for practices related to grazing and silvopasture like, but not limited to, windbreak shelterbelt renovation and establishment, fencing, heavy use area protection, and forage harvest management.

Though there are many potential challenges, there are also different opportunities for a silvopasture to be feasible. Farmer in agroforestry projects in New York have access to the Agriculture Management Assistance Program (AMA). AMA pays up to 75 percent of the cost of installing conservation practices without exceeding $100,000 per participant per fiscal year. This program offers an additional cost-share mechanism for underserved farmers as well.

The Conservation Reserve Program Grasslands (CRP Grasslands) provides rental payments and cost-share assistance during the duration of the contract period. The CRP through FSA provides an annual rental payment up to 75 percent of the grazing value of the land covered by the agreement as determined by FSA for the duration of the contract. CRP Grasslands also provides cost-share assistance that is not more than 50 percent of the participants' costs in establishing approved practices.

Every state identifies their most critical needs. New York State has the Greater Adirondack Resource Conservation Project that encompasses the entire northern portion of New York State to address water quality, soil health, and inadequate habitat issues utilizing EQIP funding throughout the Lake Champlain, St. Lawrence River, Upper Hudson River and Black River Watersheds. This could give an opportunity for silvopasture projects in New York to address issues related to this project.

Finally, the protocol should be designed with farmers' data privacy concerns in mind. The data required by the protocols, while clearly necessary for the success of verification, also intimately describes the conditions of farmers' land. As a farmers' most valuable asset is their land, special consideration should be paid to preserving farmers' trust in the verification process. The team does not anticipate these privacy concerns will be render protocol verification infeasible, though these concerns should be addressed in more definition is added to the implementation plan for the protocol development. Identifying what information exactly can be made confidential will be an important point for research and development in the future. Additionally, as privacy concerns will likely vary from individual farmer to individual farmer, it is important that the implementation plan outlines how to gain farmer consent to this data collection. If these steps are followed, the team anticipates that farmer consent can be acquired.

Conclusion

For both alley cropping and silvopasture projects, it is important to identify the factors that, from a policy perspective, can play an important role in how accessible market outlets for either livestock ranchers or specialty crop growers. Incentives and different resources like cost-sharing mechanisms (under the Environmental Quality Incentive Program) or access to institutions (e.g. agricultural extension services) that can help farmers know what to produce, how to grow it, and where to sell are essential to reduce the risk that might come from adopting new agroforestry systems.

Appendices

Appendix A: Federal + State Drone Laws

An early concept of this project investigated the feasibility of using drones for monitoring functions. Though the project ultimately rejected this idea, should the use of drones become useful in the future, the applicable drone laws for the United States, Missouri, and New York are provided below for reference.

The reliance on Unmanned Aerial Systems ("UAS" or "drones") for monitoring and compliance verification does not face any significant legal barriers. However, there are some new drone laws pending in New York, which could be of note in the future. Additional research should be conducted prior to implementing any drone monitoring activities to ensure that no restrictive changes to the statutory regime have been enacted.

Federal Drone Law

The Federal Aviation Administration ("FAA") does have a series of regulations on the use of drones nationwide. There are two options for drone use under FAA rules: flying under the Special Rule for Model Aircraft or the Small UAS Rule. The Small UAS Rule would be the relevant set of regulations for this project, as the Special Rule of Model Aircraft is only applicable to hobby or recreational use of drones. The Small UAS Rule allows:

- Drone use for recreational or commercial purposes;
- Use of a registered drone;
- Drone operation by an FAA certified Remote Pilot;
- Use of drones under fifty-five pounds;
- Use of drone always within visual-line-of-sight*
- Use of drone away from aircraft or over people*
- Use of drone outside controlled airspace near airports* ["FAA no-fly zones"]
- Flight during daylight or civil twilight,
- Flight up to 400 feet high*

* These rules are subject to waiver.

See 14 C.F.R § 107. Given that the monitoring for this project would be conducted by a third-party outside the clients and farmers, these regulations are not a focal point of monitoring feasibility. Primary concerns for the feasibility of the project would include verification that the monitoring party is following FAA regulations and selection of a partner farmer whose land is not within an FAA no-fly zone. FAA has several no-fly zones in Missouri restricting the use of drones in areas in close proximity to sensitive locations, such as airports or air force bases.

Missouri State Drone Law

Though drone law is a rapidly evolving field of law at the moment, Missouri has not yet adopted any state-level drone restrictions or regulations. Missouri State University has adopted a no-drone-use restriction over their campus and campus related events, so monitoring activities that may occur near the University will have to keep this restriction in mind.

New York State Law

New York currently has no statewide legislation regulating the use of drones. New York City banned the use of drones within the city limits, and the City of Syracuse has banned the use of drones by government officials within the city, though neither of these regulations will impact the use of drone monitoring on farms outside these cities' limits.

Several bills are currently being considered by the New the duration of any potential silvopasture projects in New York as the passage of any one could impact monitoring plans. None of the currently pending bills are likely to significantly impede the use of drones for monitoring compliance with the silvopasture project. A list of pending legislation is provided in Table 5 for reference and easy future follow-up if necessary.

Table 3. Pending N.Y. State Drone Bills

Bill	Effect	Relevance to Project if Enacted
Assemb. B. 1670, S. B. 1979, 2017–2018 Leg., 238th Sess. (N.Y. 2017)	Restricts "personal use" (the operation of a drone solely for the purpose of pleasure or recreation) of a drone and add penalty to the NY penal code	Unlikely to impact feasibility
Assemb. B. 1437, S. B. 612, 2017–2018 Leg., 238th Sess. (N.Y. 2017)	Bans the hunting or taking of wildlife with drones	Depending on language in enacted bill, could be consideration for accidental liability in drone monitoring (for instance, if a drone accidentally hits an animal in flight)
S. B. 4710, 2017–2018 Leg., 238th Sess. (N.Y. 2017)	Bans the use of a drone to view, broadcast, or record another person who has a reasonable expectation of privacy	Consideration depending on farm surroundings (will need to be wary of whereabouts of third party individuals)
Assemb. B. 4642, 2017–2018 Leg., 238th Sess. (N.Y. 2017)	Criminalizes use of drones to look into neighbors' yard/windows	Consideration depending on farm surroundings (will need to be wary of surrounding private residences)
S. B. 2125, Assemb. B. 6930, 2017–2018 Leg., 238th Sess. (N.Y. 2017)	Bans use of drones within 1,000 feet of a correctional facility	Consideration depending on farm surroundings (farms within 1,000 feet of correctional facilities will need alternative monitoring or project could request exemption)

Appendix B: Farm Bill Renewal Considerations

York legislature, though none have gone to a vote yet. These bills will need to be monitored during

The following provisions could be applicable to either alley cropping or silvopasture projects and should be reviewed after the passage of the final 2018 Farm Bill.

1. Strengthening Our Investment in Land Stewardship Act 2018 (SOIL Act)

- Improves coordination in applications and contracting between EQIP and CSP
- Establishes a soil health & carbon storage initiative within EQIP and CSP
- Potentially very beneficial to agroforestry in general, and our alley cropping project in particular
- Creates a "graduation program" in which farmers who reach stewardship goals can move from the EQIP program to CSP
- Allows for addition of acreage mid-contract to compensate farmers adopting conversation practices on additional land and increase the overall conservation award of the contract
- Reduced EQIP contract life to 5 years instead of 10 years

2. Give Our Resources the Opportunity to Work Act (GROW Act)

- Reiterates many of the SOIL acts provisions of increasing cooperation between EQIP and CSP

3. The Healthy Fields and Farm Economies Act

- Increases USDA reporting and research on environmentally beneficial practices which could lead to better compensation for those practices in USDA programs

4. Crop Insurance Modernization Act

- Section 2(c) proposes to improve research and data gathering by the Risk Management Association (RMA) to account for soil health and other natural resources and the use of conversation practices.
  - Accounting for these factors would probably bring down the cost of insurance for alley croppers, as agroforestry practices improve soil health and qualify as conservation practices under NRCS
- Section 2(e) increases small-scale farm access to crop insurance by lower the paperwork load associated with acquiring Whole Farm Revenue Protection
  - Though not immediately applicable, should the chestnut market continue to grow and eventually get insurance coverage this could be an important consideration for partner-farmers