THE VALUE OF VERSATILE ALLEY CROPPING IN THE SOUTHEAST US: A MONTE CARLO SIMULATION

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ABSTRACT

Alley cropping offers a potential alternative to traditional land management practices. However, its implementation in the United States is extremely limited and general awareness and knowledge of alley cropping is lacking. While alley cropping does have a few barriers to entry, the cost of maintaining hedgerow products and foregone returns from primary crops particularly, its offer the potential for positive returns on investment once the hedgerow product, typically timber, is harvested. Thus we determined the need to create an economic model to assess the relative potential of alley cropping with respect to traditional land management practices under certain conditions. Through use of a stochastic Monte Carlo approach, we ran simulations comparing the results of an alley cropping system and a single crop system in the Southeast region of the United States. Preliminary results show that, under certain constraints, alley cropping may be profitable, but we believe this result is sensitive to assumptions about the interactions between system components. Through analysis of the results of these simulations we can determine in which situations alley cropping should be preferred over a single crop system. In the future, we will improve the model to account for more complex interactions and adjust input parameters as we find better data. We will evaluate how alley cropping affects farm risk and how policy programs may affect its profitability.

Keywords: Agroforestry; profitability; stochastic financial model; risk

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1 INTRODUCTION

Alley cropping is a land management methodology wherein land owners/managers use hedgerows of one or more crops to separate wider alleys of other crops. The most common format for alley cropping, and the one assumed within the model presented here, uses a single primary crop grown in the alleys and a different crop, generally a timber product, grown as the hedgerow product.

Alley cropping has not been widely practiced or studied in the United States. Several US studies have investigated yields and responses to interspecific competition within alley cropping systems (Gillespie et al., 2000; Lee & Jose, 2003; Miller & Pallardy, 2001; Zamora, Jose, & Nair, 2007; Zamora et al., 2008). We know of only one empirical study on the economic returns in an alley cropping system in the southeast US: Cubbage et al. (2012). That study found that early-year alley cropping returns on a frequently flooded agricultural site in North Carolina were poor, while tree survival and growth were relatively good by comparison. While this study provides a good starting point and important "ground-truthing" for economic analysis, (1) it only covers the first few years of the system rotation, and (2) does not control for mono-crop agricultural yields on a similar site.

The basic two crop alley cropping model with one primary crop grown in the alleys and a timber product grown in the hedgerows is the simplest model, one of the reasons for its use in this study. Most economic models assume that decision-makers seek profit maximization. Therefore, if there is a crop available which is significantly more profitable than any other crop available, then profits are greatest when this crop is grown whenever possible.

This leads to the obvious conclusion that annual returns on the land are reduced due to the hedgerow products. If, however, these products prove more profitable in the long run than the primary crops grown in the alleys, then alley cropping may be more profitable than a single crop system, hence the necessity of this study. Such could be the case on marginal agricultural land. It should also be mentioned that even if timber products are more profitable in the long run than are other crops, farmers and particularly rent-paying land managers need certain levels of annual income, thus strict timber farming could be financially impractical. Alternatively, alley cropping might be a transitional land management from open land to forest, allowing annual income in the interim. Therefore, for those dependent upon the land for annual incomes yet also with the luxury of being able to invest in the land, alley cropping, if more profitable than a single crop system, can potentially be a practical alternative land management methodology for this segment of the population.

While timber prices are a crucial factor in this model, simple verification of the relationship between timber prices and crop prices does not directly imply the relative profitability of switching to or from and alley cropping model. There are a myriad of other factors which contribute to such an analysis.

Factors such as soil exhaustion and crop rotation will force any model to choose at least a second primary crop on certain years, even in cases in which there is a clear and unique crop which should always be preferred from a pure financial standpoint. Also, while crop rotation can reduce income on certain years, sunlight and soil competition factors can reduce income each year once the hedgerow products reach a certain level of maturity. As the timber products grow they produce more shade which reduces crop exposure to the sun and decrease levels of photosynthesis and thus crop growth. But these timber products also grow more expansive root systems which inevitably compete with the root systems of the alley crops for nutrients in the soil. Therefore any modelling work in the area of alley cropping must address these issues before the analysis of the relative prices and returns of various hedgerow and alley crops can produce the relative profitability of alley cropping.

2 DATA

Before a model could be developed, much data as well as a few constraints were necessary for developing the model. These constraints were temporal and geographical; the model was designed to only last until the timber products were harvested before repeating itself, and the geographical conditions assumed in the model, e.g. soil types and climates, were indicative of the southeastern United States.

Data for historic annual crop returns were downloaded from NASS (2013). These were used to estimate long-run averages, standard deviations, and mean-reversion rates. Historic crop returns were inflated to 2013 dollars using the Consumer Price Index (CPI) (BLS, 2013).

The data collected all came from this same geographical region, specifically coming from four states: Virginia, North Carolina, Louisiana, and Missouri. These data included nominal prices of all crops and timber products, real prices, returns per acre, costs per acre, real costs per acre, and the average change in real price over time. While data was available for many of these factors for as much as the past fifty years in some cases, the previous fifteen years were used in finding the averages which were used in the model.

3 METHODOLOGY

The model itself was a Monte Carlo simulation which ran 10,000 cycles, using a stochastic, mean-reverting random walk. It found the long run continuous average of the relative gains or losses of alley cropping when compared to a single crop format.

The model began with a series of arrays of price and return information which were updated after each year within cycles and reset to their original values at the beginning of each new cycle. These arrays were then subjected to a randomly generated function which determined the additional annual change to the long run rate of change in real price, real cost, and returns due to random market shocks such as inclement weather, etc. Random number generation, as included within the model, had the additional benefit of providing a means of mean reversion in the long run since the randomly generated numbers came from a specific interval, i.e. (0, 1). Once the new data on prices, costs, and returns for that year were found, the model then found the maximum net gain from growing each of the crops and selected that crop which provided this maximal profit level.

Once the most profitable crop for that year, along with its price, cost, and returns data, was chosen, the model then made any necessary adjustments for crop rotation. Since crop rotation is a legitimate concern, being a commonplace practice due to its long run benefits, a crop rotation feature was included to mimic realistic choices within the model. If the same crop had been selected by the model for a third consecutive year, it was discarded during the third year and the model then found the second most profitable crop that year before continuing.

Once a definite choice in crop had been made by the model, profits per acre were stored to represent the profits from a single cropping system while this total was multiplied by a factor of 5/6th to represent the profits from alley cropping in that same year; the 5/6th is representative of the proportion of land dedicated to alleys within the alley cropping model and can be altered is desired, though it should be noted that a 5:1 ratio of alleys to hedgerows in terms of land area is fairly typical of an alley cropping model. Once the profits in the alley cropping model were determined, the cost of maintaining the hedgerows was subtracted from the previous profit line, thus giving the ultimate profit margin per acre within the alley cropping model.

As the model progressed, a competition function was implemented which discounted the returns on the alley crops due to the aforementioned soil and sunlight competition factors which will inevitable stunt the growth and development of the alley crops positioned closest to the hedgerows. This competition function was a basic polynomial which used the age of the tree as the sole variable and used the resistance to shade as a coefficient, thereby impacting those crops which are most heavily dependent upon sunlight most severely and impacting all crops greater as the timber products continued to grow.

This process was then repeated over the course of 32 years to allow for the maturity of the timber products. This timeframe, which slightly lower than that typically assumed by roughly two years, was assumed because trees in these hedgerows are not competing for sunlight to anywhere near the same extent as trees in a forested land area, and thus have the potential to grow slightly faster than trees in forested land areas.

In the 32nd year of the cycle, the model then harvests the timber products and, rather than subtracting the cost of maintaining the timber products, adds to the profits from the alley crop the total gains for the timber harvest. Once the cycle is complete, the model finds the average gains or losses over the total thirty two years of alley cropping with respect to a single crop system. This per acre margin is then stored until the next cycle is completed, when a continuous average is recalculated for all of the completed cycles. After the ten thousandth cycle the model outputs the average long run gains or losses in profits due to alley cropping.

After this initial simulation was completed, other simulations were ran including one in which the trees were grown in a disjoint land area with a full 35 year cycle, one mimicking the initial model in which the competition function was magnified to provide, ideally, an upper and a lower bound to the net profit margin of alley copping compared to a single crop system, and a repetition of the original model with the cycles lengthened to 35 years implying no decrease in the time to maturity of the timber products.

4 PRELIMINARY RESULTS

The results presented here are preliminary. Further refinements of the model will be undertaken to generate more accurate results and will be reported at a later date.

With no competition function and the trees kept disjoint with the crops, there was an overall increase in profits due to alley cropping of $90.01 per acre. This simply shows that, in the long run, forestry is more profitable than growing other, more traditional crops, and that crop diversification can lead to a positive investment when conditions permit.

With a modest competition function, i.e. the initial model, the profit margin was reduced to $47.48 per acre thereby showing that alley cropping can still be more profitable in the long run than traditional single crop systems, even after the negative factors associated with alley cropping are incorporated into the model.

With the severe competition function the profit margin due to alley cropping dropped to ($83.60) per acre. This is indicative of the potential for alley cropping to offer less financial compensation in the long run and leads to some interesting conclusions which will be addressed in the following section.

Finally, the original model with cycles lengthened to thirty five years led to a profit margin of ($125) per acre.

5 CONCLUSIONS

We presented preliminary results from a financial model of alley cropping on marginal agricultural land. These results should not be considered definitive, but do suggest need for further research.

The more promising preliminary results from this study suggest that alley cropping indeed has a theoretical potential to be profitable in the long run. However, as demonstrated by the third and fourth simulations particularly, alley cropping in some cases not be a worthwhile investment.

The third simulation in which the competition function is more severe than in the initial model, shows that further understanding of the impact of timber products as hedgerow products on the alley crops is necessary in order for a more constrained model to be designed. The fourth simulation, furthering the weaknesses of this model, shows that the gains in profits due to alley cropping are largely contingent upon the slightly quickened development of the timber products. If alley cropping does indeed offer a reduction in the time to maturity for certain timber products, alley cropping can prove a positive investment in the long run, but if this is not the case and timber products require a full-term growth cycle, then alley cropping loses its long run financial gains with respect to non-integrated land management methodologies.

An important result was that alley cropping under any conditions never quite performed as well as having a disjoint timber stand, thus a more practical land management methodology may very well be to invest in timber products on a portion of the land which is kept disjoint from the land designated for annual crops.

Our model leaves much work to do. It is obvious to us that more needs to be done to model better the stochastic process that agricultural and timber returns, as well as to account for more complex interactions. We will adjust input parameters as we find better data. Finally, we will evaluate how alley cropping affects farm risk and how policy programs may affect its profitability.

6 LITERATURE CITED

BLS. (2013). US Department of Labor, Bureau of Labor Statistics: Consumer Price Index – All urban consumers, not seasonally adjusted, annual average. 2013, from http://www.bls.gov/cpi/home.htm

Cubbage, F., Glenn, V., Mueller, J. P., Robison, D., Myers, R., Luginbuhl, J.-M., & Myers, R. (2012). Early tree growth, crop yields and estimated returns for an agroforestry trial in Goldsboro, North Carolina. *Agroforestry systems, 86*(3), 323-334.

Gillespie, A., Jose, S., Mengel, D., Hoover, W., Pope, P., Seifert, J., . . . Benjamin, T. (2000). Defining competition vectors in a temperate alley cropping system in the midwestern USA: 1. Production physiology. *Agroforestry systems, 48*(1), 25-40.

Lee, K.-H., & Jose, S. (2003). Soil respiration and microbial biomass in a pecan—cotton alley cropping system in Southern USA. *Agroforestry systems, 58*(1), 45-54.

Miller, A. W., & Pallardy, S. G. (2001). Resource competition across the crop-tree interface in a maize-silver maple temperate alley cropping stand in Missouri. *Agroforestry systems, 53*(3), 247-259.

NASS. (2013). US Department of Agriculture, National Agricultural Statistics Service: Crop Values Annual Summary, 1964-2013. 2013, from http://www.nass.usda.gov/Statistics_by_Subject/Economics_and_Prices/index.asp

Zamora, D. S., Jose, S., & Nair, P. (2007). Morphological plasticity of cotton roots in response to interspecific competition with pecan in an alleycropping system in the southern United States. *Agroforestry systems, 69*(2), 107-116.

Zamora, D. S., Jose, S., Nair, P., Jones, J., Brecke, B., & Ramsey, C. (2008). Interspecific competition in a pecan-cotton alley-cropping system in the southern United States: Is light the limiting factor? *Toward Agroforestry Design* (pp. 81-95): Springer.