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Toward the Adoption of New Farming Systems among Farmers: A Case study of Short Rotation Woody Crops in North Carolina

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Abstract. This study explores the human dimensions of the broad-based adoption of Short Rotation Woody Crops (SRWCs) among farmers in North Carolina. We used an actor diagramming and tracing approach to explore factors influencing farmers' adoption of SRWCs. Results suggest four factors strongly influence the adoption process: 1) market availability, 2) education awareness, 3) funding, and 4) social networking. Based on these results, we recommend that Extension professionals use the following education modules to prompt the adoption of SRWCs practices and potentially adopt other new farming practices: 1) ecological sustainability, 2) financial considerations, 3) harvesting, and 4) community building.

INTRODUCTION

There is a growing need for agricultural and forestry extension to promote sustainable farming systems through innovative approaches that foster ecosystem health, economic profitability, and social equity (Foran et al., 2014; Leeuwis, 2004). Such approaches include linking cropping systems that improve soil quality to water conservation (Traore et al., 2020; Yang et al., 2020), as well as the integration of trees and livestock to increase resource use efficiency (e.g. of water or nutrients) and agrobiodiversity (Martin et al., 2016; Nyberg et al., 2020, Sharma et al., 2016). Another promising system is the integration of Short Rotation Woody Crops (SRWC) with conventional row crop agriculture that use high input culture such as fertilization, herbicides, and pesticides on degraded or marginal lands (Domec et al., 2017; Ile et al., 2021).

Short Rotation Woody Crops SRWC are fast-growing, high-yielding tree species grown in short rotations of three to five years or more, as purpose feedstocks for bioenergy with minimal silvicultural inputs. They also have the potential to improve soil health (Ile et al., 2021; Kahle and Janssen, 2019; Zalesny et al., 2016). Species suitable as SRWC may include American sycamore (*Platanus occidentalis*), sweetgum (*Liquidambar styraciflua)*, eucalyptus (*Eucalyptus spp*), eastern cottonwood (*Populus deltoides*), and shrub willow (*Salix spp*). SRWC can contribute to global tree restoration to mitigate climate change while creating value in rural, low-income rural communities through on-farm diversification, for example, producing biomass to meet the increasing demands of the growing wood pellet industry (Bastin et al., 2019; Morris et al., 2017).

Challenges to promoting sustainable farming systems include perceptions, social norms, and inadequate information, which could hinder the willingness of farmers to grow SRWCs on their cropland (Faulkner et al., 2018; Jacobson and Kar, 2013; Shaw et al., 2012). Some landowners support the adoption of biomass production from energy crops because of their concerns with the effects of fossil fuel on the environment and the cultural value of sustainability (Kelsey & Franke, 2009; Skevas, Swinton, & Hayden, 2014). Further, government incentives and beneficial policies for environmental benefits could make SRWC planting more attractive to landowners (Parajuli et al., 2019; Place et al., 2012).

Studies have attempted to identify best practices for helping farmers increase farm sustainability through Extension educational programs (Joshi et al., 2015; Wen et al., 2009). While these studies approached increasing farming practices using communication and education, we sought to uncover new insights using behavioral theories. A behavioral approach requires examining the psychological, social, and

environmental elements influencing behavior. Therefore, we explored the behavioral factors that influence the adoption of SRWCs and potentially other new cropping systems among farmers. Additionally, if Extension professionals can create highly effective behavioral interventions that can persuade farmers to grow SRWC, perhaps, we are more likely to see increased awareness and engagement with the thriving woody biomass markets among farmers and forest landowners in North Carolina (Grebner et al., 2009, Shaw et al., 2012).

Due to the limited research using a behavioral approach for this topic, we looked at studies conducted on similar topics that used a behavioral approach. These include Warner et al. (2021) that examined stakeholders' perceptions on the willingness to conserve water; O'Brien et al. (2017) that explored forestry interventions that promote sustainability behaviors; Karppinen and Berghäll (2015) that used the norms and goals theory to determine landowner improvement decisions. Drawing from the insights generated in these studies, we utilized the behavioral theories of 1) Goal Framing, which explains behavior based on the priority of an individual's goal and circumstances (Klöckner, 2015); 2) Social Norms, which explains norms as beliefs about the expected or appropriate behavior in a group (Keizer & Schultz, 2018); and 3) Informational Strategies, which focuses on knowledge, awareness, and attitudes through education, prompting, and feedback (Abrahamse & Matthies, 2018).

METHODOLOGY

ACTOR DIAGRAMMING AND TRACING METHOD

In this study, we used a systems-approach methodology called Actor Diagramming and Tracing (Typhina, 2017), a participatory process of finding and engaging human and non-human actors of an environmental issue in the design and release of an environmental behavior change. The actors in this study were traced from several forestry-related websites, specifically the North Carolina Department of Agriculture and Consumer Services/North Carolina Bioenergy Research Initiative, North Carolina State University Extension Forestry, North Carolina Forestry Association, and Center for Agroforestry System websites. Through the review of these websites, we created the actor diagram (Figure 1) that identified potential interviewees and materials that could affect the adoption of SRWCs. Like Typhina (2017), we combined behavior change theories with stakeholders' insights to understand the factors influencing North Carolina farmers' decision about planting bioenergy trees. We then used mock-ups in participatory prototyping sessions to develop a

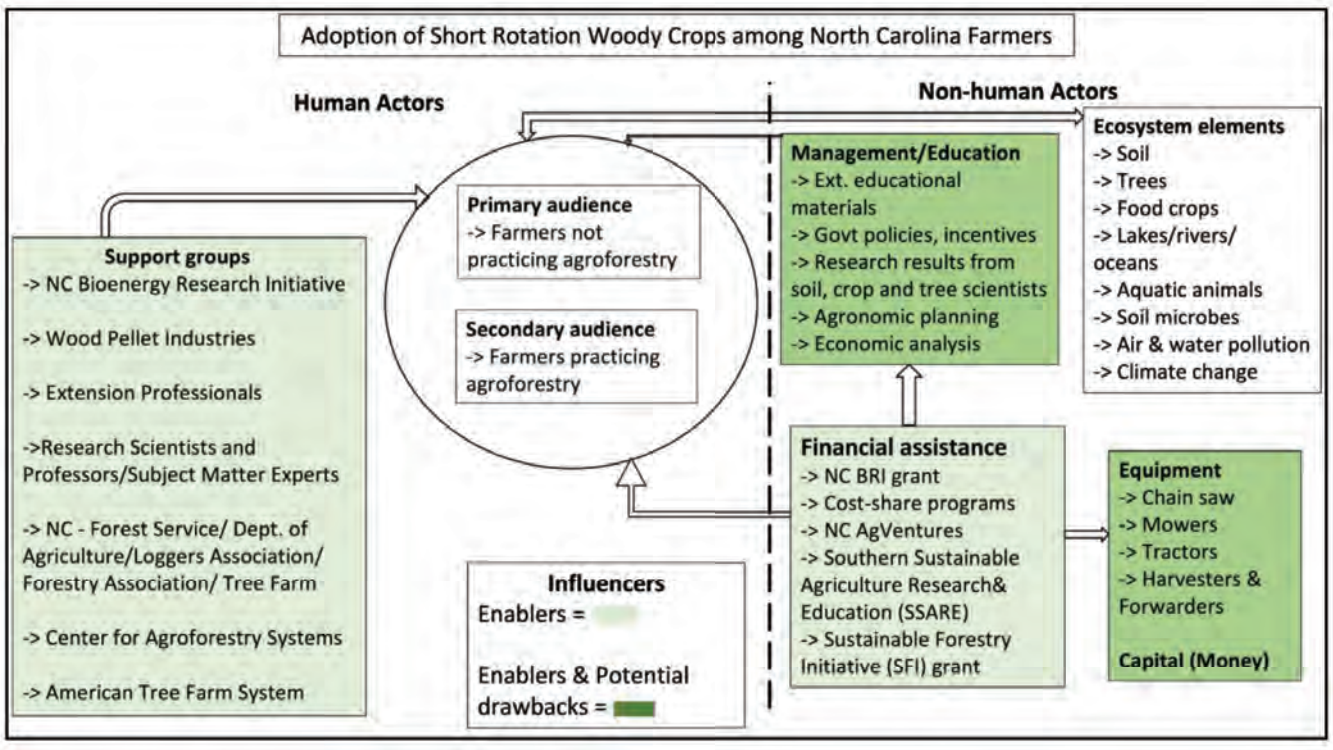

Figure 1. Influencers in the adoption of SRWCs in North Carolina.

possible intervention that Extension professionals could use to promote the integration of SRWCs into farming systems.

SEMI-STRUCTURED INTERVIEWS TO IDENTIFY BEHAVIORAL INFLUENCERS

To understand the factors influencing the farmers' behavior related to SRWCs, we conducted 60-to-90-minute semi-structured interviews from fall of 2020 through summer of 2022. The North Carolina State University Institutional Review Board approved the interview instrument and administration procedure for human subject research (IRB-23757). We conducted 30 interviews with diverse people (Table 1), primarily located in the Coastal and Piedmont regions of the state (Figure 2). We focused on these regions because of the growing presence of wood pellet production facilities in the state, which create additional market opportunities for woody feedstock offering economic benefits for local farmers. Our interview protocol included questions to identify barriers, motives, and enablers of the desired behavior (Table 2). We transcribed and analyzed the interviews by assigning codes to recurrent behavioral themes until each behavioral instance existed as a code within a well-defined category. To ensure the validity of the coded results, the second and third authors independently reviewed and coded the data and found similar themes as the first author did.

Figure 2 indicates the location of interviewees across the state. Farmers are indicated with red colors, education sector is indicated with green color, government sector represented

Table 1. Number of Stakeholders Interviewed by Sector

Stakeholder Sector	Number of Interviewees
Farmers	10
Education NC Forest Extension Professionals, Research Professors	8
Government NC Bioenergy Research Initiative, NC Forest Service, NC ForestHER, NC Department of Agriculture, Center for Agroforestry Systems	5
Non-Profit NC Farm Bureau, American Forest Foundation, Sustainable Forestry Land Retention Program	4
Industry Wood pellet, Procurement and Logging	3

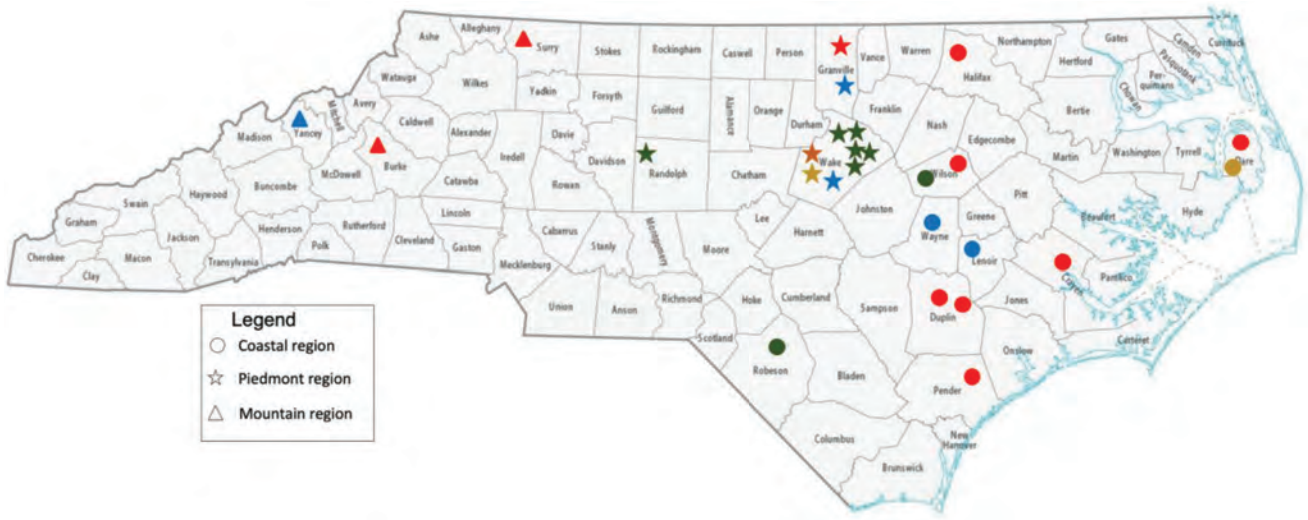

Figure 2. Location of interviewees in North Carolina.

Table 2. Protocol for Stakeholders' Interviews

	Farmers	Education, Government, and Non-Profit professionals	Industries
1	What are the top challenges to farmers related to planting and growing bioenergy trees?	What are your perceptions about farmers adding short rotation woody crops to their farming strategy?	What are the top challenges you face in getting landowners to start growing bioenergy trees?
2	How might a farmer go about adding short rotation woody crops to their farm?	How might a farmer go about adding short rotation woody crops to their farm?	What actions must farmers do to engage in sustainable production of bioenergy trees?
3	What might farmers perceive as beneficial about planting bioenergy trees on a rotation basis with their traditional agricultural crops?	What are the top challenges for farmers to grow bioenergy short rotation woody crops?	What are the top challenges farmers face in the process of sustainably growing bioenergy trees?
4	What might farmers perceive as a drawback to engaging in planting bioenergy trees on a rotation basis with their traditional agricultural crops?	What might they perceive as a draw-back to selling bioenergy trees compared to row crops?	What might farmers perceive as beneficial or rewarding about growing these trees for wood pellets?
5	What could effectively enable farmers to engage in planting bioenergy trees?	What might farmers perceive as beneficial or rewarding about growing and selling bioenergy trees?	What might farmers perceive as a drawback about growing these trees for wood pellets?
6	What issues/ problems/ challenges exist with these solutions?	What materials and resources might enable farmers to engage in planting bioenergy trees? Example: Planting design, demonstrations, site preparation, money etc.	What most effectively enables farmers to engage in woody bioenergy production?
7	What ideas for innovations have you heard of that could enable farmers to grow bioenergy trees?	What materials and resources have you found effective in helping farmers produce?	What most effectively enables farmers to sell their feedstocks to you? Examples: Incentives from pricing or transportation
8	What types of innovations would help farmers to plant bioenergy trees?	What ideas for innovations do you have, or have you heard of that could enable farmers to adopt planting bioenergy trees?	What innovations do you have that could enable farmers to grow bioenergy trees for wood pellets and energy production?
9	Are there any materials, such as books, articles, websites, or documentaries I should look at to learn more about getting farmers to adopt the short rotation woody crops into their farming?	What would be the primary group that would purchase/use a product or service that would lead to the adoption of the planting system? (Demographics, land size?)	What types of innovations would not help farmers to grow trees for energy production?
10	Are there any people I should contact concerning farmers' willingness to plant bioenergy trees, to interview or gain additional insight from?	Are there training programs that could help farmers with the adoption of planting SRWCs?	What types of innovations would help farmers to plant bioenergy trees and integrate it with their traditional farming system?
11		What would it need to contain to be effective and persuasive (land size, funding resources, training videos etc)?	Would you know of any farmers who might be interested in doing this that I could speak to?
12		Would you know of any farmers who might be interested in doing this that I could speak to?	

by blue color, non-profit organizations represented by the gold color, and industry is represented by orange color. Two interviewees from the non-profit organization were located outside of North Carolina but have staff that work in the state. Further, two sustainability experts working in the wood pellet industry were located outside of the state.

PARTICIPATORY PROTOTYPING SESSIONS TO ENGAGE ACTORS IN DEVELOPING INTERVENTIONS

Using the themes identified during coding, we identified three behavior change theories that aligned with our results and used them for the initial development of a prototype intervention. We chose the following theories as they aligned with our results in the following ways: Goal Framing (Klöckner, 2015)—we identified that landowners' goals "frame" their decision to adopt growing SRWCs based on multiple motivations that inherently influence their decision; Social Norms (Keizer & Schultzs, 2018)—we identified that trust is a big factor, where landowners are more likely to grow SRWC if a neighbor, friend, family member or a networking group such as a cooperative has done it; and Informational Strategies (Abrahamse & Matthies, 2018)—we observed that access to information and education may positively influence landowners to grow SRWCs on eroded, fallow agricultural land. After developing the initial prototype educational intervention, we conducted participatory prototyping sessions with interviewees to determine how to refine the intervention best to meet their needs and motives.

RESULTS AND DISCUSSION

AGE AND LAND SIZE DEMOGRAPHICS

We asked interviewees what demographics, specifically the age and land size of a farmer, would most likely engage in planting SRWCs. Our findings show farmers between 40 to 50 years of age with acreage (> 40 acres) would most likely integrate SRWC into traditional agricultural systems, such as fallow agricultural land (Figure 3). Stakeholders explained that farmers with larger acreage typically use their land for multiple purposes and often try new farming techniques; thus, they would likely have an interest in diversifying their farm economies with short rotation woody crops.

BEHAVIORAL THEMES AND CORRESPONDING THEORIES

We identified the following three behavior theories that best explain the action and inaction around our target behavior of encouraging planting of SWRCs.

GOAL FRAMING THEORY

According to Goal Framing Theory, behavior is triggered by achieving set goals at a particular time concerning decision making (Klöckner, 2015). From our findings, farmers that have the goal of passing on their land to heirs would be more interested in planting SRWCs. Further, participants mentioned specific goals to diversify their income and make profits. We can see that these goals could influence farmers to grow and sell bioenergy trees through the lens of goal framing theory. Although increasing market demand for wood pellets aligns with farmer's income and profit goals, as stated by one participant, the timing could greatly influence follow through. For example, one interviewee stated, "*…the timing from tree planting to harvesting may be considered a draw-back for farmers reaching their income and profit goals.*" On the other hand, 62% of the interviewees believed that the short rotation length of the bioenergy trees might be a good factor for farmers because they can harvest trees in three to five years. In addition, one interviewee stated, "…landowners have lands lying around that used to be farmed, for some reason they do not see the value of planting anything. The SRWCs can be a benefit for them because it is like a short-term agricultural crop."

Twenty-seven percent of interviewees felt an incentive for planting SRWC bioenergy trees was the benefits to the land; such farmers want their land to be aesthetically pleasing or they want to restore depleted soil health of their unproductive land. For example, one interviewee stated, "*Landowners are often more interested in things like ecosystem services, and economic benefits of crops, and that sort of thing.*" In addition, one interviewee believed that "*the benefit would be another use for that unproductive land.*" A study on the educational needs of North Carolina's Forest Landowners reported that majority of forest landowners are interested in protecting nature (77%), beauty and scenery (70%), and to protect wildlife (70%) compared to the 51% interested in timber production (Bardon et al., 2022). Additionally, the national woodland survey (Butler et al., 2016) in Figure 4 corroborated our findings as both studies showed landowners most receptive to growing SRWCs value owning land due to its Recreation/Protection and Family/Personal uses.

SOCIAL NORMS THEORY

Social Norms Theory explains behavior as derived from one's beliefs about a group's expected or appropriate behavior (Keizer & Schultzs, 2018). Interviewees mentioned family and their relationship to the land as a major influence of adopting the integrated system. Farmers interested in passing the land to their children and grandchildren would preserve the land, enhance its environmental and economic capacity, especially if other members of their community are already doing the same. However, an interviewee explained that if their family before them cleared the land, why would they go back and plant trees on it, stating, "It is essentially the idea that if their family didn't do something why should they?"

Additionally, Extension professionals suggested that farmers' cooperatives could influence the adoption of bioenergy trees and ease the financial constraints related to initial

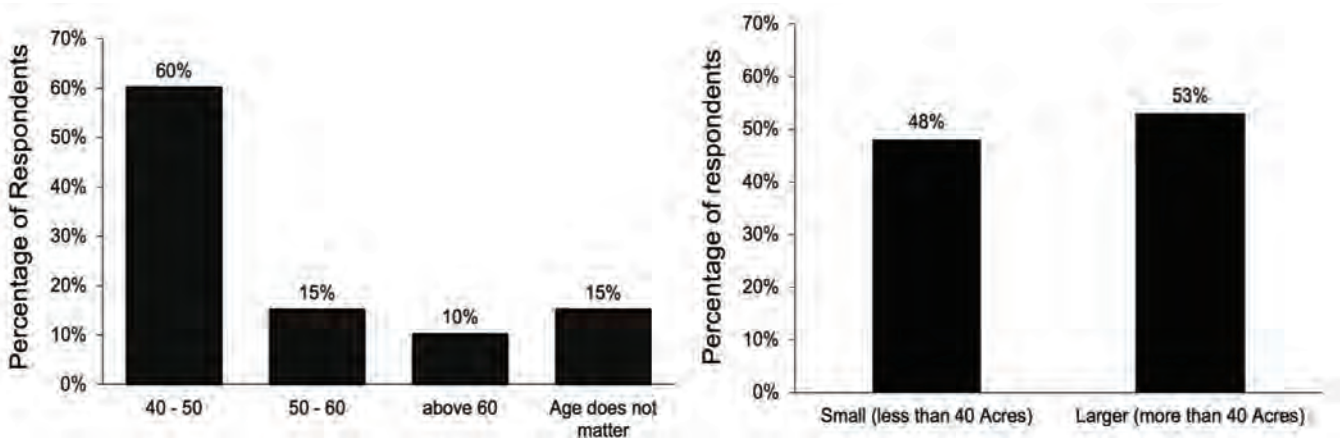

Figure 3. Age and land use demographic.

stand establishment. Farmers are greatly influenced to adopt new planting practices by following the lead of an innovative, risk-averse farmer into the practice (Covery et al., 2012; Morris et al., 2017). Furthermore, Typhina (2017) found that social norms influence a farmer's behavior, specifically related to the engagement in sustainable forest management. Typhina (2017) highlighted the need for social networks that foster direct interaction and relationship building with farmers and forestry professionals.

INFORMATIONAL STRATEGIES THEORY

Following Informational Strategies Theory, behavior is influenced by the amount and availability of knowledge related to the viewer's needs and attitudes (Abrahamse and Matthies, 2018). All interviewees stated that Extension education materials have and could influence their behavior related to farming practices, especially field demonstrations. One participant stated that "using science and research results to show clear economic benefits of these hardwood trees are greater than the alternative of loblolly pine or a row crop or how the practice is better for the soil in the long term". These findings are supported by Gowan et al. (2018), who recommended providing farmers with information on how to grow and harvest bioenergy trees, as well as associated environmental benefits.

Interviewees also mentioned the importance of testing messaging with audiences and gaining their feedback prior to release of materials. One interviewee stated, "The wording you use is important because words like 'bioenergy' will immediately turn them away from the project, though you want to be upfront with all the information and make sure that the science is there for them to look at while being very prepared to be a good listener." A sustainability expert further explained that some people want to think of trees as trees, and not as crops, emphasizing the need to frame messages to suit the audience's perceptions. One participant emphasized the importance of getting feedback on program development, before finalizing programs. Specifically, the participant stated, "they make us fit into the programs, instead of designing programs tailored to our needs. One of the things I really liked about the initial meeting that I had with the Sustainable Forestry Land Retention Program, I sat down at the table with all the resource professionals together, and, being a former state employee, I was waiting for them to start telling me about all these programs they got, you know they didn't do that, they said what do you want to do with your land?"

In addition, respondents mentioned they are likely to adopt a technique once they've tried it. This "try and do" effect is commonly referred to as the "foot in the door" technique (Baron, 1973; Freedman and Fraser, 1966). Kabwe et al. (2015) reported similar findings that farmers who did a trial integration of trees into their traditional farming system were more responsive and inclined to retain the new practice.

PARTICIPATORY PROTOTYPING SESSIONS TO REFINE THE INTERVENTION

Using the results discussed in the previous section, we developed a prototype intervention that took the shape of an online training course. To confirm our initial findings and further refine the intervention, we re-engaged Extension professionals and farmers in participatory prototyping sessions where we asked for their direct feedback on the intervention. The findings from these sessions confirmed four factors that strongly influence the adoption process: 1) market availability, 2) education and awareness, 3) funding, and 4) their social network. Based on our interviews and prototyping sessions, we recommend that interventions promoting SRWC farming and similar new techniques target: 1) young farmers because they are more open to trying new techniques and 2)

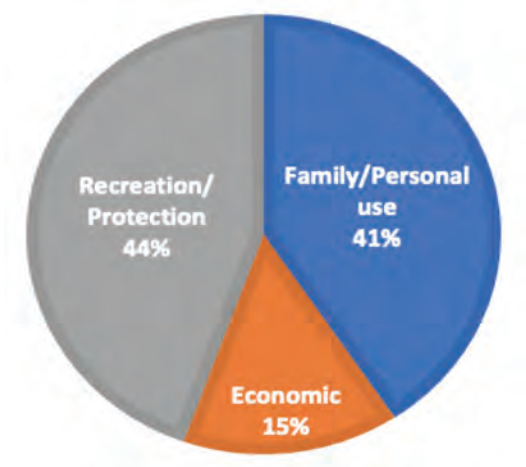

Figure 4. Reason for land ownership in North Carolina. Data from Butler et al., 2016

farmers holding marginal lands (low productive agriculture land) close to wood pellet manufacturing facilities.

The results of the sessions led us to identify two possible interventions: The first is a farmer's cooperative that would ease the burden of acquiring the expensive equipment needed for planting and harvesting bioenergy trees. This cooperative would enable farmers to borrow or rent equipment, facilitate partnerships with loggers and pellet producers, provide private investors contacts, and inform members of government grants and farm bills. The second is an online training for county extension agents that would facilitate technology and knowledge transfer related to SRWC. Ideally, agents could receive continuing education credit(s) or use it in some way for professional development. The training would include explanatory pictures of field trials, in-person field visits to SRWC experimental plots across the state and bioenergy research stations, as well as content on the: (1) ecological sustainability, (2) financial considerations, (3) harvesting process, and (4) community building resources needed to grow and harvest SRWC (Table 3). Additionally, the extension professionals interviewed emphasized the need for feedback on the educational materials to continually improve the content, which we incorporated into the "community building" portion of the online training. Typhina et al. (2015) and Typhina (2017) showed the importance of developing feedback opportunities in online environments to improve the content and increase the influence of the social network.

CONCLUSIONS, RECOMMENDATIONS, AND IMPLICATIONS FOR EXTENSION

Based on several behavioral theories, we evaluated farmers' motivations and perceptions to engage in SRWCs in North Carolina. Integrating new planting practices into conventional agriculture, such as SRWCs, can provide economic and environmental benefits to local communities and beyond. Due to these new practices' complexity and unfamiliar terrain, farmers need social, financial, technical, and educational support. Findings from this pilot study suggest that information on market demand, ecological sustainability and harvesting of SRWC is required to support adoption by farmers. Questions farmers might want answers to include: 1) What amount of wood product will be required to make a profitable return on investment? 2) How would the land be affected from harvesting SRWC trees on shorter rotation cycles compared to traditional forestry? and 3) What

Table 3. Modules and Topics Formulated from Interviews Held with Stakeholders and Participatory Prototyping Sessions

Module 1	Module 2	Module 3	Module 4
Ecological Sustainability	*Financial Considerations*	*Harvesting*	*Community Building*
• Meeting sustainability standards	• Growing volume and value of trees	• Pre-planning a successful harvest	• Revising objectives and primary goals
• Climate impacts: Assess your land	• Setting the price of products	• Harvesting operations	• Work with forestry professionals
• Planting arrangement and design consideration	• Calculate your Return on Investment	• Environmental considerations for harvesting	• Contacts for resources: loggers, equipment, seedlings
• How tree cropping improves soil health	• Quantify and price carbon offsets on land	• Haulage, costs, and labor planning	• Ask Instructors and Subject Matter Experts
• Pests, fertilization, and nutrient management	• Funding incentives and tax breaks for growing trees	• Negotiating with loggers	• Field demonstrations / farmer's field trial
			• Join our Facebook group for networking

is the appropriate spacing to plant the trees at to match the current spacing for row crops and avoid broken machinery and or down time? Our results also suggest the importance of tailored information to target farmers, especially for farmers in underrepresented groups that may be dealing with heirs' property and may already have gaps in understanding of basic forest management practices.

We found that with adequate resources, such as online extension training and cooperatives, farmers can gain the information and support they need to potentially adopt new farming systems. Based on our findings, we recommend using collaborative and participatory techniques, such as the Actor Diagramming and Tracing Method (Typhina, 2017), to gather community feedback to achieve shared goals and outcomes. We found that through the process of involving actors and stakeholders in developing suitable innovations, we could better understand the behavioral factors that influence farmers' motivations, decisions, and actions. We also recognized that the process enabled us to support diversity, equity, and inclusion efforts by decentralizing decision making (Bain et al., 2021), which can create more inclusive materials (Chazdon et al., 2021). In conclusion, the process described here offers a way to develop training and outreach materials that will meet the specific needs of stakeholders and provide Extension professionals with a better understanding of the unique needs of the communities they serve.

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