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# Agricultural Impact Report for Renaissance Fiber Hemp Processing Facility

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# Executive Summary

This report provides an overview of the hemp industry and evaluates the agricultural impact of a potential hemp-fiber processing plant in North Carolina. The fiber-hemp industry is still in it's infancy, with a very small share of the state's crops (roughly 6,000 total acres in 2021). Conversations with hemp agronomy experts suggest hemp's long term expected yield is uncertain due to a lack of data. We apply a crop switching model to estimate farmers' willingness to switch to hemp using current price and productivity levels. Although the time it will take to develop the correct hemp varietals for North Carolina growing conditions is unknown, we expect growth in hemp production if yields and prices are favorable. We evaluate the size of the agricultural impact of a new processing facility. The new facility will provide a market for 350 million lbs of hemp stalk. If the facility is constructed and can offer a price to induce this level of production, which we estimate at around 70,000 acres we find that farmer surplus would increase by up to $3.8 million.

# Contents

# 1 Background

Industrial hemp can be used to make a wide variety of products — from rope and clothes to medicine — but was illegal to grow in the United States until recently due to its genetic similarity to illicit marijuana plants which contain high levels of the chemical THC. The 2014 Farm Bill established a hemp pilot program and industrial hemp was fully legalized in the 2018 Farm Bill, although the THC content of plants is still tested and regulated. This recent change in legal status has allowed new markets in hemp oils (CBD) and hemp fiber to emerge and may provide a new crop for North Carolina farmers to grow. In this report we focus on the economic viability of industrial hemp for fiber as a crop in North Carolina.

Hemp is one of the fastest growing plants in the world and one of the first used as a spinable fiber, and this remains one of its primary uses as a cultivated crop. Hemp fiber has desirable properties to textile producers, and is a feasible substitute for cotton fiber. Over the last year, the U.S. market for cotton fiber was 60 billion pounds priced at an average of $1.15 per pound, giving a market value in excess of $84 billion.[1,2,3] Recent research also suggests hemp may be a more sustainable alternative to cotton.[4,5] Hemp crops use significantly less water, require less pesticide, and produce more durable fabrics.

To produce fiber, hemp is first harvested using the same equipment as for hay. To convert harvested hemp to fiber, the plants must pass through multiple processing stages. After harvest, the plant is decorticated, which is the process of separating the hard woody stalk

[1] Cotton Incorporated. *Monthly Economic Letter: Cotton Market Fundamentals Price Outlook*. 2022. URL: https://www.cottoninc.com/market-data/monthly-economic-newsletter/

[2] Xinlin Zhao et al. "Industrial Hemp—an Old but Versatile Bast Fiber Crop". In: *Journal of Natural Fibers* 18 (2021)

[3] D. Matykiewicz et al. "Comparison of Various Chemical Treatments Efficiency in Relation to the Properties of Flax, Hemp Fibers and Cotton trichomes". In: *Journal of Natural Fibers* 18 (2021)

[4] Ana Gabriela Duque Schumacher, Sergio Pequito, and Jennifer Pazour. "Industrial hemp fiber: A sustainable and economical alternative to cotton". In: *Journal of Cleaner Production* 268 (2020)

[5] Dinesh Chandra Agrawal, Rajiv Kumar, and Muralikrishnan Dhanasekaran. *Cannabis/Hemp for Sustainable Agriculture and Materials*. Springer Singapore, 2022

of the plant from the soft fibrous exterior, or bast. The process produces bast fiber and the soft core of the hemp stalk called the hurd.[6] The hurd has desirable properties as a secondary product, being dust free and highly absorbent, and is an ideal candidate for animal bedding, mulch, and for construction materials.[7,8] After decortication, the bast fiber still needs further processing in the form of degumming and milling.[6] It is then ready to be used as a high-quality input by the textiles industry.

This report provides an agricultural impact assessment of the opening of a degumming plant in Wilmington, North Carolina focused on the effects such a plant would have on North Carolina agricultural producers. To evaluate agricultural impact, we must first posses an understanding of the current state of North Carolina hemp production and hemp fiber supply chains – how hemp product moves from farm to fiber. We then use economic models to determine the flow of potential dollars through the hemp supply chain and farmers' willingness and ability to switch to hemp production.

## 1.1 Current State of the Hemp Industry

The North Carolina's domestic hemp industry is still in its infancy and changes are occurring rapidly. In 2014, North Carolina Industrial Hemp Pilot Program was initiated after being authorized by Congress and subsequently in N.C. through the Industrial Hemp Bill.[9] Legally grown hemp is labeled "industrial hemp" and must have THC content less than 0.3% for legal production. In 2018, hemp was removed from the controlled substances act and became a legal commodity under the oversight of the USDA.

[6]Stfano Amaducci and Jorf Gusovius Hans. *Hemp cultivation, extraction and processing.* Industrial applications of natural fibres: structure properties and technical applications, 2010

[7]Nadezda Stevulova et al. "Water Absorption Behavior of Hemp Hurds Composites ". In: *Materials* 8 (2015), pp. 2243–2257

[8]Seeds are another output from the hemp plant, which can be sold.

[9]North Carolina Department of Agriculture and Consumer Services. *Hemp in North Carolina.* 2021. URL: `https://www.ncagr.gov/hemp/`

In 2021, North Carolina became the first state to discontinue its pre-existing hemp pilot program and pass full control of hemp oversight to the USDA. Beginning January 1, 2022 the governance of hemp cultivation in North Carolina became regulated by the USDA Agricultural Marketing Service.[9,10,11] Because the oversight of N.C. hemp has transferred to the USDA and because the program is so new, data on production is limited.

What data we have comes from the North Carolina Industrial Hemp Program for the years 2019 and 2020, before hemp oversight was passed to the USDA. According to that data, there were just over 17,000 licensed acres of hemp in 2019 and just under 15,000 acres in 2020. Of those licensed acres, in 2020 18.9% were under 10 acres in area by license (farm size); 63.5% were between 10 and 100 acres; and 17.5% were greater than 100 acres.

Table 1: Current Hemp Production 2019 and 2020 for Top Counties

| County | 2019 Acres | 2020 Acres | Avg. Share of Hemp |
|---|---|---|---|
| Harnett | 1,084 | 868 | 6.1% |
| Pitt | 1,022 | 818 | 5.7% |
| Sampson | 703 | 595 | 4.1% |
| Alamance | 111 | 903 | 3.4% |
| Bertie | 443 | 615 | 3.4% |
| Robeson | 460 | 472 | 2.9% |
| Buncombe | 420 | 490 | 2.9% |
| Lee | 499 | 386 | 2.8% |
| Johnston | 583 | 309 | 2.7% |
| Duplin | 595 | 292 | 2.7% |
| Guilford | 355 | 443 | 2.5% |
| Edgecombe | 495 | 309 | 2.5% |

[10]Hemp Industry Daily. *With North Carolina exit, will more states give up hemp oversight?* 2021. URL: https://hempindustrydaily.com/north-carolina-exit-will-more-states-give-up-hemp-oversight/#:~:text=North%20Carolina%20has%201%2C500%20licensed,Would%20more%20time%20help%3F

[11]This means hemp producers no longer have to pay the $500 license fee plus $2 per acre required by the state, but now may face further bureaucracy in compliance testing.

## 1.2 Supply Chain Organization

Decortication via specialized machinery occurs close to the location where the hemp is harvested. Prior to decortication, hemp is bulky and expensive to transport. After decortication, transport becomes much more efficient as the bast moves to the degumming process and the hurd can be used or discarded in proximity to the decortication operation. Renaissance Fiber is proposing to open a processing plant (degumming and milling) in Wilmington that will service decorticated hemp from across the state (and potentially regionally) as seen in Figure 1. To create this figure we assumed the minimum efficient scale for decorticaiton is around 4,000 acres and use 2019 and 2020 hemp acreage to assign production to the top-12 producing counties. This hypothetical production setup is useful to illustrate a hypothetical geographic distribution in the state and its role in the supply chain.[12]

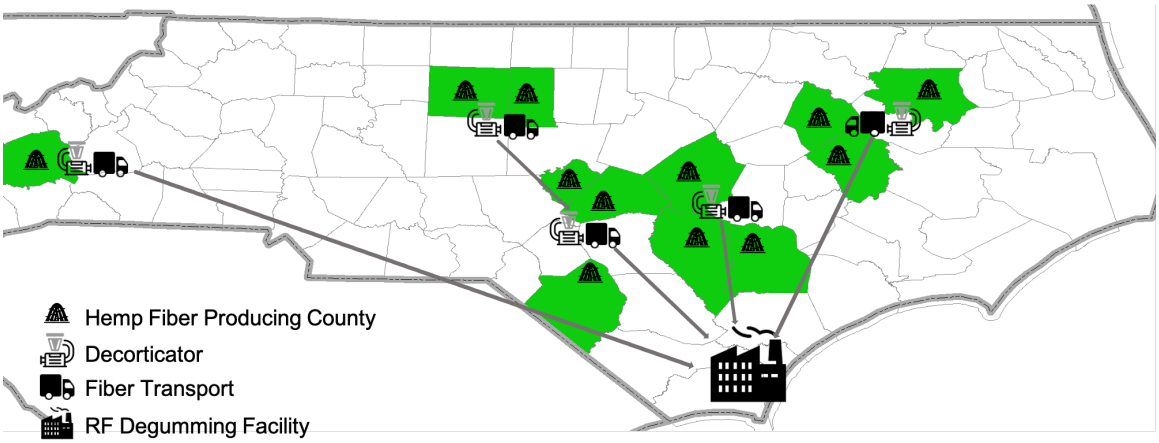


Figure 1: North Carolina Degumming Supply Chain

Options for ownership of decortication operations include independent ownership, farmer-owned, co-op ownership, and ownership by the degumming facility. Here we explore each option and the typical economics of different options for vertical integration:

[12]Because hemp is such a nascent industry, predictions of locations of production are highly speculative and for illustrative purposes only.

1. Independent ownership would entail a private decortication operation that purchases hemp stalk from farmers and sells decorticated hemp fiber to fiber processors. This is the default expectation from economics for the organization of a processing operation.

2. Farmer-owned decortication would allow a farmer to ensure the existence of a decortication operation for their harvested hemp, but would not be viable if the economic scale of a hemp operation differed dramatically from a decorticator.

3. Co-op ownership would allow a group of local farmers to own the primary processing jointly, which would align the scale of the group with the economic scale of the decortication operation. This method would allow profit sharing and solve local bilateral monopoly problems, and has been documented to be viable where capital assets would become stranded if local production was lower than expected. Decortication equipment is fairly mobile and would likely not suffer from stranded asset problems, reducing the economic benefits of this type of organization.

4. Ownership by the degumming facility is also feasible, but a degumming facility would receive input from many different decortication operations and so the optimal scale of these two businesses would not align. This sort of vertical integration is more likely when the downstream processor wants to directly control and ensure the quantity and quality of inputs. Contracts written between the degumming plant and decortication operations on the quality and quantity of inputs, however, would likely make this option unnecessary.

We expect that the structure of the hemp fiber supply chain is such that independent ownership is the most likely organization of decorticaiton operations. These operations, however, could enter into long-term contracts with the fiber processing facility. Currently, we are aware of only one independent decorticator in North Carolina, The Hempville Inc. The limited current development of this processing activity is likely due to lack of locations with

clusters of hemp acreage as well as the limited current scope of the market for hemp bast. The low number of decorticating operations is a potential barrier for hemp growers.

## 1.3 The Market for Fiber

While hemp input markets are still in their infancy in North Carolina, there is a U.S. hemp fiber market. High-priced hemp fiber has historically been imported. Given the chance to switch to domestic fiber, textiles producers would welcome a lower priced product if available. Hemp import statistics from 2017 and 2021 can be seen in table 2 and are taken from the US trade census.[13]

Table 2: Hemp Import's in 2021

| Product | Units | 2017 | 2021 |
|---|---|---|---|
| True Hemp, Raw (HS 530210) | $1,000 | 37 | 541 |
| True Hemp, Processed (HS 530290) | $1,000 | 744 | 910 |
| True Hemp, Yarn (HS 5308200000) | $1,000 | 2,739 | 2,027 |
| True Hemp, Woven Fabrics (HS 5311004010) | $1,000 | 1,819 | 4,508 |

The combination of existing hemp fiber demand and the size of the cotton fiber industry show the potential market for hemp fiber market.

## 1.4 Agronomy and Feasibility in North Carolina

Hemp has clear potential to be produced in the United States. In 1943, the U.S. produced 70,000 tons of hemp fiber, but by 1950 production had completely ceased. Hemp is a highly regional crop, with many varieties growing well in different climates. The plant is extremely vulnerable after planting. Heavy rains that cause a soil crust to form can cause total crop

[13]USA Trade Census. *USA Trade Online*. 2022. URL: https://usatrade.census.gov/

loss if seeds are not able to sprout. After sprouting, hemp becomes a highly resilient plant. It is naturally less attractive to pests and is adapted to endure weather variability. The fiber hemp planting and harvesting process can be achieved using the same equipment as hay. Although not well researched yet, hemp can likely be used in rotation with corn, wheat, and other standard field crops. More research is needed to understand planting and harvesting times, as well as crop genetics, best suited for the climatic and soil conditions found throughout North Carolina.

While hemp for fiber is certainly feasible to grow in North Carolina, the issue of quality is less certain. Quality of hemp fiber is a key aspect of it's price that passes through the supply chain. For example, degummers are very price sensitive to quality, leading decorticators to offer farmers a wide range of prices based on quality. From our discussions, the range can be as large as 10-20 cents per pound of dry stalk depending on the quality. To complicate matters, there are no regulated standards of hemp quality, so price is often negotiated per batch. Unknown yields and quality of yields are key current barriers to the adoption of hemp crops by farmers.

# 2 Estimation Approach

In this section we describe a methodology to estimate the agricultural impact of opening the Renaissance Fiber plant. Because the hemp fiber market is limited, we first estimate a reasonable expectation of the price range of the output hemp fiber product. Second, given the output price range, we determine the price range Renaissance Fiber will be able to offer for decorticated hemp. Third, we estimate price pass-through from decorticators to farmers. We use Renaissance Fiber's model for decorticator operations for this process. Fourth, we apply our price estimate to create a hemp profitability metric on a per acre basis considering

a range of potential yields. Finally, we estimate farmer willingness to switch to hemp given a range of hemp stalk prices and hemp profitability metrics which includes our estimated metric from the previous steps. This process allows us to evaluate the potential acreage that the opening of the Renaissance Fiber plant could induce as well as estimates for acreage at other prices/yields. The result of our analysis is a range of potential hemp acreage estimates that correspond to underlying market price assumptions and potential yields.

## 2.1 Market Assumptions

We use assumptions from Renaissance Fiber's (RF) business model to determine how value moves through the supply chain. RF expect to sell their product for roughly $3 per pound and expect to purchase decorticated bast for 55 cents per pound. These prices represent their assumption of market demand for the product and their assumption of a feasible price of decorticated fiber, an input. These price estimates assume a moderate grade of hemp fiber, though specific batch prices will vary based on fiber quality. While we use our own estimates of these prices in our model, we make use of the price ratio to determine RF's willingness to pay for decorticated hemp based on the price of their output.

### 2.1.1 Price Pass Through to Decorticators

We assume a constant linear price pass through to decorticators. We find an increase of $1 in the price of output hemp fiber leads to a 31 cent increase in price offered to decorticators. For this calculation, an increase in the hemp fiber output's price is passed through at a constant rate to the price offered to decorticators, but is scaled to account for the loss of fiber in the degumming process. Renaissance Fiber assumes they will lose 30% of fiber weight during the degumming process and 15% during the refining process for a loss ratio of 40.5%. This

is equivalent to using 1.68 lbs of decorticated fiber to produce 1 pound of marketable hemp fiber. Therefore, the price offered to decorticators is scaled down by this ratio to account for the fiber loss.

### 2.1.2 Price Pass Through to Farmers

We use Renaissance Fiber's decorticator model to estimate price pass through to farmers. Their model considers variable costs, such as electricity and labor, as well as startup costs and hemp stalk costs. It also considers the price of two outputs - hurd and fiber. For the startup costs, we assume a return on capital of 7% to calibrate the price decorticators are able to offer farmers. Some primary assumptions are:

- Hurd is sold for 40 cents per pound
- Fiber yield per lb of stalk is 20%
- Hurd yield per lb of stalk is 75%

We use a estimate for hurd price based on current suppliers, although current market opportunities suggest that the price could be higher. Hempstone, who use hemp hurd as an input, documents that they import higher quality foreign hurd for 50-65 cents per pound (before shipping) and purchase domestic hurd for 70-85 cents per pound.[14] Old Dominion Hemp, located in Virginia, currently sells hemp hurd bedding for 94 cents per pound in 33 lb bags.[15] Hempville, the only decorticator operating in North Carolina to our best knowledge, sells a 400lb bag of hemp hurd for $389.[16] Hemp hurd is currently a niche product. As hemp production increases, we do not expect these prices to endure.

[14]Hempstone. *Making sense of supply.* 2022. URL: https://hempstone.net/
[15]Old Dominion Hemp. 2022. URL: https://www.odhemp.com/
[16]The Hempville. *Our Products.* 2022. URL: https://thehempville.com/our-products/

The fiber content of hemp is over 35%, while the current fiber yield of industrial hemp decorticators is roughly 15-20%, showing potential improvement is possible in the future.[17] The current fiber yield implies a hurd yield, with an assumed 5% loss, of 75-85%.

### 2.1.3 Price Scenarios

We evaluate two fiber price scenarios and their pass through to decorticators, and then to farmers, shown in table 3. The fiber price is the price that Renaissance Fiber will sell its processed hemp fiber. The decorticated bast price is the price Renaissance Fiber will be able to offer decorticators. The hemp stalk price is the price that decorticators will be able to offer farmers. Because hemp fiber does not have a well defined market in the U.S., we use two price scenarios for hemp fiber that are taken from the price of a hemp fiber substitute: cotton fiber.[18]

To be clear, hemp fiber does not have the same properties as cotton fiber. Hemp fabrics are stronger, more absorbent, more durable, and better insulating than cotton. Additionally, they don't stretch out of shape. However, cotton fabric is softer and more comfortable against the skin.[4] Hemp-cotton fiber blends also show potential for an improved fiber.[19] There are many differences between cotton and hemp fiber, but given the absence of a developed hemp fiber market price, we use cotton price as the best-available estimate.

For the first scenario, we use the price of organic cotton fiber, a high quality form of cotton fiber, to represent the case in which hemp fiber is able to differentiate itself from cotton fiber and command a large price premium. For the second scenario, we use the price of cotton

[17] Hanna Tikhosova Galina Boyko and Tatiana Ternova. "Optimization of the Decortications Process of Industrial Hemp Stems". In: *INMATEH - Agricultural Engineering* 60.1 (2020)

[18] This price is approximately the same as Renaissance Fiber has used in its business models.

[19] W Cierpucha et al. "Applicability of Flax and Hemp as Raw Materials for Production of Cotton-like Fibres and Blended Yarns in Poland". In: *Fibers Textiles in Eastern Europe* 3.47 (2004), pp. 13–18

fiber, which would likely serve as a price floor for hemp fiber due to their similarities. For the price of cotton, we use a yearly moving average price of Cotton 1 futures contract on the Intercontinental Exchange. For the price of organic cotton fiber, we use the Organic Cotton Market Report published by The Textile Exchange.[20] The organic cotton price is consistent with the price Renaissance Fiber's expects to receive.

Based on the price of organic cotton fiber and Renaissance Fiber's business models, we estimate a price of 11 cents will be offered to farmers. This is not an estimate of the future market conditions of hemp fiber - this is simply the result of passing organic cotton fiber's price through Renaissance Fiber's business model. If Renaissance Fiber or decorticators were able to offer a higher price, and the higher price passed through to farmers, on-farm profitability would be improved. This would also be the result of higher prices for hemp hurd. This section of the analysis serves as an estimate of price offered to farmers, but our results regarding farmer adoption and welfare will cover a range of prices due to the current market uncertainty.

Table 3: Hemp Fiber Price Scenarios

| | Fiber Price | Decorticated Hemp Price | Hemp Stalk Price |
|---|---|---|---|
| Organic Cotton Fiber | \$3.25 | \$0.60 | \$0.11 |
| Cotton Fiber | \$1.16 | \$0.26 | \$0.05 |

### 2.1.4 Profitability

Farmers make acreage decisions based on expected profitability. It is useful to gain a sense of the expected profitability of hemp compared to other staple crops in North Carolina. We compare the crop budgets of Hemp, Soybeans, Corn, and Cotton. Corn and Soybeans are chosen due to their high crop shares in North Carolina. Cotton is chosen because of its

[20]Cotton Market News Division. *Organic Cotton Market Report 2021.* Tech. rep. The Textile Exchange, 2021

similarities to hemp, and it serves as a proxy for hemp in our crop switching model. Cotton and hemp both are fiber crops that must be processed further after harvest: cotton must be ginned and hemp must be decorticated. They both have complements in production: cotton seeds for cotton and hemp hurd/seeds for hemp. Also, as we show below, they have a similar expected profitability.

The cotton, soy, and corn crop budgets are formed from the 2021 North Carolina State University crop budgets for conventional till crops.[21,22,23] The HIF line item includes costs for herbicides, insecticides, and fungicides. Other variable costs (VC) include labor, machinery, hauling, drying, surfactant, aerial application, and ginning, when applicable to each crop. Other costs include fixed cost and general overhead (assumed 7% of VC). Our hemp crop budget is formed from the University of Kentucky's 2021 hemp fiber crop budget. The table reflects the Kentucky budget modified with regional adjustments we made after discussions with North Carolina hemp researchers and farmers.[24] Numbers that are adjusted are noted with an asterisk.

Our hemp crop budget does not serve as a projection of profitability in a developed hemp market, but rather our assessment of current market conditions. To this point, hemp seed prices are illustrative. We use the price $4.00/lb for seed from discussions with local experts. It is likely the case, however, that as the hemp market develops over time seed price will fall. This could result in an increase in hemp grower profitability. We discuss this further in the results section.

[21] Derek Washburn Ashley Wollett Gary Bullen Ron Heiniger. *Corn, Conventional-2021.* Tech. rep. North Carolina State University, 2021

[22] Wesley Everman Derek Washburn Ashley Wollett Gary Bullen Jim Dunphy. *Soybean, Full Season-Conventional-2021.* Tech. rep. North Carolina State University, 2021

[23] Ashley Wollett Charles Cahoon Derek Washburn. *Cotton, Conventional-2021.* Tech. rep. North Carolina State University, 2021

[24] Tyler Mark and Jonathan Shepherd. *Corn, Conventional-2021.* Tech. rep. Hemp and Enterprise Budget Model, 2021

| | Unit | Qty | Corn Price | Total | Unit | Qty | Soy Price | Total |
|---|---|---|---|---|---|---|---|---|
| Gross Receipts | Bu | 140 | $4.49 | $628.60 | Bu | 40 | $10.37 | $414.80 |
| Add'l Receipts | | | | | | | | |
| Total Receipts | | | | $628.60 | | | | $414.80 |
| Seed | Thou. | 30 | $2.66 | $79.8 | Thou. | 110 | $0.40 | $44.00 |
| Fertilizer | Acre | 1 | $140.46 | $140.46 | Acre | 1 | $38.81 | $38.81 |
| HIF | Acre | 1 | $32.72 | $32.72 | Acre | 1 | $31.59 | $31.59 |
| Other VC | | | | $142.57 | | | | $92.61 |
| Total VC | | | | $395.55 | | | | $207.01 |
| Income Over VC | | | | $233.05 | | | | $207.79 |
| Other Costs | | | | $77.44 | | | | $69.16 |
| Total Costs | | | | $472.99 | | | | $276.17 |
| Net Return | | | | $155.61 | | | | $138.63 |

| | Unit | Qty | Cotton Price | Total | Unit | Qty | Hemp Price | Total |
|---|---|---|---|---|---|---|---|---|
| Gross Receipts | lbs | 900 | $0.69 | $621.00 | lbs | 5000* | $0.11 | $550.00* |
| Add'l Receipts | lbs Seed | 1503.00 | $0.08 | $120.24 | | | | |
| Total Receipts | | | | $741.24 | | | | $550.00* |
| Seed | Thou. | 42 | $2.11 | $88.62 | Lbs. | 50 | $4.00* | $200.00 |
| Fertilizer | Acre | 1 | $63.35 | $63.35 | Acre | 1 | $48.5 | $48.5 |
| HIF | Acre | 1 | $99.61 | $99.61 | Acre | 1 | $0.00 | $0.00 |
| Other VC | | | | $298.88 | Acre | 1 | $143.19* | $143.19* |
| Total VC | | | | $550.46 | | | | $391.69* |
| Income Over VC | | | | $190.78 | | | | $158.31* |
| Other Costs | | | | $156.28 | | | | $122.00 |
| Total Costs | | | | $706.74 | | | | $513.69* |
| Net Return | | | | $34.50 | | | | $36.31* |

## 2.2 Crop Switching Model

For our analysis, we use profitability from an expected crop budget to estimate farmers' willingness to switch land use based on profitability expectations based on our assumptions from the crop budget. For expected yield, we use a six year moving average of mean yields for North Carolina, taken from NASS Quickstats.[25] For expected price, we use the commodity price in October of the previous year, when farmers often make planting decisions. Our model uses relative crop profitability, so changes in crop budgets that are similar across crops, such as labor costs, are omitted from the model. Variations in crop budgets that are crop-specific, such as seed costs, are included.

For the crop switching model, we follow Droller and Fiszbein (2021), using a fractional multinomial logit (FML) framework.[26] We construct a system of equations where the outcome variables are the crop shares of crop $i$ in county $c$. By construction, in the FML framework, the crop share variables sum to one. The crops included in this model are soybeans, corn, cotton, and a residual of all others. The form of the FML model is

$$\hat{\theta}_{ic} = \frac{e^{\phi_i' A_i}}{1 + \sum_{j=1}^{I-1} e^{\phi_j' A_j}} \tag{1}$$

where $\hat{\theta}_{ic}$ is the crop share, $A_i$ is a vector of regressors and $\phi_i$ are coefficients. $A_i$ is comprised of an intercept, a yearly expected profitability variable for each crop, and a dummy variable for each county. The county level dummy variables absorb fixed effects in crop share differences not attributed to profitability. For example, weather variation, soil quality, or local preference. The model estimates how expected profitability influences crop acreage choice

[25] National Agricultural Statistics Service. *Quick Stats*. 2022. URL: `https://quickstats.nass.usda.gov/`

[26] Federico Droller and Martin Fiszbein. "Staple Products, Linkages, and Development: Evidence from Argentina". In: *Journal of Economic History* 81.3 (2021), pp. 723–762

while controlling for the fact that counties may be better suited to specific crop production.

We do not have sufficient data to include hemp in the model, with only a few years of hemp acreage data to work with and no market price. To overcome this, we include cotton in the model as a substitute for hemp. We chose cotton because it is consistent with our assumption that cotton price is a lower bound for hemp prices; both are fiber crops with complements in production; and both crops need additional processing for fiber use. The need for additional processing is a barrier for farmers of both crops who may consider producing. They need to either purchase equipment (cotton gin or hemp decorticator) or enter into contracts with equipment owners. For these reasons, we believe that farmer's willingness to produce cotton will be most similar to their willingness to switch to hemp.

The use of cotton as a proxy for hemp in our model is necessary, but embeds key assumptions in our model. Specifically, this assumes that hemp acreage decisions as a result of changes in hemp profitability will mimic that of cotton. thus, the model assumes hemp acreage decisions based on price variation will mimic those of cotton and that farmers consider hemp a viable crop for production as opposed to the current experimental stage of the industry. Primarily, this means we assume hemp is a well developed market. The estimation model makes no assumptions about future hemp price or profitability and makes no assumptions about demand. These assumptions are made separately based on characteristics of hemp, not cotton.

After estimation, we use the crop-switching coefficients for cotton, our current knowledge of hemp acreage, and a range of prices to determine potential increases in hemp acreage. To do this, we apply any estimated increases in acreage to locations which currently produce higher shares of hemp in NC.

# 3 Results

## 3.1 Hemp Production Supply Curve

As discussed in the previous section, our model uses the results of farmer response to changes in cotton profitability and assumes total hemp acreage will respond similarly to changes in hemp profitability. One key assumption used in our findings that has high uncertainty and we anticipate may change is seed price. We already allow hemp stalk price and yield to vary in our results, so for brevity we do not include seed price as an additional sensitivity variable. Because our results are based on profitability, changes in seed price would be interpreted similarly to other profitability changes, e.g. an increase in total receipts of $100 (due to either price or yield increase) would have an identical results to a decrease in seed cost of $100.

We estimate a supply curve for hemp by fixing current hemp acreage based on a current price of $0.11/lb and then allow prospective hemp price to vary, observing how acreage in hemp responds based on the model. The resulting hemp supply curve is shown in figure 2. The curve is an estimate of how statewide hemp acreage changes with the per acre profitability of hemp, given an assumed hemp yield of 5000 lbs/acre. The flat portion of the curve represents prices at which expected hemp profitability does not exceed substitute goods and therefore no hemp is grown.

At current prices, hemp acreage is low because per-acre profitability is low. If prices were to rise, per-acre profitability would increase, inducing farmers to switch some production to hemp. Currently soybean and corn profitability is much higher than hemp, and these crops are planted on hundreds of thousands of acres in the state. Based on our model, if prices rose to the point where hemp profitability was near the level of corn and soy, farmers

would switch hundreds of thousands of acres into hemp production, as shown on the supply curve. This scenario is unlikely to occur given any reasonable assumptions of the nature of the market in the near-term.

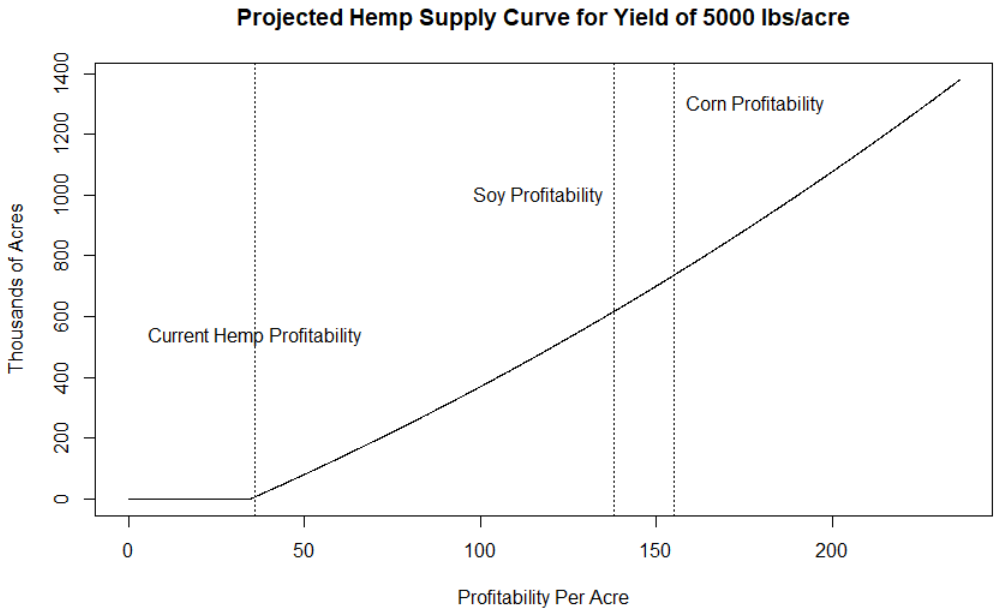


Figure 2: Hemp Supply Curve

Figure 3 zooms in to the more relevant range of the hemp supply curve and shifts the y-axis from profitability to hemp price per lb.[27] The figure provides three estimates of the hemp production supply curve based on different estimates of per-acre hemp yields. At 5500 lbs/acre the curve is shifted up because more farmers are induced to produce hemp at a particular price, and conversely less production occurs if yields are closer to 4500 lbs/acre. This figure illustrates the critical importance of yields to the ability of farmers to profitability grow and sell hemp.

[27]In this exercise profitability only varies based on price so the axes are interchangeable.

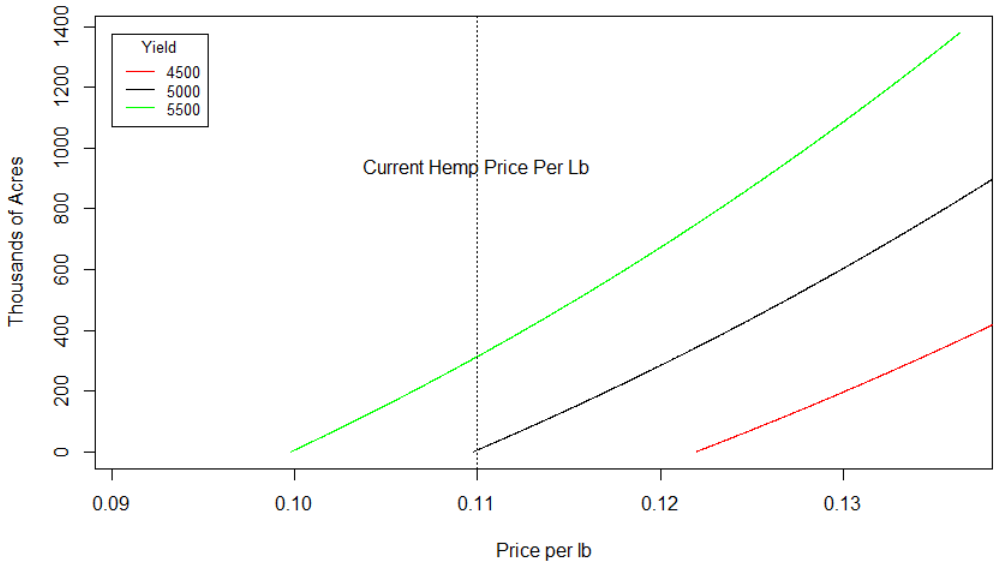


Figure 3: North Carolina Projected Hemp Supply Curve

## 3.2 Minimum Efficient Scale and Location of Production

Using the hemp production supply curve, we can determine what price will needed to be offered for North Carolina farmers to produce a certain number of acres. We use 70,000 acres as the illustrative production of hemp needed to supply Renaissance Fiber's plant.[28] Our results show that a price of $0.1124/lb of hemp stalk would induce farmers to grow 70,000 acres of hemp. This calculation is illustrated in figure 4.

[28]This analysis does not offer an assessment of RF's profitability or viability at different levels of production. Instead, we approximate the acreage needed to supply the facility and use that to estimate the agricultural impact.

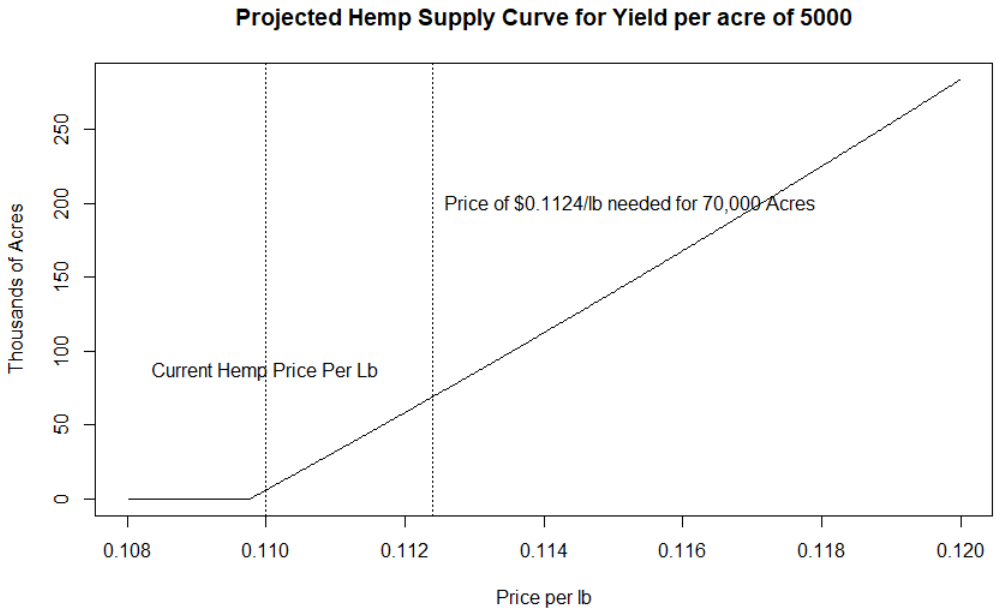


Figure 4: North Carolina Projected Hemp Supply Curve

While we assume the acreage response to price will be similar for hemp and cotton, we take into account potential differences in where in North Carolina hemp will be grown. The proportional increases in hemp acreage will likely take place in different counties due to differing soils, climates, and access to markets.

Table 1 shows the current distribution of hemp production to the top 12 counties. As mentioned earlier, efficient hemp decortication occurs at an economic scale different from production and degumming. While a range of hemp decorticating machines exist, we assume the efficient scale for a decortication operation is around 4,000 acres.[29]

We take the total projected increase in hemp acreage and allocate it proportionally to an average of the 2019 and 2020 hemp acreage data. For example, if one county accounts for 5% of hemp acreage in 2019 and 2020, we assume that 5% of the total acreage increase will

[29]One decorticator currently available processes one ton per hour (we estimate this would cover about 800 acres per year), but a new product that processes 5 tons per hour (4,000 acres per year) may be a more realistic commercial scale (see `thejacobsen.com/2020/07/28/appropriate-scale-for-fiber-processing/`)

happen in that county. We apply a criteria that each county has a minimum scale production to support a decortication operation (4,000 acres). Transportation of hemp stalk outside the immediate vicinity of a farm prior to decortication is too expensive. When we apply this criteria, we project the 12 counties shown in table 1 would each produce more than 4,000 acres, as shown in figure 5.[30]

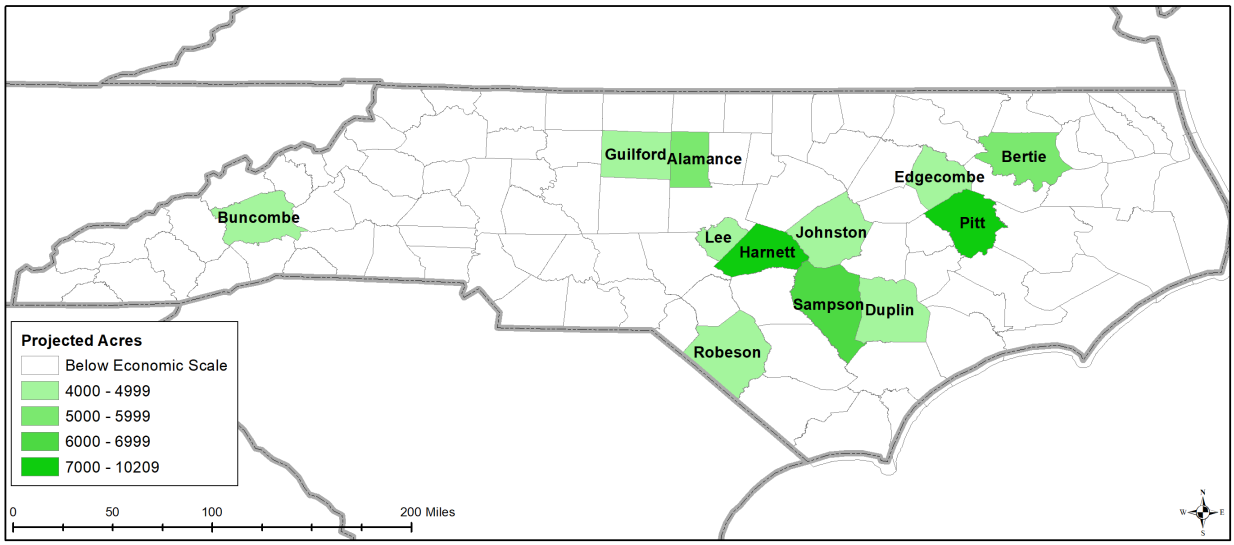


Figure 5: Projected Fiber Hemp Production

## 3.3 Producer Surplus

The supply curve provides a means of estimating the producer surplus obtained by North Carolina farmers. This surplus measures the additional income farmers see from switching to hemp above their status quo production.[31] Table 4 shows the increase in producer surplus to farmers for a range of yields and prices. Welfare gains are relative to the current level of use. This represents plant agricultural impact. For example, a price of 11.5 cents per pound at a yield of 5,000 lbs/acre would result in benefits to North Carolina farmers of $1.611 million.

[30]These projections are illustrative only and based on the historic distribution of hemp production in the state.

[31]We Riemann-integrate the area under the supply curve to derive this measure of producer surplus.

To estimate the monetary impact of the facility we use the price of 0.1124, which is the price needed to induce 70,000 acres of production. For a per acre yield of 5,000 lbs, this would amount to roughly $3,800,000 in producer surplus. At a yield of 4,500 lbs/acre farmers in the state would see no net benefits, and at 5,500 lbs per acre gains would be about $12,000,000.

Table 4: Producer Surplus (in millions)

| Price/lb | 4000 | 4250 | 4500 | 4750 | 5000 | 5250 | 5500 | 5750 | 6000 |
|---|---|---|---|---|---|---|---|---|---|
| 0.08 | | | | | | | | | |
| 0.085 | | | | | | | | | |
| 0.09 | | | | | | | | | |
| 0.095 | | | | | | | | | 1.059 |
| 0.1 | | | | | | | | 1.661 | 6.794 |
| 0.105 | | | | | | 0.004 | 2.013 | 7.864 | 17.899 |
| 0.11 | | | | | | 2.013 | 8.260 | 19.081 | 34.834 |
| 0.115 | | | | | 1.661 | 7.864 | 19.081 | 35.639 | 58.077 |
| 0.12 | | | | 1.059 | 6.794 | 17.899 | 34.834 | 58.077 | 88.125 |
| 0.125 | | | 0.412 | 5.159 | 15.656 | 32.350 | 55.888 | 86.675 | 125.482 |
| 0.13 | | 0.017 | 3.283 | 12.590 | 28.512 | 51.648 | 82.623 | 122.077 | 170.662 |
| 0.135 | | 1.491 | 9.049 | 23.514 | 45.636 | 75.976 | 115.430 | 164.489 | 224.178 |
| 0.14 | 0.263 | 5.477 | 17.899 | 38.256 | 67.313 | 105.858 | 154.701 | 214.658 | 286.539 |

# 4 Discussion

## 4.1 Risks to Farmers

*Required Growth of Production*

Table 5 shows the necessary increase in production in North Carolina's largest hemp growing counties to build a base of production large enough to support a degumming facility in the state (estimated at 70,000 acres). As discussed in the prior section, the price offered to hemp farmers must rise above current levels to make this happen. As shown in the table, production in the state would need to increase around 1,000%. While our model supports the idea that if the price is right, farmers can be induced to switch, a key risk facing the RF

endeavor is the massive increase in acres that they will need to induce into production to support their facility.

Table 5: Hypothetical Production Increases to Reach 70,000 Acres

| County | 2019/2020 Mean Acres | Projected Acres | Acreage Increase |
|---|---|---|---|
| Harnett | 976 | 10,209 | 946% |
| Pitt | 920 | 9,628 | 946% |
| Sampson | 649 | 6,807 | 949% |
| Alamance | 507 | 5,738 | 1031% |
| Bertie | 529 | 5,674 | 972% |
| Robeson | 466 | 4,929 | 958% |
| Buncombe | 455 | 4,843 | 964% |
| Lee | 443 | 4,624 | 945% |
| Johnston | 446 | 4,584 | 928% |
| Duplin | 444 | 4,546 | 924% |
| Guilford | 399 | 4,259 | 967% |
| Edgecombe | 402 | 4,160 | 935% |
| Total | 6,636 | 70,000 | 955% |

*Yields*

Because hemp production is so new, there is considerable uncertainty over yields and quality of product. Hemp genetics need to be fine-tuned to North Carolina and particular county growing regions. As shown in table 4, if yields are low, say 4000 lbs/acre, even prices as high as 13.5 cents per pound do not result in any additional surplus to farmers; given this low expected productivity, farmers would not switch into hemp production.

*Production and Price Volatility*

Volatility in the price of hemp offered to farmers is a key risk. The hemp oil market suffered a large price run-up and crash when excess production exceeded demand at higher prices. Without a time-series of price information, producers cannot gauge the expected price level and volatility, which adds considerable risk relative to more established crops. Because the current hemp fiber market is so limited, farmers also face risk as a result of having a single

buyer.

## 4.2 Limitations of Analysis

We consider many aspects of the hemp market in North Carolina, but are not able to account for everything with limited data. A primary limitation of our analysis is the use of cotton as a hemp proxy. While we believe cotton response to price may be the most similar to hemp response to price due to their shared attributes, more research will be needed if hemp production increases.

Our analysis does not consider farmers risk preferences, which are likely a large factor in decisions to adopt hemp. We also do not consider the impact of crop insurance or lack thereof. Revenue protection for hemp is offered nationwide under the Whole-Farm Revenue Protection plan of insurance.[32] A pilot Multi-Peril hemp insurance program is also available in select counties. Farmers willingness to switch may be impacted by the greater variety of crop insurance options available to cotton (our proxy for hemp in the model).

Because our price variable is not county specific, our analysis may suffer from differences in county willingness to grow hemp not related to price. Our method assumes the adoption rate will be uniform and does not account for local agronomic factors. We do our best to eliminate this variance by only considering counties already growing a relatively large share of hemp. This issue should be revisited when more is known about the relative suitability of various areas to particular hemp genetics.

[32]Risk Management Agency United States Department of Agriculture. *Hemp*. 2022. URL: `https://www.rma.usda.gov/en/Topics/Hemp`

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