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Cashew Adoption in Senegal - Nevin Dawson

Introduction

Senegalese farmers have been cultivating cashew trees for many years, but their use within alley-cropping systems is a relatively new technology that is still infiltrating many rural regions. Cashew alley-cropping is a low-risk, high-return venture with few apparent barriers to adoption. In the small rural villages of Simong and Mamuda, most households have adopted cashew alley-cropping, such that the likelihood of adoption is not an issue. The factors influencing the pace of adoption presents a more interesting question. In this paper, I provide background information on the adoption of cashews in Simong and Mamuda, and then choose the most appropriate of the four common economic diffusion theories (epidemic, order, stock and rank) to explain the pace of adoption. I find that the rank theory is the best fit for conditions in Simong and Mamuda, and elaborate on the implications this theory has for the adoption process that occurred in these villages.

Background

The adoption of cashew alley-cropping has substantial benefits, like increases in cash income and improved soil conditions, with a few drawbacks, like market dependence and harboring pests. This section details the benefits and tradeoffs of cashew alley-cropping in Simong and Mamuda, as well as provides background information on conditions and current production systems in these two villages.

Simong and Mamuda are two small villages of about 200 and 150 people respectively, located 1 km apart in the Sine-Saloum region of Senegal. Simong comprises 22 households, while Mamuda has 7 major households with 2-4 sub-households each. Neither village has running water, but low-voltage solar energy was installed in 2003. Labor is manual with animal traction (usually cows) for plowing and seeding. There is no labor market-all labor is by family or friends. Crops are mostly subsistence, including millet, rice, sorghum, corn, and beans. Cash crops include peanuts, watermelon, vegetables (dry season), and cashews. Most crops are cultivated during the wet season, which runs from mid-June to mid-September. Before the introduction of alley-cropping, cashews were grown primarily in orchards close to the village itself.

Cashew trees grow up to 8 m tall and can reach a diameter of up to 20 m with low spreading branches if left unpruned. Improved varieties common in the region will produce first fruit in the
second year, but it is best to remove these flowers and wait until the third year to begin harvesting. The first fruits ripen in early June several weeks before the wet season begins, and harvest continues for about two months. Cashew nuts are enclosed in a casing which is attached to the bottom of a fleshy pear-shaped "apple". The apple and nut are harvested by hand, and the nut is then twisted off.

Alley-cropping is an agricultural system in which rows of trees are interspersed among rows of traditional field crops. In the case of Simong and Mamuda, alley-cropping refers to rows of cashews spaced 15-20 m apart with millet grown between. Although most farmers have already adopted this technology, adoption only began 7 years ago such that no plots have yet reached full maturity (i.e. the cashew canopy is not yet closed within rows). Many physical and economic aspects of cashew trees make them an attractive option for alley-cropping. A line of cashew trees serves as a firebreak, its dense canopy shading out any source of fuel for an approaching blaze. Any trees planted in agricultural fields will serve as a windbreak. This reduction of wind speed is especially important with the region's very flat terrain and spindly 2.5 m tall millet, which is very vulnerable to wind damage. Both fire- and windbreaks are communal benefits, as they extend beyond the boundaries of the alley-cropped plots. Tree roots reach deep into the soil and are able to bring up nutrients that crops are unable to reach. These nutrients collect in the leaves and are cycled into the topsoil after leaf-fall. Root systems also reduce soil erosion through soil stabilization and wind reduction. And finally, while the cashew apples are not presently marketable in Senegal, they are very high in vitamin C and several minerals, and are enjoyed by children when in season. The potential for the development of marketable apple products such as preserves, juice, and dried fruit is high and a Senegalese nongovernmental organization is currently extending these skills.

In addition to physical and environmental benefits, cashew alley-cropping provides operational and economic advantages to adopting farmers. The relatively early ripening of cashew fruit allows for its harvest to begin before the cultivation of other crops begins, thus spreading labor out from the bottleneck normally present at the onset of the wet season. Cashew harvesting is relatively non-strenuous and can be performed by children who would oftentimes be otherwise unemployed. As with any diversification, the addition of cashews to a farming system will increase its ability to absorb shocks from crop failure, low prices, and pests or pathogens.

Capital required for alley-cropping adoption is minimal or zero, but the labor required can be a limiting factor. Seeds are available locally from friends or relatives, and can be planted directly in the fields. For a higher survival rate seedlings can be grown in special tree sacks in a nursery, weeded once or twice, and then outplanted after several months. More labor is required for this method, but free sacks can be acquired at the nearest government Water and Forestry agency, and the cost of travel can be dispersed among multiple households. The changeover from monocropping to alley-cropping takes up to 10 years as the trees grow and shade out more and more of the intercrop. This gradual change allows for adjustments in variables like labor allocation and consumption habits to be made slowly and without the large errors that can accompany sudden drastic changes.

While fairly healthy and able to meet all basic needs, these two villages are very cash-poor due to a largely subsistence economy. Reliance on subsistence crops results in a steady source of food, but very little money to spend on things like clothing and medicine. Cashew alley-cropping represents an opportunity to dramatically increase income and buying power for non-food goods and thereby increase quality of life.

As cashew trees in the alley-cropping system begin to shade out a proportion of the intercropped millet, millet yield will begin to decline. This reduction in subsistence crops, i.e. food, will be compensated by an increase in bought food, made possible by the additional income from cashew
sales. Diet variety and overall nutrition may increase with this ability to choose a higher proportion of their diet, although extension efforts may be required in order for this new freedom to be fully exploited.

The following descriptive model further explains current conditions in Simong and Mamuda.

Assume:
* Farmers want to maximize their utility
* Only cashew and peanuts are sold in the market (subsistence crops have no market value)
* Transactions cost increases with volume of cashew sold
* External income does not conflict with cashew or subsistence crop production (different seasons)

Max:

\[ U = u(S, Y, l) \] (1)

Subject to:

\[ S = HS(LS, KS)*AS \] (2)
\[ C = HC(LC)*AC \] (3)
\[ G = HG(LG)*AG \] (4)
\[ Y = PC*C + PG*G - PK*KS - t(C) + X \] (5)
\[ A_{\text{total}} = AC + AS \] (6)
\[ L_{\text{total}} = LS + LC + LG \] (7)
\[ T = l + L \] (8)

Where:

\[ S = \text{subsistence crop total yield} \]
\[ Y = \text{income} \]
\[ l = \text{leisure time} \]
\[ H = \text{yield/unit area} \]
\[ L = \text{labor time} \]
\[ K = \text{capital input} \]
\[ A = \text{area} \]
\[ C = \text{cashew total yield} \]
\[ G = \text{groundnut (peanut) total yield} \]
\[ P = \text{market price} \]
\[ t = \text{transaction costs} \]
\[ X = \text{other income} \]
\[ T = \text{total time} \]

Although there is no labor market, a household's labor resource is valuable for its role in the cultivation of subsistence crops, including peanuts during the wet season, as well as many dry season activities. Because the optimum time for seeding and planting cashews is also during the wet season, the labor required for adoption reduces the labor available for peanuts. This makes acquisition cost equal to the utility of lost yield of subsistence crops plus the utility of lost income from peanuts. For the wet season in which adoption occurs:

\[ PA = UAS + UAG \] (9)
\[ UAS = U(HS(LAS,KAS)*AS - K) \] (10)
\[ UAG = PG*(HG(LAG,KAG)*AG - K) \] (11)
\[ L_{\text{TOTAL}} = LAS + LAG + LS + LG \] (12)
Where A is acquisition, and LAS, LAG, KAS, and KAG are labor time and capital that would be used for subsistence crops and peanuts respectively if adoption had not been chosen. Although an adopting farmer regains capital that would have gone into the production of other crops, we can assume that the disutility of PAS and PAG is greater than the utility of KAS and KAG, or else the capital input would add no value to the system, i.e., a farmer only has incentive to add fertilizer if the utility of the expected yield increase is greater than the utility of the capital.

**Economic Diffusion Theories**

Four economic theories are commonly used to model diffusion of an innovation: epidemic, order, stock, and rank. In this section I briefly discuss each and its compatibility with the situation in Simong and Mamuda. I find that the rank model is best-suited for use in Simong and Mamuda.

The epidemic theory is the classic diffusion model (see Mansfield 1961). It assumes that all firms have an equal likelihood of adoption, and that a firm's decision to adopt is based on the amount of information about the new technology they have received from other adopters in their social network. In Simong and Mamuda, cashews have been grown in village orchards for many years so knowledge of the tree's properties is widespread, and the small village sizes promote quick information transfer. While there may be some lag in information availability with regard to the specifics of inter-cropping, other factors overshadow these effects in the adoption decision. This model is therefore not well-suited to cashew adoption in Simong and Mamuda.

The order diffusion theory assumes that the present value of the difference in returns between new and old technologies, or "net return on adoption," is determined by access to a locally limited critical resource like land or a limited labor pool with the necessary skills, so earlier adopters receive higher net returns because they are able to seize a larger share of this limited resource. More and more firms adopt as net return on adoption increases over time due to external economies of scale, learning by doing, falling search costs, and/or depreciation of existing capital (Blackman 1999). Resources required for cashew adoption are land, seeds, and labor. Although land and labor are limited, neither resource is communal nor publicly available so early adopters gain no advantage in terms of these resources. Early adopters may gain an advantage through earlier access to market networks leading to reduced transaction costs and higher net returns. However, this long-term
scenario is not likely to play into a farmer's adoption decision. For these reasons, the order model is not suitable for cashew adoption in Simong and Mamuda.

The stock model builds on the concept that early movers obtain higher returns through a bigger share of the market. It goes further to say that the innovation reduces production costs enough to reduce market price. Net return on adoption falls for the marginal adopter due to unavailability of a limited resource, but it also rises over time due to the factors listed for the order model. As these effects are similar to the early adoption advantage described above, the significant lag between adoption and full production capacity also nullifies this approach for use in Simong and Mamuda. That is, late adopters will be at a disadvantage, but because the full effect of this disadvantage will not be felt until 5-10 years down the road when the trees are at full production level, it does not influence adoption, which occurred in Simong and Mamuda almost completely within a span of 5 years.

The rank model assumes that heterogeneity in one of several critical variables determines the rate of diffusion. Like all models discussed here, the rank model assumes that net return on adoption increases over time, and that a firm will adopt when the net return exceeds acquisition costs and becomes positive. The possible critical variables are capital, firm size, beliefs about profit, search costs, input prices, input productivity, and regulatory costs. Of these variables, labor availability (input prices) and beliefs about profit are most likely of importance in Simong and Mamuda. When learning by doing, falling search costs, and/or depreciation of existing capital boost net returns enough to outweigh uncertainty and costs of labor, more and more people will adopt. The rank theory is a good approximation of the situation in Simong and Mamuda. In the following section I will elaborate on rank effects as they are likely to appear in Simong and Mamuda, with an emphasis in turn on the critical variables of 'labor variability' and 'beliefs about profits.'

**Rank Model in Simong and Mamuda**

Labor is the input in Simong and Mamuda that is likely to cause heterogeneity in time of adoption across households. The value of labor varies by household with respect to available labor per unit of cultivated land. The quality of labor available is also a factor, as girls, boys, women, and men all have different suites of fairly rigid specializations (e.g. women and girls work in the gardens but only women work in the rice paddies; boys and girls but not adults care for livestock). Households with more labor per unit land have lower-valued labor. Since labor is a key input for cashew production, opportunity costs for other crops will be lower and returns on adoption will be higher for these households. Because cashew yield is a function of labor and net revenue per unit labor is assumed constant across households, households with more available labor will have higher returns on the more profitable cashews compared to the less-profitable subsistence crops (in terms of utility) and peanuts.

Beliefs about profits are also a likely difference among potential adopters. The amount of optimism or pessimism a farmer holds about the potential returns on adoption will effectively set the net return on adoption by which time of adoption is determined (Stoneman 1980). In this scenario, the most optimistic farmers with the highest expected net returns will be the first to adopt, and the average perception of net returns will increase in sync with the real returns, exceeding acquisition costs for more and more pessimistic farmers. The exhibited level of pessimism is likely correlated with risk averseness.
Conclusions

These observations on the factors involved in the adoption of cashew alley-cropping lay the groundwork for further research on time of adoption in Simong and Mamuda. Now that the rank economic theory of diffusion is established as the appropriate framework, this theory can be applied to empirical data to test for the predicted effects.

Works Cited


1 Increasing external economies of scale are not likely to be an issue in the Simong/Mamuda scenario since external infrastructure is already in place for the sale of cashews. It is possible however for the current infrastructure to become overloaded as cashew production increases, causing an increase in transaction costs and decrease in net return, which could then be followed by increasing external economies of scale and increasing net returns.

2 For example, suppose that the national price of cashews is higher than the local equilibrium price, and cashew buyers are looking for more business when adoption begins. Early adopters are a new source of cashews and shift supply out until the local equilibrium price rises to meet the national price while forming long-term relationships with buyers. Late adopters are always one step behind early adopters, and must sell to whomever they can find and pay higher middleman fees.
3 Karshenas and Stoneman (1993) state that a firm's personal net return on adoption is static and adoption occurs when acquisition cost drops below net returns. I believe Blackman's interpretation of the model (1999) is much more appropriate for Simong and Mamuda, as net return is more likely to increase than acquisition cost is to decrease in these villages, where acquisition costs are the relatively stable opportunity costs of foregone production of other crops.

4 Labor prices are in terms of opportunity costs for subsistence crop and peanut cultivation, as described in (9) - (12).

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