INTEGRATION OF MEDICINAL AND CULINARY HERBS IN AN AGROFORESTRY COMBINATION ON ST. CROIX, UNITED STATES VIRGIN ISLANDS

By

BRIAN N. BECKER

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This document is dedicated to the small-scale farmers of St. Croix.

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INTEGRATION OF MEDICINAL AND CULINARY HERBS IN AN AGROFORESTRY COMBINATION ON ST. CROIX, UNITED STATES VIRGIN ISLANDS

By

Brian N. Becker

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Farmers in the United States Virgin Islands (USVI) may find economic advantages by diversifying their agricultural systems with lesser-known crops. Bush teas derived from culinary and medicinal herbs are a part of the local culture of the Virgin Islands that can be adapted for internal and export markets. This study examined the production of high value culinary and medicinal herbs intercropped with *Moringa oleifera*, a small multipurpose tree, on St. Croix, USVI. The objective of the study was to assess the productivity and economic costs and benefits of selected herbs when intercropped with *Moringa* compared to their sole-crop yields. The study, conducted on farm and at the Agricultural Experimental Station (AES), University of the Virgin Islands, included thirteen species of herbs along with *Moringa*. Herb intercropping and *Moringa* hedgerows were established with drip irrigation in strip-split plot designs with randomized subplots. Yields were determined from harvests and inputs were totaled for calculating economic returns. Herbs were ranked according to their sensitivity to intercropping and Net Present Value (NPV), Benefit/Cost Ratio (BCR) and Relative Net Return (RNR) criteria were employed for comparison of the profitability of the various

sole and intercrop systems. Sensitivity analyses were conducted with four different discount rates and five different market prices for herb intercrops.

Yields of all intercropped herbs were lower than their sole-crops. On-farm yields were not statistically different between treatments while the yields at the AES demonstrated statistical differences among treatments. Between species comparisons indicated that *Cymbopogon citratus* and *Stachytarpheta jamaicensis* performed similarly with the highest yields, *Cymbopogon* yields being slightly higher. Economic analysis indicates that *Cymbopogon* provided the greatest economic return, NPV and BCR, while *Ocimum basilicum* had the greatest RNR. Comparison of results from this research to previous AES enterprise budgets suggests that even one of the lowest yielding systems tested, the *Allium schoenoprasum* sole-crop, will provide greater economic return than the same unit area of conventional tomato. Suboptimal densities and invading *Moringa* roots likely affected intercrop herb yields as much as shading did. Future research on herb culture and planting density on yields is warranted.

CHAPTER 1
INTRODUCTION

Agriculture has figured prominently in the history of St. Croix. One of the three principal islands of the United States Virgin Islands (USVI), St. Croix, in the eastern Caribbean, developed during the heydays of the colonial era to become, by the eve of the American Revolution, the sixth leading producer of sugarcane (*Saccharum officinarum*) in the West Indies. The loss of cheap labor after the abolition of slavery followed by shifts in global markets led to a decline in plantation agriculture and, finally, the closing of the last sugar factory in 1966. After Castro's Cuba became off-limits to American tourists, the USVI redefined themselves as popular tourist destinations (Dookhan 1994). Today, St. Croix seeks to rebuild her economy with an eclectic mix of industries such as petroleum refining and casino gambling.

Despite challenges, small-scale farming persists on St. Croix for domestic consumption and local markets. Like small-scale producers throughout the world, St. Croix farmers face competition from industrially produced imported products. One viable strategy for small-scale farmers is to produce specialty products for niche markets. In almost any farm, home- or patio-garden in the USVI culinary and/or medicinal herbs can be found, grown for seasoning dishes or brewing up 'bush tea'. This investigation examines the potential for small-scale farmers to produce culinary and medicinal herbs on a commercial scale.

Historical Overview

The Virgin Islands usually generate images of tropical paradise. These popular tourist destinations have been well visited beginning in the 3rd century B.C. when the Taino (Ciboneys) followed by the Arawaks and Caribs indigenous groups settled the islands in successive waves, traveling up the Lesser Antilles island chain from South America. On his second voyage in 1493, Christopher Columbus named what is now the island chain of British and US Virgin Islands after St. Ursula and her pilgriming virgins. A long period of intermittent European settlements ensued from the 16th to the 18th century during which time the Spanish, Dutch, English, French, Knights of Malta, and Danish flags flew over the Virgin Islands. The strategic location of the islands along the Anegada Passage, a key sailing route, attracted pirates and buccaneers, who preyed upon Spanish galleons loaded with South American silver. By the mid-eighteenth century, plantations producing cotton (*Gossypium hirsutum*) and sugarcane with African slave labor were the basis of the economy. The loss of cheap labor after emancipation of the slaves on St. Croix in 1848 and competition from sugar beets (*Beta vulgaris*) grown in Europe spelled an end to the plantation era by end of the nineteenth century. Since the early twentieth century the United States of America has maintained sovereignty over the Virgin Islands of St. Croix, St. Johns and St. Thomas (Dookhan 1994).

Current State of the Economy

Historically dominated by plantation economies for export markets, many Caribbean islands like the USVI have diversified through industry and tourism. Changes in the global economy and environmental challenges have meant that some islands have enjoyed only a precarious prosperity. Of the three principal islands of the USVI, St. Johns and St. Thomas offer tourists azure waters lapping palm-lined white sand beaches, a national park and a natural deep-water port that can provide safe harbor for the largest of cruise ships. Capitalizing on her natural harbor, St. Thomas has prospered since the colonial era as a free trade port. In 2002, over two million tourists (BER 2003) shopped for duty-free jewelry in the markets of Charlotte Amalie, the port city on St. Thomas and capital of the territory of the USVI.

St. Croix, in contrast, hosted fewer than 250,000 tourists during 2002 (BER 2003), despite her natural attractions such as scuba diving 'The Wall' at Cane Bay, a nine hundred fifty meter coral-encrusted drop-off just a short swim from shore, and the Buck Island Reef National Monument, a three and half square kilometer underwater preserve. Created by upliftment rather than volcanism like St. Thomas and St. Johns, St. Croix bears a mostly rocky coastline with no natural deep-water harbor, limiting her ability to capitalize on tourism. Instead this larger island has relied on agriculture and industry.

While the USVI overall are still heavily dependent on tourism, which comprise seventy percent of the economy, manufacturing and one of the worlds largest petroleum refineries on St. Croix accounts for another twenty percent. Today, agriculture contributes to less than ten percent of the USVI economy and employs only one percent of the labor force (CIA 2003). As of January of 2003, the overall unemployment rate in the territory stood at 9.6 percent. Illuminating the unemployment and underemployment disproportionably felt on St. Croix, her 12.0 percent unemployment rate is nearly double the 7.6 percent rate of St. Thomas and St. John (Mills 2003). Civil unrest in Venezuela during the summer of 2002 cut off the supply of crude oil to St. Croix's refinery, resulting in the layoff of 300 employees. Nervousness amongst tourists over terrorism has been attributed to an 8.2 percent decline in tourist arrivals in 2002 (BER 2003).

Environmental Challenges

Ecological challenges also abound in the Virgin Islands. St. Croix is routinely hit by hurricanes, experiencing four major storms in the past 15 years, hurricanes “Hugo” (1989), “Marilyn” (1995), “Georges” (1998) and “Lenny” (1999). Before the plantation era began, St. Croix was covered in thicket vegetation from the arid east side gradually transitioning into forests in the wetter west end. St. Croix’s geographic isolation, even during the Ice Ages, permitted the evolution of a number of endemic species (Wiley and Vilella 1998). Drastic alterations of the island’s vegetation composition began during the Danish era when most of the arable land on St. Croix was converted to cotton and sugarcane plantations (Dookhan 1994). In the early 20th century the shrubby nitrogen-fixing ‘tan-tan’ (*Leucaena leucocephala* syn. *glauca*) was introduced as a goat browse. The plant readily naturalized and now aggressively dominates open areas, displacing St. Croix’s indigenous vegetation and requiring fields used for agriculture to be plowed and pastures burned to keep them open. The centuries of deforestation for timber and agriculture have stripped St. Croix’s soil of most of its water-retaining humus layer. The lack of tree cover, continually blowing easterly winds and the low relief of the island have left St. Croix semiarid with no naturally occurring surface water or perennial streams. When rain does fall, rapid runoff carries sediment and rubbish from bare agriculture fields, overgrazed pastures, streets, parking lots and construction sites directly into the ocean, threatening St. Croix’s coral reefs.

St. Croix Agriculture

The most recent soil survey of the USVI (Davis 2000) estimated that approximately sixteen percent of the surface area of the islands is devoted to agricultural purposes. Seventy-eight percent of this land is used for grazing or pasture and the majority of it is located on St. Croix. Censuses of the agriculture sector for the USVI (USDA 1995; 1998) dating back to 1987 indicate that after contracting through the mid-nineties following the destruction of Hurricanes Hugo (1989) and Marilyn (1995), the agriculture sector has begun to expand again. Especially noteworthy is the increase in sales of horticulture specialties products. As a small market on the far end of a distant marketing chain, the prices of inputs such as fertilizer, pesticide, irrigation and other farming equipment generally place Virgin Island farmers at a competitive disadvantage against imported produce and commodities. Unique and indigenously produced specialty products, however, may be suitable for lucrative niche markets (Palada et al. 2000).

Culinary and medicinal herbs are specialty products that Virgin Island farmers produce for a steady local market. The consumption of herbal teas (rather than green or black tea, *Camellia sinensis*) for their culinary and medicinal properties in the Virgin Islands is a legacy of the synthesis of African and European healing traditions blended on the islands during the plantation days (Kuby 1979). Commonly referred to as 'bush medicine' or 'bush tea' throughout the West Indies, these teas are consumed on a daily basis by Virgin Islanders for their medicinal effects or simply as culinary refreshments. Herb production is usually small-scale and sales are mostly in farmers' markets and roadside stands. Herbs are important to the diet of locals and tourists alike, and their economic significance to small-scale farmers provides the justification for research on USVI herb horticulture and the potential for their commercial production for export markets (Palada et al. 2000).

A Way Forward

The Agricultural Experimental Station (AES), University of the Virgin Islands (UVI), in cooperation with the Center for Subtropical Agroforestry (CSTAF), University of Florida, has been investigating agroforestry[1] as a means to address some of the social, economic and environmental issues prevalent on St. Croix. Researchers at the AES on St. Croix are investigating combinations of agroforestry systems that will permit farmers to produce economically viable crops while maintaining a cover of useful or native trees that will conserve the soil resource, contribute to improvements in the water quality and quanity and enhance the natural beauty of the island (CSTAF 2003). Drawing upon the indigenous wealth of knowledge and traditions related to medicinal and culinary herbs in the Virgin Islands, the following research investigates the potential economic viability of incorporating herbs in an agroforestry combination utilizing a multipurpose tree on St. Croix. This study evaluates the physical yields and economic cost and benefits of establishing and producing the desired products in alleys of the multipurpose tree *Moringa oleifera* versus in sole stands. The specific objectives of the study are to compare the productivity of culinary and medicinal herbs produced in alleys of *Moringa oleifera* versus in sole stands; and to determine the direct economic costs and benefits of establishing and producing culinary and medicinal herbs in alleys of *Moringa oleifera* by small-scale farmers on St. Croix, United States Virgin Islands.

[1] Agroforestry is the deliberate combination and interaction between trees and crops and/or animals in sustainable systems that can maintain or increase the productivity and conserve the soil resource base in a technology or arrangement that is acceptable to local farmers (Nair 1993).

CHAPTER 2
LITERATURE REVIEW

St. Croix, like many Caribbean islands, has sought to diversify her agricultural economy with non-traditional crops. Environmental sustainability has been recognized as a requirement for successful intensification of the island agriculture (Davis 1993). Export diversification through horticultural products, particularly fruit tree, herb and botanical products, can prove lucrative for countries that have suitable growing sites if quality standards can be met (Wainwright 1994). Plantation design and maintenance as well as marketing have long been recognized as important areas requiring attention for Caribbean horticulture (Pinchinat et al. 1981). Diversification with lesser-known fruits such as barbados cherry (*Malpighia glabra*), breadfruit (*Artocarpus communis*), carambola (*Averrhoa carambola*), cashew (*Anacardium occidentale*), guava (*Psidium guajava*), lychee (*Litchi chinensis*), lime (*Citrus aurantifolia*), mangosteen (*Garcinia mangostana*), papaya (*Carica papaya*), passion fruit (*Passiflora edulis*) and soursop (*Annona muricata*) and in combination with vertical integration of producers, processors and marketing operations is recommended for tropical products originating far from consumers (Marte 1988). This chapter reviews relevant literature on culinary and medicinal plant production, the agroforestry practice of alley cropping and economic evaluation techniques that can be utilized to value this production system.

Culinary and Medicinal Herbs

The USVI has a suitable climate for the production of tropical herbals and botanicals for domestic and export markets (Palada et al. 2000). Increasing popularity in the domestic and international markets and well suited for cultivation in both small corners of homegardens and out in the fields, the development of the botanical and medicinals sector is becoming increasingly attractive. Research into herbs at the USVI Agriculture Experiment Station, University of the Virgin Islands on St. Croix, has examined a variety of mulches for weed control and irrigation methods for improved production. Disease and pest resistance of various cultivars, fertilizer response, optimal spacing and minimum water requirements have also been investigated (Collingwood 1991a; 1991b; Palada et al. 1993; 1995a; 1995b; 2000).

Medicinal and Aromatic Plants–High Value Products for Agroforestry

Agroforestry has been evolving since the 1970's as a mechanism for poverty alleviation and a tool for local and regional development (Mercer and Miller 1998). The domestication of lesser known, yet locally popular, multipurpose trees and shrubs is one avenue to achieve these objectives (Leakey and Tomich 1999). The popularity of culinary and medicinal plants, many of which are annuals, makes them attractive potential products for land temporarily out of production as agroforestry systems mature. It is also more desirable for small-scale producers to have agroforests that provide a year-round supply of products from a number of different species (Leakey and Simons 1998). Commercialization, however, should be considered in tandem, as regional household-level use is an insufficient motivation or justification for farmers and/or researchers to undertake the intensive and expensive domestication process (Leakey and Izac 1996). Agroforests, intermediaries between natural forests and plantations, are suitable for production of both herbal medicines and natural products for national and international niche markets (Michon and de Foresta 1996). Reliable markets can also be found close to production sites among relocated city dwellers for whom cultural attachment to herbal remedies still persists (Waterman 1992).

Cultivation and Marketing of Medicinal and Aromatic Plants

Cultivation is increasingly being promoted to meet market demands, stem the overexploitation and erosion of the genetic base, and as a potential foundation for enterprise and community development. Cultivated materials can assuage market fluctuations, improve quality control, ensure botanical identification and reduce the potential adulteration of the plant material, provide an arena for genetic improvement and agronomic manipulation and facilitate post-harvest handling (Palevitch 1991). For many popular aromatic, culinary and medicinal herbs field production techniques are well developed. Many species, such as basil (*Ocimum basilicum*), are either started from broadcast seeds or transplants set out at four to six weeks in rows 30 to 60 cm apart. Basil can have in-row spacing of 20 to 40 cm, and should be pinched at 12 cm to encourage branching (Simon 1985; Putievsky and Galambosi 1999). Higher density increases competition between plants, producing higher oil and dry herb production. Lower density planting (15 to 17 versus 8 to 14 plants per m^2) is better for fresh herb production (Putievsky and Galambosi 1999). In tropical regions three to five harvests can be expected per year, where plants are harvested prior to flower appearance for fresh or dried leaves (Simon 1985). For essential oils, plants are harvested from just prior to flower appearance up to the time when 50% of the seeds have ripened (Putievsky and Galambosi 1999).

Research continues on crops lesser known in the United States (US). Five volumes of the proceedings of the national New Crops symposiums (Janick and Simon 1990; 1993; Janick 1996; 1999; Janick and Whipkey 2002) have been released providing information on new crops for marketers, researchers and US growers. Meanwhile, research is well established in countries like India where many aromatic, culinary and medicinal herbs unfamiliar to the US are commonplace. For example, in two recent studies from India, Singh et al. (1998) concluded that pigeonpea (*Cajanus cajan*) intercropped with palmarosa (*Cymbopogon martini*) in Lucknow competed more for light than for water or nutrients due to differential rooting patterns, while Singh (1999) identified the moisture regime and fertilizer application required for the optimal yield of East Indian lemongrass (*Cymbopogon flexuosus*) biomass grown in Bangalore but concluded that neither had an effect on the quality or content of essential oil.

Cultivation of medicinal and aromatic herbs can provide a steady supply for which sound marketing plans can be developed. Plantations geared towards market booms, however, may overwhelm benefits that can be captured by small-scale producers (Leakey and Izac 1996). The development of high yielding domesticated medicinal plants, the product of research efforts for plantation production, will mostly benefit elites with access to capital and just as the high-yielding grains of the green revolution. Small holders will be hit with the double-whammy of not being able to afford capital intensive ‘improved’ stock then face the market price drop for their ‘unimproved’ products as a result of the output of highly productive plantations. Agroforestry practices such as alley cropping or forest farming may be utilized as an alternative to plantation agriculture, as is the case with American ginseng (*Panax quinquefolius*). Limited supply, seasonality and genetic variety of undomesticated species are disadvantages when seeking larger markets because the products will lack the market appeal to encourage greater commercial interest. Therefore, small-scale producers like the farmers on St. Croix, who cannot compete with commercial production, should focus their efforts on lesser known products and cultivate niche markets.

A Role for Agroforestry

General Introduction to Agroforestry

Agroforestry is a name for land use systems and practices that spatially and temporally combine woody perennials with agricultural crops and/or livestock. An agroforestry system is a specific local example, variations of which can be grouped into agroforestry practices – alley cropping, forest farming or silvopasture (Nair 1993). The science of agroforestry includes the ecological and economic interactions between the components of the systems. These potential interactions between trees and crops in an intercropped system can be commensalistic, where there is a positive effect on one species and no observable effect on the second, amensalistic where there is a negative effect on one and no observable effect on the second species, inhibitory where there is a negative effect on both species, or synergistic interaction where there is a positive effect on both species (Nair 1993). Key characteristics of agroforestry systems are that trees recycle nutrients and regenerate soil fertility, shading helps in weed suppression and hedgerows provide in situ mulch and green manure. Nitrogen-fixing tree species can increase the supply of nutrients by biological N_2 fixation, retrieval of nutrients from below the rooting zone of crops and reduction of erosion and nutrient loss from leaching (Kang 1997).

Introduction to Alley Cropping

Alley cropping or hedgerow intercropping should be particularly suitable technologies for the conditions present on St. Croix, potentially reducing soil erosion, increasing soil fertility positively influencing yields and reducing disease and insect infestations. In the tropical alley cropping system, the trees are periodically pruned and the leaves, if not used for other purposes, are either placed on the surface as mulch or incorporated into the soil as a green manure. Incorporated prunings and root turnover affecting the physical and chemical nature of the soil as mentioned, are an integral part in the management of the nutrients cycle of the system (Nair 1993). Benefits of alley cropping depend on the site, component selection, age of the system and management. While the soil fertility improvements take time to develop, the sometimes less obvious but more pressing soil erosion control effect can be immediate (Haggar 1994). Tropical alley cropping and hedgerow intercropping research conducted in sub-Saharan Africa, south Asia and southeast Asia (Paningbatan et al. 1995; Presbitero et al. 1995; Craswell et al. 1998; Narain et al. 1998) attributes decreased soil erosion and increased soil fertility to a combination of rainfall interception by mulches from pruning, contours and hedgerows that intercept water runoff and encourage soil deposition and a fallow effect resulting from having trees present, particularly when they are nitrogen fixers. The underlying principle is that fast-growing, preferably N_2-fixing trees and shrubs will create soil-improving conditions (recycling nutrients, suppressing weeds, and controlling erosion on sloping lands) similar to the fallow phase of shifting cultivation (Nair et al. 1999).

<u>Agroforestry Interaction and Competition</u>

Before agroforestry can be announced as a panacea, it is warranted to be clear about what takes place (Sanchez 1995). While facilitative effects are evidenced from the interaction between trees and crops, competition is also present. Facilitative effects include hydraulically lifted water by deeper roots of trees becoming available to herbaceous companion plants (Richards and Caldwell 1987; Caldwell et al. 1998) and the potential for translocation of nutrients such as phosphorus as was observed with kacholam (*Kaempferia galangal*) intercropped with coconut (*Cocos nucifera*) in humid southern India (Kumar et al. 1999). Competitive effects can be more pronounced, however, as was observed in an experiment in the Phu Wiang watershed, northeastern Thailand, where the yields of cassava (*Manihot esculenta*) and mungbean (*Vigna radiata*) rowcrops, intercropped with *Eucalyptus camaldulensis*, *Leucaena leucocephala* and *Acacia auriculiformis* grown for charcoal production, declined significantly after two years (Wannawong et al. 1991). Eucalyptus grown for timber provided some benefits as shelterbelts, but the overall effect in semiarid northern India was a steadily increasing crop loss attributed to shading of the intercrop as the trees aged (Ahmed 1989). And hedgerow intercropping research with Leucaena, pigeonpea and sorghum (*Sorghum bicolor*) in semi-arid southern India utilizing 4 to 5 m alleys had severe yield reductions after the first year due to tree competition for water (Rao et al. 1990).

It is misleading to generalize about hedgerow intercropping; system performance is location specific and sensitive to management (Nair et al. 1999). Sanchez (1995) concluded that the fundamental principles of agroforestry are that competition and complexity determine profitability and sustainability. The objective is to develop designs that maximize the facilitation while minimizing the competition. While early research into alley cropping was overly optimistic, it will work on sites that are naturally fertile with ample rainfall. Sanchez (1995) recognized that agroforestry practices will not likely meet 100% of the nutrient requirements for maximum yields of most agronomic crops, though nutrients from the available organic material subsidizes the requirements for inorganic fertilizer. Additionally, Sanchez (1995) noted that agroforestry must come to terms with the paradox that while what is profitable is not necessarily sustainable in agronomic, ecological, or social terms, agroforestry must be profitable if adoption is to be expected.

Economic Evaluation

Economics is a critical factor in producers' adoption of new crops and technologies. Aspects of economic benefits of agroforestry include 1) maintenance or restoration of the productivity of land or the provision of low cost alternatives to fertilizer and soil conditioners, 2) direct economic benefits to farmers by the addition of products or the diversification of the range of farm outputs, 3) introduction of trees into agricultural lands leads to a reduction in labor per unit area of land required for the trees compared to traditional agricultural crops, freeing up or reducing labor loads, 4) products provided by trees that normally would be bought, and 5) capital reserves in the form of trees that accrue value over time and can be harvested as needed (Arnold 1983).

A basic assumption of agroforestry is that benefits to farmers and the community will increase with agroforestry. A comparison of systems 'with' (treatment) and 'without' (control) a particular agroforestry technology is the basis of comparative research. The comparison of 'with' and 'without' is distinguished from a 'before and after' comparison because conditions change over time and benefits and costs unrelated to the agroforestry practice under investigation may manifest (Gittinger 1982). In addition to the science of testing the biophysical characteristics of the basic assumptions, economic analysis is required to determine the most practical and appropriate allocation of scarce resources.

The cost-benefit analysis can be used to determine which of a combination of systems is the most efficient. The three principal components of a cost-benefit analysis are the determination of Net Present Value (NPV), the Internal Rate of Return (IRR) and the Benefit/Cost ratio (B/C ratio). The NPV of a system is the sum of the discounted benefits (goods and services) minus the costs (excluding intangibles) generated over a period of time. If the NPV is greater then zero then the system will have a net economic benefit over the time evaluated. This provides insight into the magnitude of the value of a system, and can be used as a basis for comparison between mutually exclusive systems i.e. either/or comparisons (Gittinger 1982). This is particularly important for agroforestry systems where various products will mature at different times during the lifetime of a system.

The IRR is the internal rate of return on the investment, the amount of interest that is generated by the investment. Looked at another way, it is the maximum amount of interest that can be paid for the project to still break even. A higher IRR is preferred when comparing alternatives (Wojtkowski 1998).

The B/C ratio, simply the ratio of benefits to costs currently being incurred by an enterprise modified by an estimator that discounts the ratio over time, provides a snapshot of the present value of the system. The B/C ratio allows a simple comparison of the costs and benefits, a ratio greater than one indicating a net benefit. The B/C ratio can be used as a basis for comparison between alternative systems, when the same discount rate is applied. The discount rate at which the B/C ratio is equal to one is the IRR[2].

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[2] All three indicators, NPV, B/C ratio and IRR are used in an economic analysis; however, they may not necessarily lead to the same conclusion. The B/C ratio is a comparison of the sum of benefits and costs, without regard to magnitude while the NPV considers the magnitude of the sum of benefits to costs, but may hide particular costs that may be unacceptable. For example, the B/C ratio of a project with $5 dollars of costs and $10 dollars of benefits would be the same as a project with $500 dollars costs and $1000 benefits, while they would have very different NPV's. Conclusions based solely on IRR would be based on economic criteria without regard to the quality or quantity of actual benefits or costs incurred.

Discounting is required because not all the benefits and costs incurred during the lifespan of a project can be directly compared. While direct comparisons are not possible, discounting theoretically permits comparisons of monetary value across time. Money invested in a project now has an opportunity cost – the potential interest on the money if it had been invested instead of spent. Discounting projects the value of an investment at maturity in today's value, the opposite of compounding[3].

For economic comparisons between alternative systems to be valid, the same discount rate must be applied to each. Discount rates also carry an inherent bias. High discount rates distort the evaluation of projects that might have the majority of the costs up front and the benefits further down the line. This is because the costs would be valued in or near today's values while the benefits would be valued at discounted rates, deemphasizing the true benefits. When selecting a discount rate, one can use the investor's best alternative investment (equity), the current interest rate of borrowed capital (loan debt) or a mixture of equity and debt. Subsistence farmers without access to credit require a social discount rate that is based on farmers' time preference. A high time preference for a return on their investment requires a higher discount rate. IRR can alleviate this problem of searching for a proper discount rate by determining the discount rate where NPV = 0 (Betters 1988).

[3] Discounting attempts to accommodate the time value of money, considering that money available today is worth more to an individual than the same amount available at a future date. A high time preference indicates placing greater weight on current rather than future consumption, requiring a higher discount (interest) rate when determining the present value of a future benefit.

Another way of comparing two systems (i.e. a sole-crop and an intercrop) is by determining the relative net return:

$$RNR = \left[\left(P_a Y_{ia} + P_b Y_{ib}\right) \pm \left(D_{ab}\right)\right] \big/ \left(P_a Y_{ma}\right) \qquad \text{(eq. 2.1)}$$

where P_a and P_b = price of crops *a* and *b*; Y_{ia} and Y_{ib} = yields of intercropped crops *a* and *b*; D_{ab} = differential cost of cultivation of crops combination *ab* compared to the sole-crop of *a*; and Y_{ma} = the yield of sole-crop *a* (Singh et al. 1998).

There are numerous recent examples of economic return studies of alley cropping: Tonye and Titi-Newl (1995) analyzed maize/groundnuts (*Arachis hypogaea*) intercropped with *Leucaena* sp. in Cameroon; Akyeampong and Hitimana (1996) conducted a partial budget, comparing only what was different with and without a maize (*Zea mays*) and *Leucaena diversifolia* alley cropping system on an acid soil in the highlands of Burundi; maize alley cropped with *Gliricidia sepium* in the Philippines was examined by Nelson and Cramb (1998) and Nelson et al. (1998); and Countryman and Murrow (2000) investigated a variety of hardwoods intercropped with maize and soybeans (*Glycine max*) in Iowa to name just a few.

The objectives of maximum or sustainable production are not necessarily compatible with optimum production or conservation. Externalities occur when costs or benefits to others are generated for which the farmer is not compensated or charged (Filius 1982). Failure to account for externalities and market fluctuations can have unintended consequences. In a *Eucalyptus* and *Leucaena* fuelwood project in northwest India that was initiated without preliminary market research and infrastructure development prices collapsed locally from over supply while the country continued to face a wood shortage (Saxena 1991). März (1992) conducted an ex-ante economic potential of neem (*Azadirachta indica*) intercropping with white sorghum, safflowers (*Carthamus tinctorius*), and millet (*Pennisetum glaucum*). He predicted increases in farm income from fruit and wood sales but noted that fruit harvesting conflicted with agriculture activities resulting in decreased food security during harvesting years. Additionally, increased labor would be required for the processing of fruits and wood. He acknowledged that his long term projection of an increased income of 7% was dependent on market prices for the products. Considering fluctuations in market prices, Dunn et al. (1990) preformed a sensitivity analysis of the management of Alder in Ecuador for fuelwood, using multiple prices for labor, transportation and market prices of fuelwood.

The production of culinary and medicinal herbs in diverse agroforestry systems may provide small-scale farmers on St. Croix competitively priced products for local and potential export markets. Agroforestry benefits include soil improvements, microclimate amelioration and soil erosion control. Proper economic evaluation facilitates research by directing allocation of scarce resources. Determination of appropriate discount rates and costs and benefits also provides a basis upon which sound marketing plans can be developed. This study is an initial attempt to provide concrete information for researchers and farmers on St. Croix.

CHAPTER 3
MATERIALS AND METHODS

Site Descriptions

This investigation was conducted on-farm at the private Estate Rattan and at the Agricultural Experimental Station, University of the Virgin Islands, on St. Croix, United States Virgin Islands.

Location and Climate

St. Croix, USVI, is located in the eastern Caribbean (17°45'N, 64°45'W) about 200 kilometers southeast of Puerto Rico. The approximately 218 km^2 island (21,788.8 ha) is nearly 45 km long and no more then 13 km at its widest point. The climate is maritime tropical characterized by fair skies, steady winds and slight seasonal and diurnal fluctuations in temperature. Daily highs during the warmest months, August and September, average 31° C while nighttime temperatures average a balmy 24° C. The coolest months, January and February, experience days and evenings in the mid and low 20's (°C) respectively (Davis 2000). St. Croix's eastern side has low rolling hills while the central and southern sections are low lying with a broad central valley. The northern and northwestern side is punctuated with steeply rising hills, peaking in the west-central at Mt. Eagle (355 m.a.s.l.). Annual rainfall ranges from 500 to 750 mm on the east to 1270 mm on the northwestern side of the island (Davis 2000). While there is no well defined dry season, September through November tend to be the wettest months while January through June are the driest. The nearly continuously blowing easterly trade winds and high temperatures have a drying effect on the island and evapotranspiration exceeds rainfall (Table 3-1). While tropical storms and hurricanes occasionally affect the island, destroying vegetation cover and eroding soil during periods of intense rainfall, they do not contribute significantly to the annual rainfall budgets.

Table 3-1. Rainfall and temperature throughout the Virgin Islands over a 30-year period, and monthly potential evapotranspiration.

Month	Mean monthly rainfall	Mean monthly air temperature	@Monthly potential evapotranspiration
	mm	°C	mm
January	66	24.6	99
February	47	24.6	93
March	53	24.9	113
April	73	25.6	126
May	116	26.3	151
June	75	27.2	159
July	81	27.8	166
August	116	27.8	163
September	144	27.2	149
October	148	26.9	145
November	154	25.8	125
December	96	24.9	109
Total	1169	- - -	1598

@ Potential evapotranspiration estimated by the Thornthwaite formula from open-pan measurements.

Source: Adapted from Davis 2000.

Geology and Soils

The geological history of the island of St. Croix includes periods spent as shallow ocean floor and episodes of active volcanism. The volcanism has long since ceased and the island's sea level appears to have remained roughly the same since the Pleistocene. The parent materials of today's soils of St. Croix are a combination of calcareous marine sediment or volcanic rock. The soils of Estate Rattan and the AES are described as Typic Haplustolls and Typic Calciustolls respectively. Except where calcareous patches erupt to the surface (locally known as 'caliche' and avoided for agricultural purposes) these soils are considered naturally fertile with available water being the major limitation (Davis 2000).

The Rattan site has shallow, stony, well-drained soil on a west-facing slope (~10%), weathered from soft limestone bedrock. Permeability is slow, available water capacity is very low and the bulk density of the soil is 1.3 to 1.4 g cc^{-1} (Davis 2000). Analysis of soil samples conducted by A & L Southern Agriculture Laboratories, Inc. (2003), taken from the site before establishment indicate that average organic matter content is moderate to high (3.6% to 4.3%), pH is alkaline (7.7 to 7.8) and the CEC was determined to be between 36.0 to 39.8 cmol kg^{-1}.

The soil at the AES is a very deep, well-drained coarse-loamy soil formed on alkaline marine deposits on the floor of the broad central valley. The site has a slope of less then 5% and is rarely flooded. Davis (2000) describes the soil as light, with a bulk density of 1.15 to 1.30 g cc^{-1}, permeability as rapid in the rooting zone though restricted in the substratum and the available water capacity declines from high in the rooting zone to dipping below permanent wilting point below 40 cm. Soil samples taken before establishment, analyzed by A & L Southern Agriculture Laboratories, Inc. (2003) had organic matter content between 2.2 and 2.9%, an alkaline soil pH between 7.8 and 8.1, and a high rooting zone CEC, measured between 60.9 and 70.1 cmol kg^{-1}, though Davis (2000) reported that substratum CEC is very low (3.5 to 6.4 cmol kg^{-1}).

Vegetation and Land Use History

The indigenous vegetation of St. Croix, while different from and less diverse as that found on neighboring Puerto Rico, St. Thomas and St. Johns, is typical of the Eastern Caribbean. Since evapotranspiration exceeds annual rainfall in all but the wettest sites on the island, native vegetation on the island generally consists of drought-tolerant types.

Vegetation on St. Croix transitions from cacti and drought-tolerant scrub thicket on the east side to moist forest in the wetter west end. Both the Rattan site and the AES had historically been part of sugarcane plantations. The Rattan site had been fallow under *Leucaena* bush for at least 15 years before the onset of this research. The AES site was originally obtained by the United States Department of Agriculture (USDA) for creation of a Federal Experiment Station. The University of the Virgin Islands AES was established in 1972 and began conducting agricultural research on about eight hectares of the USDA Federal Experiment Station a year later (USDA 2002). The field used for this trial had been fallowed for six months under lab-lab bean (*Lablab purpureus*) and grass prior to initiation of research.

Species Descriptions

Origin and Uses

The multipurpose trees *Moringa oleifera* and *M. stenopetala* and thirteen species of herbs (*Allium schoenoprasum*, *Coriandrum sativum*, *Cymbopogon citratus*, *Eupatorium triplinerve*, *Matricaria recutita*, *Mentha* x *piperita*, *Ocimum basilicum*, *Origanum majorana*, *Rosmarinus officinalis*, *Salvia officinalis*, *Stachytarpheta jamaicensis*, *Thymus vulgaris* and *Verbesina alata*) with culinary and medicinal uses were selected for the study. All of the herbs selected except for *M. recutita* are already grown on the islands and have traditional uses as 'bush teas' and local markets or international markets for their oils and teas. The following section contains brief introductions to each species.

Moringa oleifera Lam., Moringaceae

This small multipurpose tree, hear after referred to as moringa, originally a native of South and Southeast Asia is now distributed throughout the tropics but has only recently been introduced to St. Croix. Elsewhere, moringa is commonly planted as an ornamental and in fencerows or hedges, on account of its rapid growth and vigorous coppicing ability. The leaves, flowers, pods, seeds and roots are edible. The tree is commonly called 'drumstick' on account of the long, green seedpods that can be eaten as a vegetable, and the root that can be ground into a spicy condiment, earns it the alternative name 'horseradish-tree'. The fresh leaves are popular in Asia, prepared as a spinach-like green (Morton 1991, Palada 1996). Dried into powder, the leaves provide a highly nutritive food supplement (Fuglie 2001). Ben oil, extracted from the seeds, is used as a lubricant for watches, a base for perfumes and has medicinal attributes. Crushed seeds are a natural flocculent, used to purify drinking water (Morton 1991, Palada 1996). The flowers, present nearly year round, are an excellent nectar-source for bees (Little and Wadsworth 1989; Bown 2001; Fuglie 2001).

Moringa stenopetala (Baker f.) Cufodontis, Moringaceae

M. stenopetala, native to east Africa, shares many of the same properties and uses as *M. oleifera*, including edibility and flocculating properties. *M. stenopetala* belongs to the 'bottle' group of the Moringa family, characterized by bloated, water storing stems. (Fuglie 2001).

Allium schoenoprasum L., Alliaceae

Chives are a popular perennial, clump-forming culinary herb usually consumed fresh in a variety of soups and salads, with cheeses, potatoes and eggs (Bown 2001).

Coriandrum sativum L., Apiaceae

Coriander is an annual, culinary herb grown for its foliage on St. Croix, commonly found in the farmers markets. Coriander oil, distilled from the leaves and seeds, is fungicidal and bactericidal, used for flavoring gin, vermouth and other liqueurs and is valued in the perfume industry (Bown 2001).

Cymbopogon citratus (DC) Stapf, Poaceae

Lemongrass, native to South Asia, has been introduced throughout the tropics. A perennial grass with a distinctive lemon odor, lemongrass is used on St. Croix in bush teas both for flavor and medicinally to treat fevers (Kuby 1979). Lemongrass is used internationally in food flavorings, aromatherapy and the perfume industry (Bown 2001).

Eupatorium triplinerve Vahl, Asteraceae

Known in the Virgin Islands as "Japana", this perennial herb can commonly be found growing in home gardens. Japana is native to the Atlantic coast of South America and has naturalized on St. Croix. It is utilized in bush tea as a refreshing "cooling" beverage and for treatment of coughs and colds (Thomas 1997).

Matricaria recutita L. syn. *Chamomilla recutita* (L.) Rauschert, Asteraceae

German chamomile is an annual or short-lived perennial native to Eurasia. Along with Roman chamomile (*Chamaemelum nobile*), a popular sedative tea is made from the flowers. German chamomile contains anti-inflammatory and analgesic compounds that are effective in healing burns and preventing infections and ulceration. Numerous commercial products utilize chamomile in everything from cosmetics and hair products to food flavorings (Bown 2001).

Mentha x *piperita* syn. *M. nigricans*., Lamiaceae

Peppermint is an aromatic, perennial herb hybrid between *M. aquatica* and *M. spicata*. Fresh and dried leaves are popularly consumed in teas to settle the stomach. One of the world's most popular flavorings, peppermint oil is used in products ranging from perfumes, toiletries, oral hygiene and medicines, to liqueurs such as crème de menthe and candies (Bown 2001).

Ocimum basilicum L., Lamiaceae

Basil is an aromatic annual or short-lived perennial herbaceous plant native to tropical Asia. A popular culinary and medicinal herb, it has been distributed worldwide. Numerous varieties have developed with varying combinations of volatile oils, ornamental foliage and adaptations to local conditions (Bown 2001). In the Virgin Islands basil, known locally as “mint”, “garden balsam” or “mosquito balsam”, is cultivated for use as a cooking herb and in beverage and medicinal bush teas. A bush tea made from the leaves is used to treat stomachaches (Kuby 1979).

Origanum majorana L. syn. *Majorana hortensis*, Lamiaceae

Sweet marjoram is an annual or perennial sub-shrub native to the eastern Mediterranean. It is an annual in the Virgin Islands. It is a popular culinary herb and is used commercially in body care products and food flavorings (Bown 2001).

Rosmarinus officinalis L., Lamiaceae

Rosemary is a woody perennial shrub native to rocky woodlands, scrub and coastal areas of the Mediterranean. Rosemary contains anti-inflammatory and antiseptic flavonoids, phenolic acids and volatile oils. A popular culinary and medicinal herb, it is used dried in meat dishes and internally for digestive and nervous disorders (Bown 2001).

Salvia officinalis L., Lamiaceae

Common sage is an annual or perennial shrub native to the Mediterranean. Sage is a copious nectar producer making it good honeybee forage. Common sage is a popular culinary herb for meat dishes and teas. Common sage contains camphoraceous oil that is used medicinally to suppress perspiration, improve liver function and digestion and has anti-inflammatory and anti-depressant effects (Bown 2001).

Stachytarpheta jamaicensis (L.) Vahl, Verbenaceae

Native throughout the Caribbean, the genus is commonly known as “Porterweed” or “Vervain”. This plant can be found on St. Croix growing along roadsides and on disturbed sites, where it is locally known as “Worrywine”. The fresh leaves are consumed in bush tea as a “cooling” tonic and blood cleanser, to treat “asthma” and “ulcerated stomachs” (Kuby 1979; Thomas 1997).

Thymus vulgaris L., Lamiaceae

Thyme species are small, perennial, aromatic herbs and subshrubs native to Eurasia. Thyme species are ideally suited for St. Croix, preferring stony and rocky neutral to alkaline soils. Thyme is a popular culinary herb for meat and soups and stuffings. Dried thyme leaves are used in potpourris and thyme oil is used in toothpastes and mouthwashes. Thyme also make excellent honeybee forage (Bown 2001).

Verbesina alata L., Asteraceae

Native to parts of the eastern and southern Caribbean, this plant can be found growing wild on disturbed sites. Commonly cultivated in home gardens, it is known as “Inflammation Bush” in the Virgin Islands. It is consumed in bush tea as a cleansing tonic and a treatment for coughs, colds, and bruises (Kuby 1979; Thomas 1997).

Provenances, Establishment and Management

Ripe moringa seedpods were collected from trees growing on the AES. Without any pretreatment the seeds were direct sown, three to a hole, in the field at the Rattan site in late May and at the AES in mid-August, 2002. After planting the moringa seedlings were drip irrigated with 1.27 cm (½”) polyhose lines. After two weeks the moringa was thinned to one tree per hole and supplemental water was discontinued after four weeks.

The *Matricaria*, *Mentha*, *Origanum*, *Salvia*, and *Thymus* transplants were started from Richter© seeds in Premier Pro-mix 'BX' in 72 cell styrofoam trays. Locally obtained *Cymbopogon* culms, *Rosmarinus* cuttings and *Ocimum* seed were obtained for producing plant for this study. The *Stachytarpheta* and *Verbesina* were started from locally collected seed and the *Eupatorium* was started from cuttings collected on St. Thomas the first week of June 2002. Seeds and cuttings for all the trials were started in the greenhouse in June and July then transplanted out after 6 weeks. Local *Allium* slips and Richter© *Coriandrum* seeds were planted directly in the field.

The Rattan site was first cleared with a bulldozer and bush hog to remove the existing vegetation, and then plowed to prepare the field for planting. The site was cleaned with rakes and hoes and drip irrigation lines were laid out before the trees seeds were planted. Powdered cow manure was incorporated into the soil at a rate of about 6 t ha^{-1} with rakes before planting the herb intercrops. Herb intercrops were planted out with drip tape and were mulched with straw once they reached approximately 30 cm in height. To prepare the site at the AES, the grass and lab-lab fallow was plowed under. After several weeks the field was rototilled twice. Herbs were planted with drip irrigation similar to the Rattan site. Both sites were weeded as necessary and fertigated with a soluble fertilizer (20-20-20).

Experimental Design

The Rattan site was a strip-split plot with two plots (treatments: herbs alley cropped between moringa hedgerows and herb sole cropped) and 10 subplots (10 herb species). A stone terrace wall had been constructed along the contour of the slope prior to the onset of the research, dissecting the field into an upper and lower section. The moringa seeds were sown in two rows along the contour, 1.5 m in row spacing with 25 trees per row, *M.*

stenopetala along the upper side of the terrace and *M. oleifera* in the second about 5 m further up the slope. The upper section was selected for the alley and the area below the wall was selected for the control of no alleys. To make efficient use of drip irrigation a single main line was run down the slope along the north end of the field and alternating lines of drip tape with 20.3 cm (8”) and 60.9 cm (24”) emitters spacing, 37.5 m long (120’), were run off it every meter, four lines per alley for a total of eight lines. Four plants of *Cymbopogon*, *Eupatorium*, *Ocimum*, *Stachytarpheta* and *Verbesina* were planted at randomly assigned positions in each block along the 61 cm lines. Ten plants of *Matricaria*, *Origanum*, *Rosmarinus*, *Salvia* and *Thymus* were planted at randomly assigned positions in each block along the 20 cm lines. Each species was planted on both of the alternating upper and lower lines in each block (Figure 3-1). The length of the field permitted only three replications. A total of 120 plants of each variety on the 20 cm lines (10 plants per line x 4 lines x 3 replications) and 48 plants of each variety on the 61 cm lines (4 plants per line x 4 lines x 3 replications) were required.

The AES experiment was similar to the Rattan design with modifications. Sufficient area was available at the AES for four replications and a split-plot design. The site had two treatments, herbs alley cropped between moringa hedgerows, and sole-cropped herbs, with four replications in 10 m by 8.75 m plots. The length of the field required that each block be shortened, which was compensated for by increasing the number of rows. The three hedgerows were planted five m apart, with trees within rows spaced at 1.75 m for a total of 18 trees per block (3 rows x 6 plants/row). Alley width was 5 m with two alleys per plot. Seventy-two *Moringa oleifera* trees (18 trees x 4 reps) were established by direct seeding at 10 cm depth. There were twelve rows of herbs intercrop per plot, six per alley spaced at 0.71 meters (28”) between rows. A main line was run along the western end of the field and six lines of drip tape with 20.32 cm (8”) emitter spacing and six lines of drip tape with 61 cm (24”) emitter spacing, each 41 meters long (134.5’), were run off of it the length of the field (Figure 3-2). Each plot of *Cymbopogon*, *Eupatorium*, *Ocimum*, *Stachytarpheta* and *Verbesina* consisted of three plants along each of the six adjacent lines, for 18 plants per plot, at randomly assigned positions in each block along the 61 cm lines. Each plot of *Allium*, *Coriandrum*, *Mentha*, *Origanum* and *Thymus* consisted of seven plants of each species planted along each of the six adjacent lines, for 42 plants per plot, at randomly assigned positions in each block along the 20 cm lines. A total of 336 plants of each variety on the 20 cm lines (7 plants per line x 6 lines x 2 treatments x 4 replications) and 144 plants of each variety on the 61 cm lines (3 plants per line x 6 lines x 2 treatments x 4 replications) were required.

Data Collection and Measurements

The trees and intercrops in this experiment were monitored separately. The following variables were monitored for the trees: height, number and length of leaves, onset of flowering and fruiting, number of fruits, and biomass (fresh and oven dried weight) of fruits, foliage, and woody material. Heights and leaf lengths were measured in the field with a 2-meter ruler. Fresh weights were determined in the field to the nearest decagram. One hundred gram sub samples of leaf and stem material were oven dried at 90° C for 24 hours and dry weights were determined to the nearest gram.

The following variables were monitored for the intercrops: height, number of stems, and biomass (fresh and oven dried weight) of foliage and stems at each harvest. While all plants at the AES were sampled, at the Rattan site only the middle two plants of each species in each block on each 61 cm line and the middle six plants on each 20 cm line were sampled. Randomly selected plants of each species from each row in each block were oven dried at 90° C for 24 hours and dry weights were determined to the nearest 0.1 gram.

Input values for the economic analysis were obtained from the AES trial data, previous AES enterprise budgets, informal surveys of local markets and World Wide Web searches.

Data Analysis

Total yields were summed from each harvest. Mean fresh and dry weight yields of the sole-crop and intercrops herbs were averaged for each species, by treatment and block in a Microsoft Excel XP™ spreadsheet. Total yields for each species were compared with a mixed linear model (PROC MIXED) in SAS™ for Windows 8e, utilizing the Tukey-Kramer adjustment of means. Yields of fresh herb sole and intercrops and dried Moringa (powdered dried leaves) were then extrapolated for an area of 250 m^2 (1/16th acre) for the purpose of making them comparable with previous AES enterprise budgets. The economic analysis included the determination of break-even cost for each intercrop, the net present value (NPV) for a 20-year production of the system[4], and a benefit/cost (B/C) ratio, which can be used as a basis of comparison between alternative systems when the same discount rate is applied. A sensitivity analysis was performed utilizing multiple discount rates (3, 5, 7 and 9%) and several different market values, reflecting a decline in price as markets become saturated by increased production. The relative net return, calculated with the yields extrapolated for the 250 m^2, was used to determine the relative productivity of the different species of herbs.

[4] 20 years is the length of a typical lease on agriculture land from the Virgin Islands Department of Agriculture.

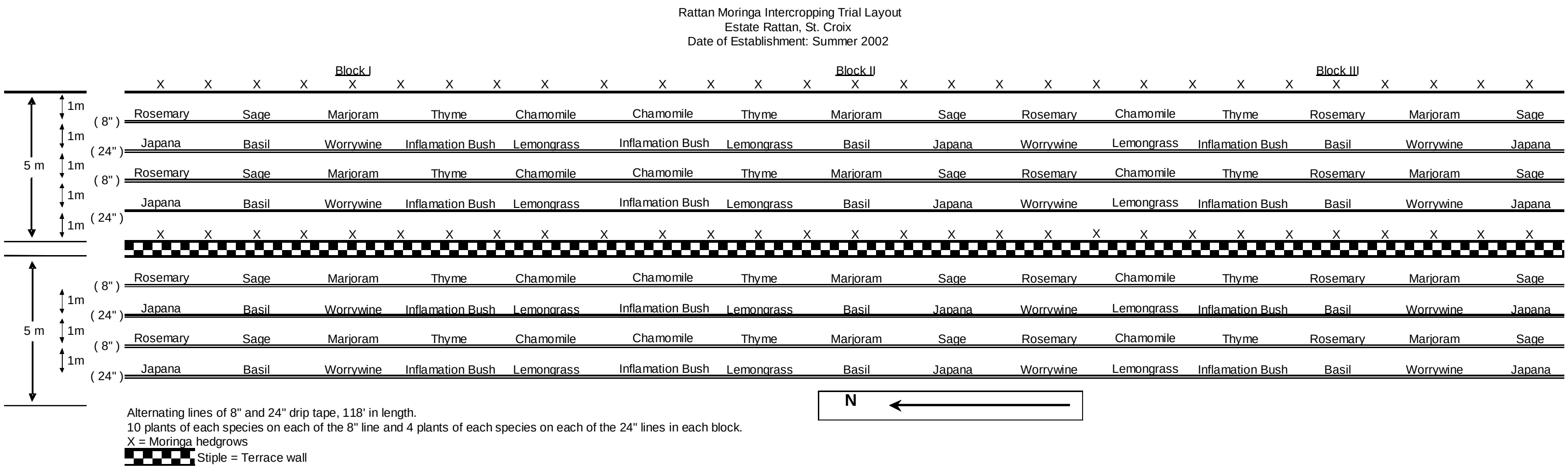

Figure 3-1. *Moringa oleifera*, *M. stenopetala* and culinary and medicinal herb intercropping trial layout at Estate Rattan, St. Croix, U.S. Virgin Islands, during the 2002-2003 field season.

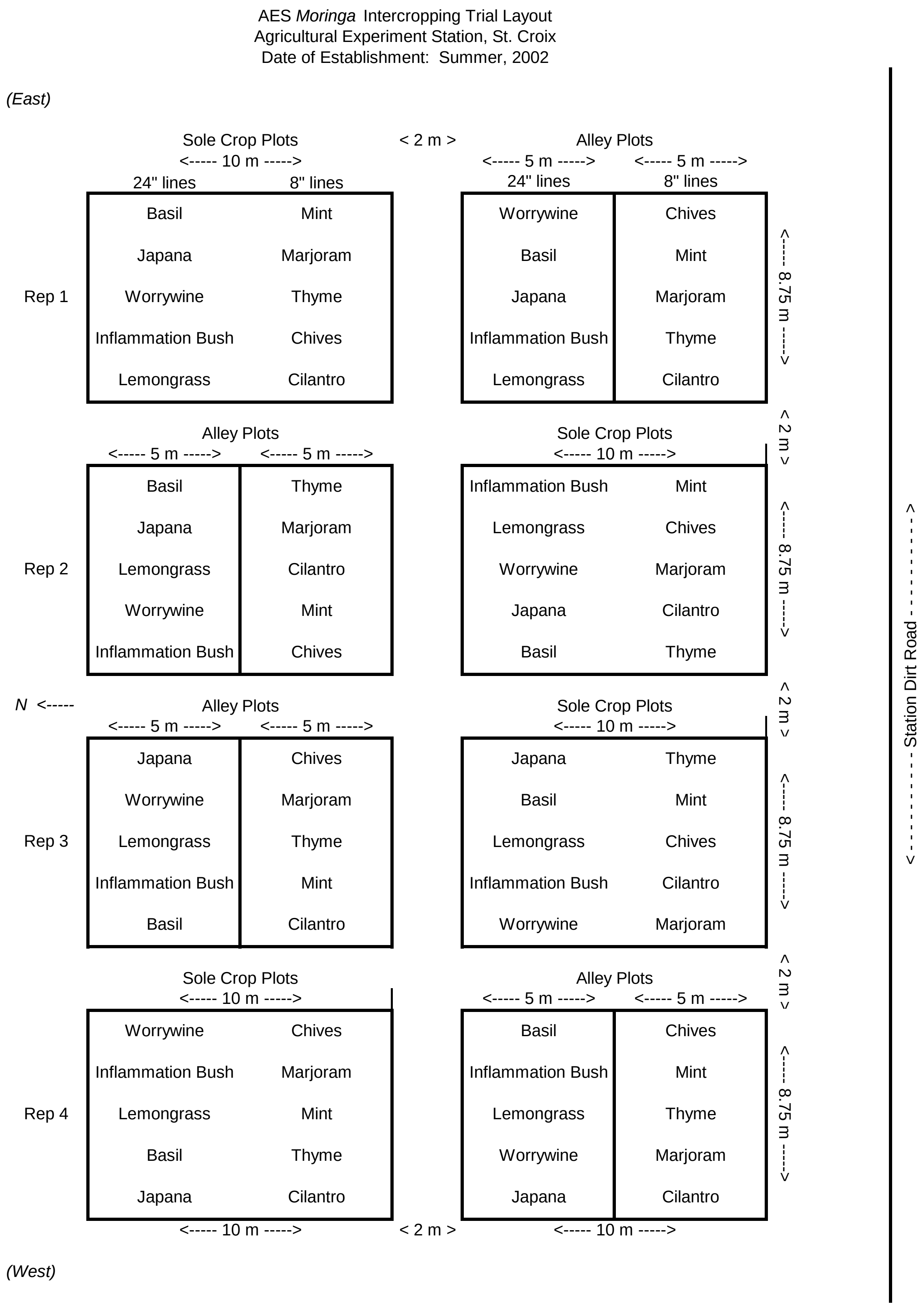

Figure 3-2. *Moringa oleifera* and culinary and medicinal herb intercropping trial layout at the AES, St. Croix, U.S. Virgin Islands, during the 2002-2003 field season.

CHAPTER 4
RESULTS

The following sections present the results of the first year trials at Estate Rattan and the AES sites. The agronomic yields from Estate Rattan and the AES trials are presented first. After the agronomic data, economic analysis of each system sole- cropped and intercropped for each species is presented. Included are the breakeven points, benefit/cost (B/C) ratio, a net present value (NPV) sensitivity analysis, and the relative net return (RNR) for each species.

Agronomic Evaluation

The agronomic yields are presented as mean yields per harvest, total yields per area and average yield per plant. Yields from moringa pruning are presented as total yield per area and average yield per plant. Statistical comparisons of yields between treatments and species are made for each planting density utilizing a Tukey-pairwise comparison.

Estate Rattan Moringa-Herb Intercropping Trial

At the Estate Rattan *Stachytarpheta* and *Verbesina* produced four harvests, *Ocimum* three and *Cymbopogon*, *Origanum* and *Salvia* only one harvest each. Regrowth after initial harvest of the last three species did not permit additional harvests. Establishment and subsequent growth of *Eupatorium*, *Matricaria*, *Rosmarinus* and *Thymus* was extremely poor and of the four species only a partial harvest of the *Thymus* was possible (Table 4-1). Between the sole-cropped and intercropped treatments, none of the species showed statistical differences in their yields ($P > 0.05$). Between species, the difference between the mean yields of the sole-cropped *Cymbopogon* and *Ocimum*, *Cymbopogon* and *Verbesina*, *Ocimum* and *Stachytarpheta* and between *Origanum* and *Salvia* were not significant ($P > 0.05$) while *Cymbopogon* and *Stachytarpheta*, *Ocimum* and *Verbesina* and *Stachytarpheta* and *Verbesina* were highly significant ($P < 0.01$). The difference in mean yields between intercropped *Cymbopogon*, *Stachytarpheta* and *Verbesina*, between *Cymbopogon* and *Ocimum* and between *Ocimum* and *Verbesina* were all highly significant ($P < 0.01$), while the difference between the mean yields of intercropped *Origanum*, *Salvia* and *Thymus* were not statistically significant ($P > 0.05$).

The average height of the *Moringa oleifera* six months after planting from seed was 427 cm while the *M. stenopetala* averaged 299 cm. The mean wet weight yield of *M. oleifera* prunings was 4.3 kg tree^{-1} and *M. stenopetala* prunings were 3.1 kg tree^{-1}, 73% of the *M. oleifera* yield. *M. oleifera* prunings averaged 25.4% dry matter after oven drying, the mean yield of dry leaf matter was 356 g tree^{-1}. *M. stenopetala* dry matter after oven drying averaged 24.9%, the mean yield of dry leaf matter was 299 g tree^{-1}, 84% of the *M. oleifera* yield. *M. oleifera* yielded 8.9 kg dry leaf matter from 90 m^2, equaling 99 g m^{-2} or 0.989 Mg ha^{-1}. *M. stenopetala* yielded 7.475 kg dry leaf matter from 90 m^2, equaling 83 g m^{-2} or 0.831 Mg ha^{-1}.

Agriculture Experiment Station Moringa-Herb Intercropping Trial

While *Allium*, *Coriandrum*, *Cymbopogon*, *Ocimum* and *Stachytarpheta* grew well at the AES, the *Verbesina* provided three very small yields, and the *Eupatorium*, *Mentha*, *Origanum* and *Thymus* grew slowly and could only be harvested once each (Table 4-2). Between the sole-crop and intercrop treatments, mean yield differences were significant for *Ocimum* ($P = .0197$) and highly significant for *Allium*, *Coriandrum*, *Cymbopogon* and *Stachytarpheta* ($P < 0.01$). Between species, the differences between mean yields of sole-cropped *Cymbopogon* and *Stachytarpheta*, *Eupatorium* and *Verbesina*, and between

Mentha, *Origanum* and *Thymus* were not statistically different ($P > 0.05$), while the difference between the mean yields of *Cymbopogon* and *Eupatorium*, *Ocimum* and *Verbesina*, between *Eupatorium* and both *Ocimum* and *Stachytarpheta*, between *Ocimum* and both *Stachytarpheta* and *Verbesina* and between *Allium* and *Coriandrum* both between each other and with *Mentha*, *Origanum* and *Thymus* were highly significant ($P < 0.01$). The difference in mean yields between intercropped *Cymbopogon* and both *Eupatorium* and *Verbesina*, *Eupatorium* and both *Ocimum* and *Stachytarpheta*, and between *Verbesina* and both *Ocimum* and *Stachytarpheta* were highly significant ($P < 0.01$), between *Cymbopogon* and *Ocimum* were significant ($P < 0.01$), while the difference between mean yields of *Eupatorium* and *Verbesina*, between *Stachytarpheta* and both *Cymbopogon* and *Ocimum* and between *Allium*, *Coriandrum*, *Mentha*, *Origanum* and *Thymus* were not significant ($P > 0.05$).

At the time of the first pruning, four months after planting from seeds, the moringa trees averaged 275 cm in height. Lopped at 1.5 m, they averaged 337 cm three months later at the time of the second pruning. Average wet weight yield of the prunings was 6.4 kg. Leaf wet weight was 2.8 kg, yielding 30.5% after oven drying, for an average dry leaf matter yield of 767 g tree^{-1}. Total yield for the 410 m^2 areas was 55.224 kg, equivalent to 0.135 kg m^{-2} or 1.35 Mg ha^{-1}.

Table 4-1. Leaf yield of herbs sole-cropped and intercropped with *Moringa oleifera* and *M. stenopetala* at Estate Rattan, St. Croix, U.S. Virgin Islands, during the 2002-2003 field season.

Fresh weights (kg) of leaves harvested during the season

Species	Area (m^2)	*n*	Sole-crop					*n*	Intercrop				
			Harvests				Total		Harvests				Total
			1	2	3	4			1	2	3	4	
Cymbopogon citratus	12.5	12	6.77				6.77[ac]	12	5.50				5.50
Eupatorium triplinerve	12.5	12					***	12					***
Matricaria recutita	12.5	36					***	36					***
Ocimum basilicum	12.5	12	1.50	4.30	4.16		9.95[ab]	12	1.24	2.96	5.53		9.73[a]
Origanum majorana	12.5	24	1.24				1.24[d]	24	1.15				1.15[b]
Rosmarinus officinalis	12.5	36					***	36					***
Salvia officinalis	12.5	24	0.97				0.97[d]	24	0.78				0.78[b]
Stachytarpheta jamaicensis	12.5	12	1.24	1.19	1.39	8.80	12.61[b]	12	1.15	1.27	1.32	6.73	10.47[a]
Thymus vulgaris	12.5	36					***	16	0.68				0.68[b]
Verbesina alata	12.5	12	0.34	0.43	0.79	1.91	3.47[c]	12	0.21	0.30	0.29	1.04	1.83

Letters indicate species with total yields with no statistical difference ($P > 0.05$), Tukey-Kramer Means Adjustment.

*** = Incomplete harvests.

Table 4-2. Leaf yield of herbs sole-cropped and intercropped with *Moringa oleifera* at the AES, St. Croix, U.S. Virgin Islands, during the 2002-2003 field season.

Fresh weights (kg) of leaves harvested during the season

Species	Area (m^2)	*N*	Sole-crop					*n*	Intercrop				
			Harvests				Total		Harvests				Total
			1	2	3	4			1	2	3	4	
Allium schoenoprasum	9.4	157	9.79	10.77			20.56**	155	4.30	5.18			9.48**
Coriandrum sativum	9.4	70	4.16	4.86	5.10		14.13**	44	0.89	1.32	1.45		3.65**
Cymbopogon citratus	9.4	72	24.66	27.87	20.56	37.10	110.18[a]**	72	26.65	20.59	13.84	22.86	83.94[a]**
Eupatorium triplinerve	9.4	72	4.87				4.87[b]	72	2.69				2.69[b]
Mentha x piperita	9.4	168	5.16				***	168	1.83				***
Ocimum basilicum	9.4	72	37.99	20.85	19.93		78.77	72	40.25	11.70	12.46		64.4[c]
Origanum majorana	9.4	168	1.19				***	168	0.94				***
Stachytarpheta jamaicensis	9.4	72	45.94	57.89			103.83[a]**	72	40.50	32.75			73.25[ac]**
Thymus vulgaris	9.4	168	1.17				***	168	0.20				***
Verbesina alata	9.4	55	4.55	4.72	1.45		10.71[b]	50	3.80	1.58	1.26		6.64[b]

Letters indicate species with total yields with no statistical difference ($P > 0.05$), Tukey-Kramer Means Adjustment.

** = Significant difference between treatments ($P < 0.05$).

*** = Incomplete harvests.

<u>Economic Evaluation</u>

Due to incomplete records of inputs the economic analyses were based upon data collected from research plots at the AES. *Allium*, *Coriandrum*, *Cymbopogon*, *Ocimum*, *Stachytarpheta* and *Verbesina* were selected for further analysis. Estimated cost and returns with break-even points (see appendix A), NPV and B/C ratios were determined for each species in sole-crop and intercropped with moringa production systems. A sensitivity analysis was conducted for each species to examine the effect of price and discount rates on each system. The RNR for each species is also presented.

Allium schoenoprasum

Sole-cropped chive yields of 235.8 kg ha^{-1} yr^{-1} at current market prices gross \$3,350 pre tax. With a 5% discount rate the estimated twenty-year NPV of the system is \$41,743. Sensitivity analysis of market prices and discount rates (Figure 4-1) indicate that the system remains profitable until chive market prices dip below \$7.80 kg^{-1}. Intercropped chive yields of 87.8 kg ha^{-1} yr^{-1} and moringa powder yields of 34.25 kg ha^{-1} yr^{-1} gross only \$139 pre tax. The twenty-year NPV with a 5% discount rate is \$1,905. Sensitivity analysis of market prices and discount rates indicate that the system is only profitable at the current chive market price of \$22 kg^{-1} due to the additional income from the moringa yield. The B/C ratio of the sole-crop is 2.82 while the intercrop B/C ratio is 1.08. The RNR of the intercrop compared to the sole-crop is 38%.

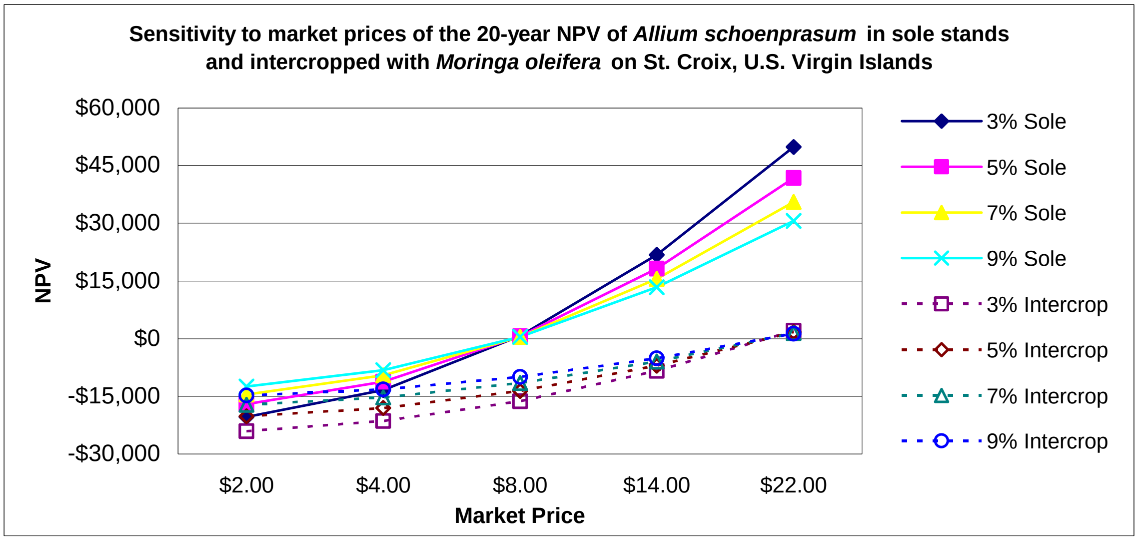

Figure 4-1. NPV sensitivity analysis of *Allium schoenoprasum* sole-cropped and intercropped with *Moringa oleifera* on St. Croix, U.S. Virgin Islands

Coriandrum sativum

Yield of sole-cropped cilantro of 363.6 kg ha^{-1} yr^{-1} at current market prices grosses $6,111 pre tax. With a 5% discount rate the estimated twenty-year NPV of the system is $76,162. Sensitivity analysis of market prices and discount rates (Figure 4-2) indicate that the system remains profitable until market prices dips below $5.19 kg^{-1}. Intercropped cilantro yields of 121.0 kg ha^{-1} yr^{-1} and moringa powder yields of 34.25 kg ha^{-1} yr^{-1} gross $828 pre tax. The twenty-year NPV with a 5% discount rate is $10,490. Sensitivity analysis of market prices and discount rates indicate that the system remains profitable until cilantro market prices dip below $17.23 kg^{-1}. The B/C ratio of the sole-crop is 4.24 and the intercrop B/C ratio is 1.41. The RNR of the intercrop compared to the sole-crop is 34%.

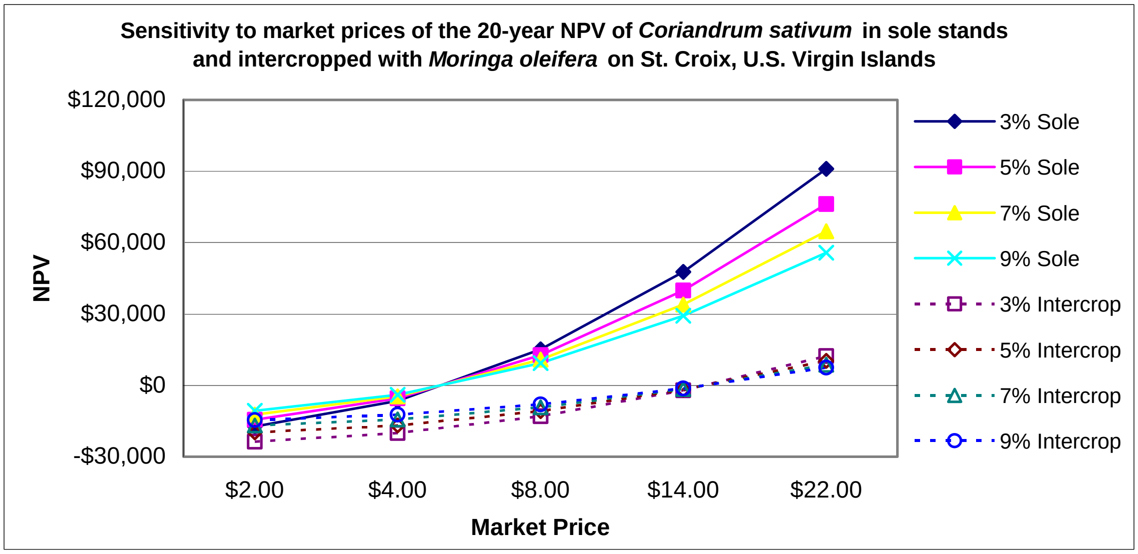

Figure 4-2. NPV sensitivity analysis of *Coriandrum sativum* sole-cropped and intercropped with *Moringa oleifera* on St. Croix, U.S. Virgin Islands.

Cymbopogon citratus

Sole-cropped lemongrass yields of 918.0 kg ha^{-1} yr^{-1} at current market prices gross $16,580 pre tax. With a 5% discount rate the estimated twenty-year NPV of the system is $208,077. Sensitivity analysis of market prices and discount rates (Figure 4-3) indicate that the break-even point of the lemongrass system is $1.94 kg^{-1}. Intercropped lemongrass yields of 559.7 kg ha^{-1} yr^{-1} and moringa powder yields of 34.25 kg ha^{-1} yr^{-1} gross $9,447 pre tax. The twenty-year NPV with a 5% discount rate is $119,087. A sensitivity analysis of market prices and discount rates indicate that the system remains profitable until lemongrass market prices dip below $3.57 kg^{-1}. The B/C ratio of the sole-crop is 11.04 while the intercrop B/C ratio is 6.06. The RNR of the intercrop compared to the sole-crop is 61%.

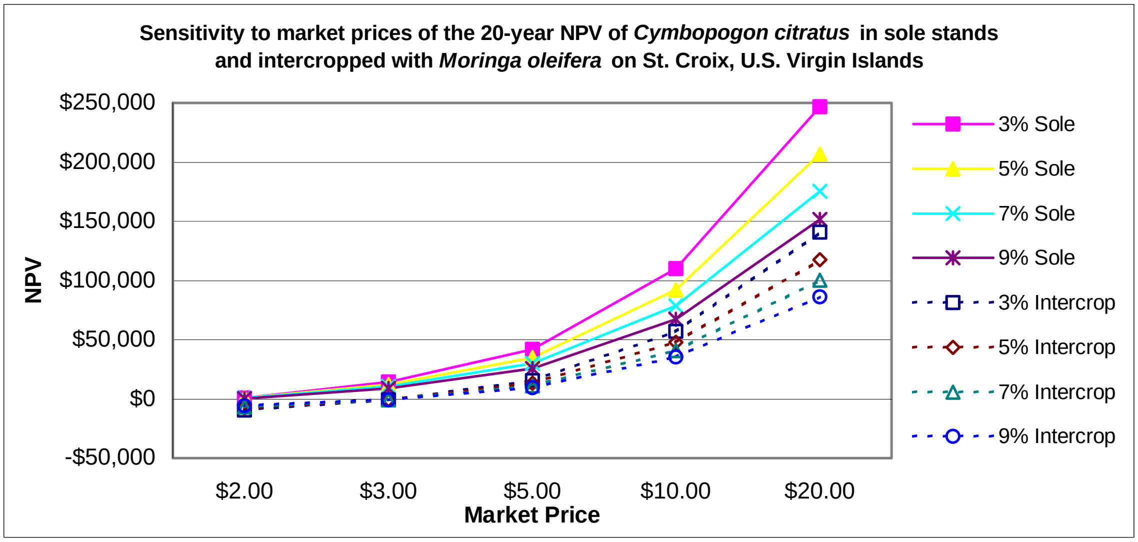

Figure 4-3. NPV sensitivity analysis of *Cymbopogon citratus* sole-cropped and intercropped with *Moringa oleifera* on St. Croix, U.S. Virgin Islands.

Ocimum basilicum

Yield of sole-cropped basil of 656.4 kg ha^{-1} yr^{-1} at current market prices grosses $11,286 pre tax. With a 5% discount rate the estimated twenty-year NPV of the system is $140,648. Sensitivity analysis of market prices and discount rates (Figure 4-4) indicate that the break-even point of the basil production system is $2.81 kg^{-1}. Intercropped basil yields of 429.3 kg ha^{-1} yr^{-1} and moringa powder yields of 34.25 kg ha^{-1} yr^{-1} gross $6,790 pre tax. The twenty-year NPV with a 5% discount rate is $84,793. Sensitivity analysis of market prices and discount rates suggest that the system remains profitable until basil market prices dip below $4.77 kg^{-1}. The B/C ratio of the sole-crop is 7.13 while the intercrop system is 4.35. The RNR of the intercrop compared to the sole-crop is 66%.

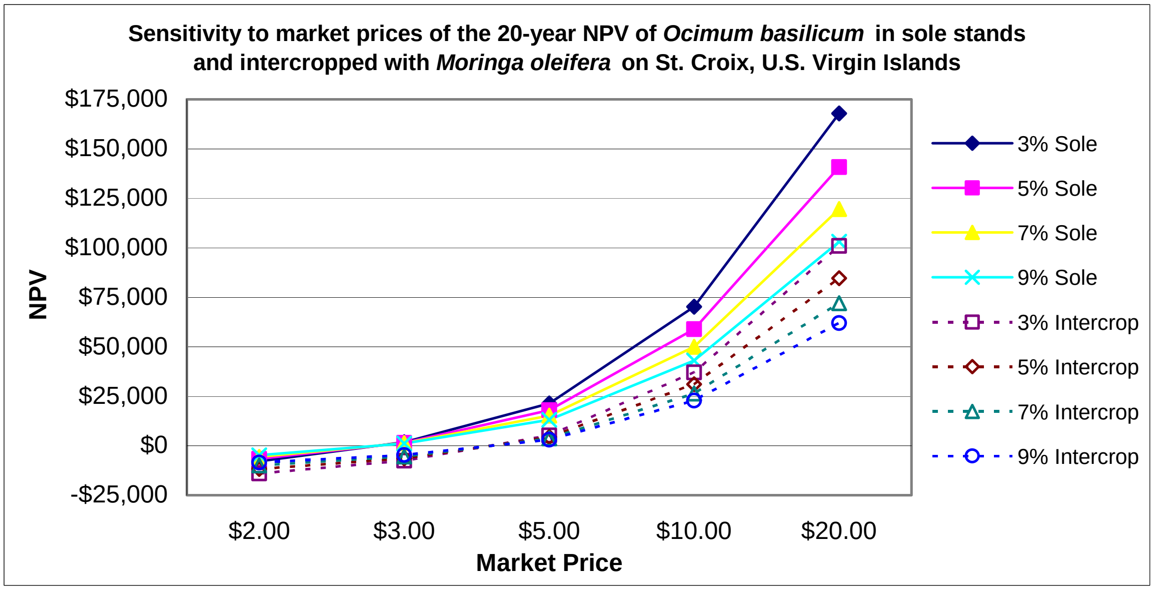

Figure 4-4. NPV sensitivity analysis of *Ocimum basilicum* sole-cropped and intercropped with *Moringa oleifera* on St. Croix, U.S. Virgin Islands.

Stachytarpheta jamaicensis

Sole-cropped worrywine yields of 865.2 kg ha^{-1} yr^{-1} at current market prices gross $15,657 pre tax. With a 5% discount rate the estimated twenty-year NPV of the system is $195,117. Sensitivity analysis of market prices and discount rates (Figure 4-5) indicate that the break-even point of the worrywine production system is $1.90 kg^{-1}. Intercropped worrywine yields of 488.2 kg ha^{-1} yr^{-1} and moringa powder yields of 34.25 kg ha^{-1} yr^{-1} gross $8,123 pre tax. The twenty-year NPV with a 5% discount rate is $101,395. A sensitivity analysis of market prices and discount rates indicate that the system remains profitable until worrywine market prices dip below $3.88 kg^{-1}. The B/C ratio of the sole-crop is 10.5 and the B/C ratio of the intercrop is 5.33. The RNR of the intercrop compared to the sole-crop is 56%.

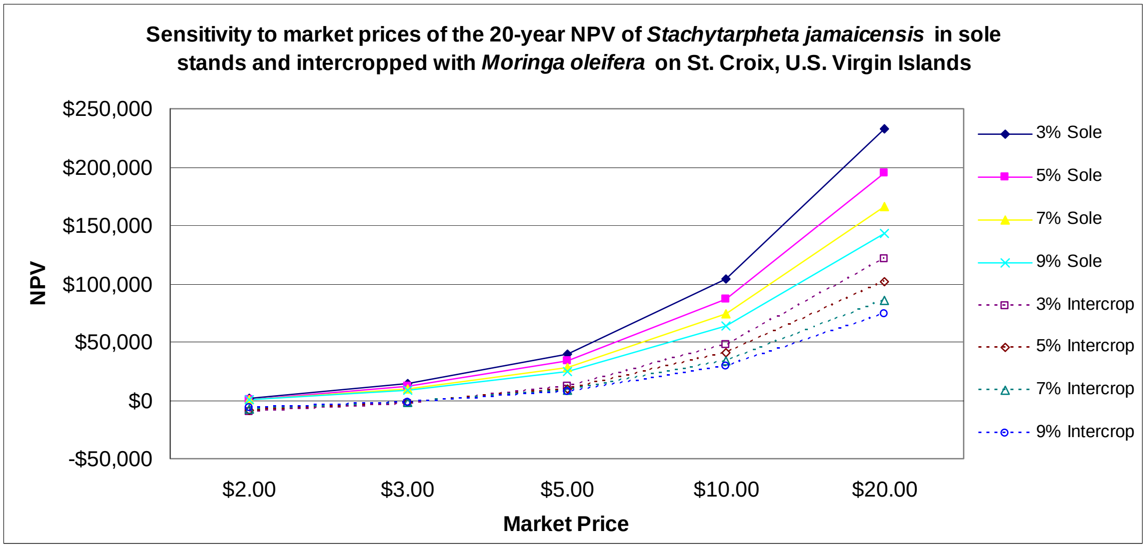

Figure 4-5. NPV sensitivity analysis of *Stachytarpheta jamaicensis* sole-cropped and intercropped with *Moringa oleifera* on St. Croix, U.S. Virgin Islands.

Verbesina alata

Yield of sole-cropped inflammation bush of 121.2 kg ha^{-1} yr^{-1} at current market prices grosses $1,316 pre tax. With a 5% discount rate the estimated twenty-year NPV of the system is $17,857. Sensitivity analysis of market prices and discount rates (Figure 4-6) indicate that the break-even point of the inflammation bush production system is $14.14 kg^{-1}. Intercropped inflammation bush yields of 63.8 kg ha^{-1} yr^{-1} and moringa powder yields of 34.25 kg ha^{-1} yr^{-1} gross, at current market prices, -$98 pre tax. The twenty-year NPV with a 5% discount rate is only $140. Sensitivity analysis of market prices and discount rates indicate that the system is not profitable at current market prices. The B/C ratio of the sole-crop system is 1.9 while the intercrop system is only 1.01. The RNR of the intercrop system compared to the sole-crop system is 53%.

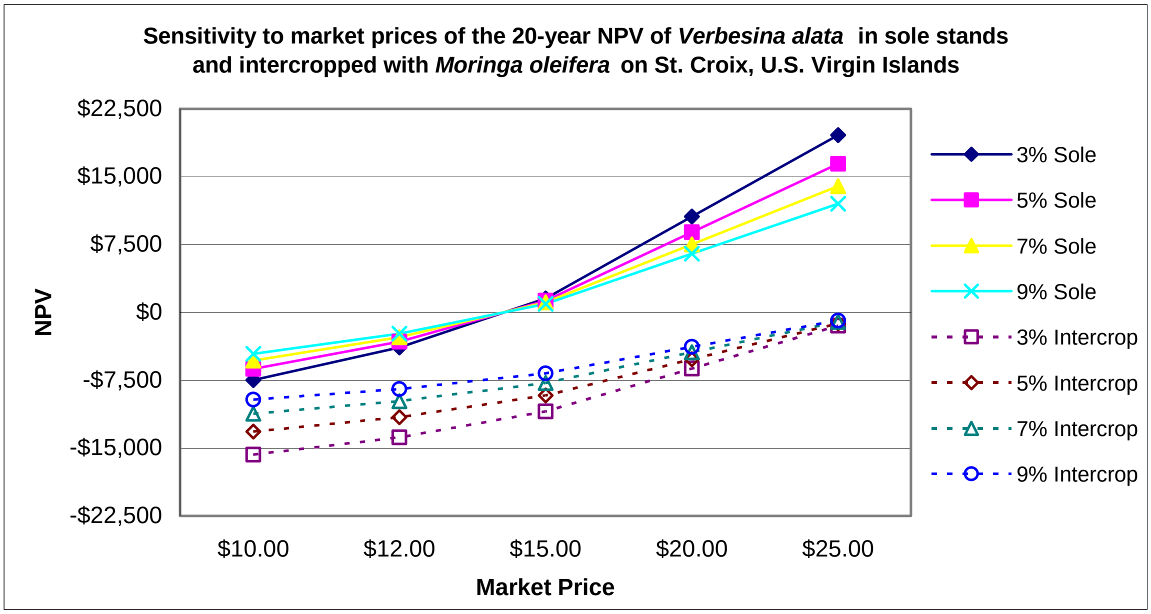

Figure 4-6. NPV sensitivity analysis of *Verbesina alata* sole-cropped and intercropped with *Moringa oleifera* on St. Croix, U.S. Virgin Islands.

CHAPTER 5
DISCUSSION

This investigation examined thirteen different species of herbs intercropped with moringa. The apparent yield reductions evident in the intercropped systems at both sites failed to demonstrate statistical significance for most species. This lack of statistical significance with the yields is attributed to the variability in the data magnified by the split-plot treatment of the data. Data variability is a consideration with the design of agroforestry experiments with large plot sizes, since the area is large and the land may be more variable, in addition to the excessive strain on labor, which likely affected the reliability of data collected (Nair 1993). Greater confidence is therefore held in the validity of the results of the on-station trials, where greater control over and records of inputs and harvests were kept, then the on-farm trial, where weeding, watering and harvesting was not consistent or recorded.

Culinary and Medicinal Herbs

The herb intercropping trial on the private Estate Rattan did not result in significant differences between control and intercropped plots. Droughty conditions, poor quality and survival of *Eupatorium*, *Rosmarinus*, and *Thymus* planting material, overzealous harvesting of *Cymbopogon*, *Origanum* and *Salvia* and their poor subsequent regrowth contributed to the wide variability in the yields between blocks that were responsible for the statistical results. *Matricaria* in particular failed to establish on the arid and alkaline site. *Stachytarpheta* and *Verbesina*, both native species commonly present on disturbed sites, did well at the Estate Rattan site. The performance of the *Eupatorium* is attributed to the poor quality of the planting material derived from material purchased in local farmers markets and the straw mulch, applied after planting for weed control and moisture retention, which interfered with the rooting of runners. The sensitivity of the selected herbs to intercropping ranked accordingly from the least sensitive to the most as: Basil → Marjoram → Worrywine → Lemongrass/Sage → Inflammation Bush.

The herb intercropping trial on the AES demonstrated significant differences between the control and intercropped plots in the species that performed well overall, i.e. *Allium*, *Coriandrum*, *Cymbopogon*, *Ocimum*, and *Stachytarpheta*, while the species that preformed poorly overall, i.e. *Eupatorium*, *Mentha*, *Origanum*, *Thymus*, and *Verbesina* did not. The sensitivity of the selected herbs to intercropping ranked accordingly from the least sensitive to the most as: Basil → Marjoram → Lemongrass → Worrywine → Inflammation Bush → Japana → Chive → Mint → Cilantro → Thyme.

AES control plot *Ocimum* yields of 656.4 kg (26.3 Mg ha^{-1}) from this research were similar to earlier research station yields of 29.7 Mg ha^{-1} (Collingwood et al. 1991a). Of the highest yielding systems, estimated single year returns from the yields of fresh *Cymbopogon* and *Stachytarpheta* sole-crops, while statistically equivalent, varied financially by more then $900 (Table 5-1). Likewise, the estimated single year return from fresh *Cymbopogon* intercrop was financially more lucrative than *Stachytarpheta* by over $1000. Estimated single year fresh weight yields of *Ocimum* sole-crop and intercrop, while not statistically different, varied by nearly $4500 or 40%, highlighting the difference between statistical significance and practical differences. Of the systems selected for economic analysis, *Cymbopogon* sole-crop had the greatest twenty-year 5% NPV of $208,077 and a B/C of 11.04 while the *Verbesina*-moringa intercrop had the lowest of \$140 and 1.01 respectively (Table 5-1). The RNR of the *Ocimum* systems was the highest at 66% and the *Coriandrum* system was the lowest at 34%.

This study's single year estimated *Allium* return of 235.8 kg for 250 m^2 is slightly higher than the 218.2 kg for 250 m^2 obtained in a 1999 mulch and irrigation study of organic chives, organic tomatoes and conventional tomatoes conducted at the AES (anonymous, unpublished). The 1999 adjusted returns of \$3780 from 250 m^2, which did not include the cost of slips, irrigation equipment, or the particular insecticides used during this study, are similar to the estimated sole-crop returns from this study of \$3350 for 250 m^2. Both the 1999 study and the results from this trial conclude that sole-cropped *Allium*, one of the lowest producing herbs in this study, offers producers higher returns then the adjusted estimated returns of \$2,970 for 250 m^2 of conventional tomatoes.

The use of the current market prices when determining the profitability of the systems could be misleading. St. Croix is small market comprising fewer than 55,000 people (US Census 2000). The introduction of the produce of even a single 250 m^2 field into the St. Croix fresh herb market will certainly drive down prices. Therefore, five different prices were selected when determining the profitability of each system to examine the impact of falling prices on profitability. During an examination of the listing price of over 80 parcels of land one hectare or less on St. Croix in June, 2004 the average price per hectare was over \$217,000. At one half the current market prices, only the *Cymbopogon* system would provide an economic return sufficient to equal the land value.

Several factors likely contributed to the reduced yields and economic returns from the intercrop systems. Resource competition, lower herb plant densities in the intercrops and the differential production costs between sole-crop and intercrop systems appear

Table 5-1. Summary of actual and estimated yields and results of herbs sole-cropped and intercropped with *Moringa oleifera* during the 2002-2003 field season, AES, St. Croix, U.S. Virgin Islands. Herbs are presented ranked according to their actual yields and estimated 20-year NPV.

	Sole-crop					Intercrop					
Species	Actual Yield (kg / 9.4 m^2)	Estimated Yield (kg / 250 m^2)	Estimated Returns ($/ha/yr)	Estimated NPV ($)	B/C	Actual Yield (kg / 9.4 m^2)	Estimated Yield (kg / 250 m^2)	Estimated Returns ($/ha/yr)	Estimated NPV ($)	B/C	RNR
1. *Cymbopogon citratus*	110.18	918.0	16,580	208,077	11.04	83.94	559.7	9,447	119,087	6.06	61%
2. *Stachytarpheta jamaicensis*	103.83	865.2	15,657	195,117	10.5	73.25	488.2	8,123	101,395	5.33	56%
3. *Ocimum basilicum*	78.77	656.4	11,286	140,648	7.13	64.4	429.3	6,790	84,793	4.35	66%
4. *Coriandrum sativum*	14.13	363.6	6,111	76,162	4.24	3.65	121.0	828	10,490	1.41	34%
5. *Allium schoenoprasum*	20.56	235.8	3,350	41,743	2.82	9.48	87.8	139	1,905	1.08	38%
6. *Verbesina alata*	10.71	121.2	1,316	17,857	1.9	6.64	63.8	-98	140	1.01	53%

obvious. Both the sole-crop and intercrop herbs and moringa hedgerows received fertilization and drip irrigation. Assuming that nutrient and water requirements were sufficiently and equally met for both the sole-crop and intercrops, then yield reductions were likely due to light interception by hedgerows. The sole-crop yields in the AES trials were also possibly reduced somewhat, compared to earlier research, by invading moringa roots competing for below ground nutrients. Tree roots invading control plots are a common problem with alley-cropping research (Coe 1994).

It is evident that intercrop planting densities requires further investigation. Farmers in the Virgin Islands typically plant herbs in small, informal gardens and at a much closer spacing than might be expected for field trials. Shalaby and Razin (1992) concluded that increased height of *Thymu*s in dense planting was due to light competition, with shorter plants from less dense plantings that permitted the growth of laterals resulting in overall greater yield per plant. Denser plantings however, despite the smaller plants, produced greater yield per area. Some herbs, such as *Allium*, *Coriandrum*, *Eupatorium*, and *Verbesina* might also produce greater yields at a higher density then was utilized in this study.

Of the herb species selected, the culture is well established for all but three of the local herbs, *Eupatorium*, *Stachytarpheta*, and *Verbesina*, of which little is known. The local *Cymbopogon* and *Stachytarpheta* preformed the best, producing the most biomass. An advantage of *Cymbopogon* is that it is a perennial grass that once established requires only occasional weeding and harvesting. Additionally, culms can be readily separated for new planting material. The local *Stachytarpheta* is a low, sprawling shrub that endured heavy harvesting and regrew quite readily. On sub-tropical St. Croix, *Stachytarpheta* is an annual or short-lived perennial that requires periodic replanting. *Stachytarpheta* can be a prolific seed producer and dense shrubberies could be established in a field along a drip line, requiring little attention aside from periodic harvesting. *Verbesina* is another local annual or perennial. Harvested once flowering begins, it endured severe pruning back to the base of the plant and recovered with vigor. *Verbesina* is also a prolific seed producer that could easily produce dense shrubberies in a field setting along a drip line. Some of the weeds in the research plots removed by periodic hoeing were in fact *Verbesina* seedlings. The *Eupatorium* used for this research was derived from cuttings purchased in the local farmers markets. The cuttings were rooted in water and planted in pots before being transplanted to the field. *Eupatorium* is a low, perennial herb that roots from the nodes of its creeping stems. The poor performance of this herb is attributed to the poor quality (not very fresh) of cuttings derived from market purchased material and the straw mulch that prevented the *Eupatorium* stems from rooting readily. Until established, *Eupatorium* did not appear to be very tolerant of heavy pruning.

The culture of the common aromatic culinary herb *Ocimum* is well worked out (Simon et al. 1999). *Ocimum* is an annual that will provide multiple harvests throughout the year when managed properly. The requirement for replanting during the course of this research was due to over harvesting of the plants, which should only be cut back to a basal node, just above a pair of leaves. *Allium* preformed well from sets and *Coriandrum* from seeds. *Mentha*, *Origanum*, and *Thymus* apparently are less suitable to field cultivation under the conditions present at the AES on St. Croix. Desiccating winds, intense sub-tropical sun, and drought conditions followed by flooding from periodic, intense rains all contributed to their poor performance. At the Estate Rattan, the same conditions applied. *Origanum*, *Salvia* and *Thymus* may have been particularly adversely affected by over harvesting. While *Rosmarinus* does well on the island, the failure to establish during this trial is attributed to the poor quality of the material planted. Finally, the *Matricaria*, which is not commonly grown on St. Croix, may have failed to establish due to the high pH of the soils (7.7), as *Matricaria* prefers acidic soils.

Moringa

Moringa preformed very well on the alkaline soils of St. Croix. At the Estate Rattan, planted from seed and provided supplemental water for only one month, hedgerow trees averaged four and quarter meters after six months despite the droughty conditions of the 2002 fall season. At the AES, moringa established under the same techniques as the hedges at Estate Rattan reached an average of two and three-fourths meters in four months and grew an additional one and three-fourths meters in the following four months after pruning.

It is apparent that at the planting density used for moringa in this study and the current estimated market price for moringa powder, the intercrop systems will not be profitable. A higher density of herb, moringa or further value-addition might increase the profitability of a moringa-herb intercropping system on St. Croix. A higher moringa density could also offset the low price for the moringa product in this experiment. Double row hedgerows might accomplish this, as well as closer in line spacing or narrower alleys. An additional shortcoming of this research was the lack of a moringa sole-crop. Unfortunately, the lack of a sole tree control is all too common a problem in alley-cropping experiments (Coe 1994). Without the sole-crop moringa yield data a

LER[5] calculation was not possible. Finally, the IRR could not be calculated because this study treated the Moringa as an annual crop. Without a return discounted over time, the internal rate of return is essentially the single year return.

Though moringa was selected for research based on its potential for multiple uses, this may reflect the researcher's bias. The low price used in this study for moringa powder as a food supplement reflects the lack of demand in the Virgin Islands, where malnutrition not undernourishment is a common problem. Other moringa products may find market niches though. South Asian communities in North American are a potential market for the fresh young seed pods, which are a component of the diet of South Indian cuisine. The water purifying capabilities of the crushed seeds requires scientific investigation, as there may be spin-off products and markets for related products. Value added requires consideration as the tree itself in the systems studied does not appear to be a viable economic option for small-scale farmers on St. Croix.

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[5] Land Equivalent Ratio (LER) = $(Y_{ab}/Y_a) + (Y_{ba}/Y_b)$, where *Ya* and *Yb* are the sole crop yields of species *a* and *b* respectively, *Yab* is the yield of species *a* when intercropped with species *b*, and *Yba* is the yield of species *b* when intercropped with species *a*.

CHAPTER 6
CONCLUSIONS

St. Croix, USVI is faced with historical, environmental, and economic challenges. Virgin Island farmers can find lucrative market opportunities by diversifying their agricultural systems with lesser-known crops. Bush teas derived from culinary and medicinal herbs are a part of the local culture and can be adapted for internal and export markets. This study examined the production of high value culinary and medicinal herbs intercropped with moringa on St. Croix, USVI. The objective was to determine the productivity and economic costs and benefits of selected herbs when intercropped with moringa compared to sole-crop yields. Specifically, the study determined whether the physical yields and economic benefits were greater for the selected herb-moringa intercrop system or the respective herb sole-crop.

This study was conducted at two locations – at a private estate and at the agricultural experimental station. Both sites, while considered fertile, are semi-arid. Thirteen species of herbs were selected for investigation along with moringa. Herb intercropping and moringa hedgerows were established with drip irrigation in strip-split plot designs with randomized subplots. Yields were determined from harvests and inputs were totaled for calculating economic returns. Net Present Value (NPV), Benefit/Cost Ratio (B/C) and Relative Net Return (RNR) were employed for comparison of the various sole and intercrop systems. A sensitivity analysis was included with four different discount rates and five different market prices.

Yields of all intercropped herbs were lower than their sole-crops. Yields at Estate Rattan were not statistically different while the yields between treatments at the AES were. Between species comparisons show that *Cymbopogon* and *Stachytarpheta* preformed similarly with the highest yields, *Cymbopogon* yields being slightly higher. Economic analysis indicates that *Cymbopogon* provides the greatest economic return, NPV and B/C while *Ocimum* had the greatest RNR.

Statistical results may have been confounded by the split-plot design, which magnifies variation in data from subplots. Comparison of results from this research to previous AES enterprise budgets suggests that even the lowest yielding system tested, the *Allium* – moringa intercrop, will provide a greater economic return from the same area as that of a conventional tomato crop. Suboptimal densities and invading moringa roots likely affected yields as much as shading did. Future research of herb culture, particularly of *Eupatorium*, is warranted.

A fruitful avenue for future research is in examining the effects of planting densities and culture on aromatic, culinary and medicinal herbs. Traditional herb gardens in the Virgin Islands are typically small, compact and in close association with stones used to delineate herb beds. While a trade-off can be expected with high densities producing lower yielding plants, the optimal density for overall herb yields should be determined. Working with drip irrigation lines, a proposed method to optimize densities might be to have two parallel drip lines set apart equal to their spacing, with three plants, two on the outside of the lines and one in the middle. The effect of density and culture, including whether stones lining herb beds regulate diurnal temperature fluctuations, on the yield of active ingredients and essential oils, requires investigation.

Serious marketing is required before the prospects of the Virgin Islands becoming a supplier of aromatic, culinary or medicinal herb to North American markets can be realized. Developing viable large-scale production requires vertical integration of the production and marketing infrastructure: suppliers, processors, buyers, quantity and quality control. While the value of moringa is appreciated in many parts of Asia, Africa, and the Caribbean, it does not yet appear to have gained a following in the Virgin Islands. Other native trees may hold greater potential for agroforestry systems in the Virgin Islands. Soursop (*Annona muricata*) and sugar apple (*Annona squamosa*) are two common, native trees for which a steady markets exists for both the edible fruit and medicinal leaves. Alley cropping with aromatic, culinary, and medicinal herbs might also be particularly suitable for guavaberry (*Myrciaria floribunda*), a slow growing fruit tree for which there is a great demand when in season, but few landowners plant due to the 12 year maturation period.

Rocheleau (1999) describes the formal research model with initial trials on-station with the “winners” moved to on-farm later and farmer “participatory” input restricted to “problem diagnosis” during first phase and “adaptive research” during the final stage. This limits the capacity of farmers and researchers to jointly innovate and experiment to fixed times and places. The paradigm of parallel line of research, as described by Rocheleau, with on-station and on-farm simultaneously, with researchers and farmers exchanging ideas, material and evaluation of the experiments is apparent in this study. Continued AES research along the lines of this project can produce viable agroforestry systems based on aromatic, culinary, and medicinal herbs that will benefit small-scale farmers on St. Croix.

APPENDIX A
COSTS AND RETURN ESTIMATES

This appendix contains the estimated costs and returns for a 250 m^2 sole-crop and intercrop of each herb, based on yield data collected from the AES, St. Croix, U.S. Virgin Islands, during the 2002-2003 field seasons. Explanations for values can be found in Appendix B.

Estimated Costs and Returns at Current Market Prices, St. Croix, USVI, 2002-2003

Allium Sole-crop

.025 hectare unit

Item	Unit	Qty.	Price ($)	Amt.
SALES				
Sale of fresh chives from .025 ha	kg	235.8	$22.00	$5,188
Other sales				$0
Total Revenue				**$5,188**
OPERATING COSTS				
Seedlings	plants	1800	$0.15	$270
Fertilizer (20 - 20 - 20)	bags	0.7	$23.60	$16
Herbicide and Insecticides (Azetin™, Dipel™, and Mpede™)	package	1	$245.15	$245
Drip irrigation lines	layout	1	$300.00	$300
Water	m^3	12.0	$4.49	$54
Labor: (a) irrigation (set-up & repair)	hours	9.3	$6.25	$58
(b) planting	hours	10.0	$6.25	$63
(c) fertigating and weeding	hours	83.4	$6.25	$521
(d) harvesting (including weighting & bunching)	hours	15.0	$6.25	$94
Machinery: (a) plowing	hectare	0.025	$154.44	$4
(b) harrowing	hectare	0.025	$38.61	$1
(c) tilling	hectare	0.025	$38.61	$1
Interest on operating capital	$	6%	$1,626	$98
Total Operating Cost				**$1,724**
FIXED COSTS				
Land lease	hectare	0.025	$49.42	$1
Interest on avg. investment (excl. land)	$	10.00%	1041.67	$104
Depreciation: (a) irrigation equipment	hectare	0.025	$257.40	$6
(b) other equipment	hectare	0.025	$12.87	$0
(c) well	hectare	0.025	$72.08	$2
(d) other	hectare	0.025	$5.15	$0
Total Fixed Cost				**$114**
PRE-TAX RETURNS (total revenue - total operating costs - fixed cost)				**$3,350**
BREAK-EVEN PRICE PER KILOGRAM =				**$7.80**
(at current production level) = ([total fixed costs / kgs sold] + [operating cost per kilogram])				
NET PRESENT VALUE (PRE-TAX) OF A 20-YEAR LEASE UNDER THIS PRODUCTION SYSTEM (AT 5%):				**$41,743**

Allium - Moringa Intercrop

.025 hectare unit

Item	Unit	Qty.	Price ($)	Amt.
SALES				
Sale of fresh chives from .025 ha	kg	87.8	$22.00	$1,932
Moringa Powder sales	kg	34.25	$7.33	$251
Total Revenue				**$2,183**
OPERATING COSTS				
Seedlings	plants	1440	$0.15	$216
Fertilizer (20 - 20 - 20)	bags	0.7	$23.60	$16
Herbicide and Insecticides (Azetin™, Dipel™, and Mpede™)	package	1	$245.15	$245
Drip irrigation lines	layout	1	$300.00	$300
Water	m^3	13.5	$4.49	$61
Labor: (a) irrigation (set-up & repair)	hours	9.3	$6.25	$58
(b) planting	hours	9.5	$6.25	$59
(c) fertigating and weeding	hours	83.4	$6.25	$521
(d) harvesting (including weighting & bunching)	hours	54.2	$6.25	$339
Machinery: (a) plowing	hectare	0.025	$154.44	$4
(b) harrowing	hectare	0.025	$38.61	$1
(c) tilling	hectare	0.025	$38.61	$1
Interest on operating capital	$	6%	$1,821	$109
Total Operating Cost				**$1,930**
FIXED COSTS				
Land lease	hectare	0.025	$49.42	$1
Interest on avg. investment (excl. land)	$	10.00%	1041.67	$104
Depreciation: (a) irrigation equipment	hectare	0.025	$257.40	$6
(b) other equipment	hectare	0.025	$12.87	$0
(c) well	hectare	0.025	$72.08	$2
(d) other	hectare	0.025	$5.15	$0
Total Fixed Cost				**$114**
PRE-TAX RETURNS (total revenue - total operating costs - fixed cost)				**$139**
BREAK-EVEN PRICE PER KILOGRAM (Chive) =				**$23.27**
BREAK-EVEN PRICE PER KILOGRAM (Moringa) =				**$59.70**
(at current production level) = ([total fixed costs / kgs sold] + [operating cost per kilogram])				
NET PRESENT VALUE (PRE-TAX) OF A 20-YEAR LEASE UNDER THIS PRODUCTION SYSTEM (AT 5%):				**$1,734**

Assumptions:

1. Total revenue and costs are rounded off to the nearest dollar.

Data Source:

1. Input and yield data: UVI-AES experimental plots; production data are for 2002/2003.
2. Depreciation rates: Previous UVI-CES enterprise budgets.
3. Selected costs and prices: VI Dept. of Agriculture and previous UVI-CES enterprise budgets.
4. Output price: Informal survey of local growers, farmers market and supermarket. Moringa powder price from WWW search.

Estimated Costs and Returns at Current Market Prices, St. Croix, USVI, 2002-2003

Coriandrum Sole-crop

.025 hectare unit

Item	Unit	Qty.	Price ($)	Amt.
SALES				
Sale of fresh cilantro from .025 ha	kg	363.6	$22.00	$7,999
Other sales				$0
Total Revenue				**$7,999**
OPERATING COSTS				
Seedlings	plants	1800	$0.15	$270
Fertilizer (20 - 20 - 20)	bags	0.7	$23.60	$16
Herbicide and Insecticides (Azetin™, Dipel™, and Mpede™)	package	1	$245.15	$245
Drip irrigation lines	layout	1	$300.00	$300
Water	m^3	12.0	$4.49	$54
Labor: (a) irrigation (set-up & repair)	hours	9.3	$6.25	$58
(b) planting	hours	10.0	$6.25	$63
(c) fertigating and weeding	hours	83.4	$6.25	$521
(d) harvesting (including weighting & bunching)	hours	22.5	$6.25	$141
Machinery: (a) plowing	hectare	0.025	$154.44	$4
(b) harrowing	hectare	0.025	$38.61	$1
(c) tilling	hectare	0.025	$38.61	$1
Interest on operating capital	$	6%	$1,673	$100
Total Operating Cost				**$1,774**
FIXED COSTS				
Land lease	hectare	0.025	$49.42	$1
Interest on avg. investment (excl. land)	$	10.00%	1041.67	$104
Depreciation: (a) irrigation equipment	hectare	0.025	$257.40	$6
(b) other equipment	hectare	0.025	$12.87	$0
(c) well	hectare	0.025	$72.08	$2
(d) other	hectare	0.025	$5.15	$0
Total Fixed Cost				**$114**
PRE-TAX RETURNS (total revenue - total operating costs - fixed cost)				**$6,111**
BREAK-EVEN PRICE PER KILOGRAM =				**$5.19**
(at current production level) = ([total fixed costs / kgs sold] + [operating cost per kilogram])				
NET PRESENT VALUE (PRE-TAX) OF A 20-YEAR LEASE UNDER THIS PRODUCTION SYSTEM (AT 5%):				**$76,162**

Coriandrum - Moringa Intercrop

.025 hectare unit

Item	Unit	Qty.	Price ($)	Amt.
SALES				
Sale of fresh cilantro from .025 ha	kg	121.0	$22.00	$2,661
Moringa Powder sales	kg	34.25	$7.33	$251
Total Revenue				**$2,912**
OPERATING COSTS				
Seedlings	plants	1440	$0.15	$216
Fertilizer (20 - 20 - 20)	bags	0.7	$23.60	$16
Herbicide and Insecticides (Azetin™, Dipel™, and Mpede™)	package	1	$245.15	$245
Drip irrigation lines	layout	1	$300.00	$300
Water	m^3	13.5	$4.49	$61
Labor: (a) irrigation (set-up & repair)	hours	9.3	$6.25	$58
(b) planting	hours	9.5	$6.25	$59
(c) fertigating and weeding	hours	83.4	$6.25	$521
(d) harvesting (including weighting & bunching)	hours	60.2	$6.25	$376
Machinery: (a) plowing	hectare	0.025	$154.44	$4
(b) harrowing	hectare	0.025	$38.61	$1
(c) tilling	hectare	0.025	$38.61	$1
Interest on operating capital	$	6%	$1,858	$112
Total Operating Cost				**$1,970**
FIXED COSTS				
Land lease	hectare	0.025	$49.42	$1
Interest on avg. investment (excl. land)	$	10.00%	1041.67	$104
Depreciation: (a) irrigation equipment	hectare	0.025	$257.40	$6
(b) other equipment	hectare	0.025	$12.87	$0
(c) well	hectare	0.025	$72.08	$2
(d) other	hectare	0.025	$5.15	$0
Total Fixed Cost				**$114**
PRE-TAX RETURNS (total revenue - total operating costs - fixed cost)				**$828**
BREAK-EVEN PRICE PER KILOGRAM (Cilantro) =				**$17.23**
BREAK-EVEN PRICE PER KILOGRAM (Moringa) =				**$60.86**
(at current production level) = ([total fixed costs / kgs sold] + [operating cost per kilogram])				
NET PRESENT VALUE (PRE-TAX) OF A 20-YEAR LEASE UNDER THIS PRODUCTION SYSTEM (AT 5%):				**$10,319**

Assumptions:

1. Total revenue and costs are rounded off to the nearest dollar.

Data Source:

1. Input and yield data: UVI-AES experimental plots; production data are for 2002/2003.
2. Depreciation rates: Previous UVI-CES enterprise budgets.
3. Selected costs and prices: VI Dept. of Agriculture and previous UVI-CES enterprise budgets.
4. Output price: Informal survey of local growers, farmers market and supermarket. Moringa powder price from WWW search.

Estimated Costs and Returns at Current Market Prices, St. Croix, USVI, 2002-2003

Cymbopogon **Sole-crop**

.025 hectare unit

Item	Unit	Qty.	Price ($)	Amt.
SALES				
Sale of fresh lemongrass from .025 ha	kg	918.0	$20.00	$18,360
Other sales				$0
Total Revenue				**$18,360**
OPERATING COSTS				
Seedlings	plants	600	$0.15	$90
Fertilizer (20 - 20 - 20)	bags	0.7	$23.60	$16
Herbicide and Insecticides (Azetin™, Dipel™, and Mpede™)	package	1	$245.15	$245
Drip irrigation lines	layout	1	$300.00	$300
Water	m^3	12.0	$4.49	$54
Labor: (a) irrigation (set-up & repair)	hours	9.3	$6.25	$58
(b) planting	hours	5.0	$6.25	$31
(c) fertigating and weeding	hours	83.4	$6.25	$521
(d) harvesting (including weighting & bunching)	hours	40.0	$6.25	$250
Machinery: (a) plowing	hectare	0.025	$154.44	$4
(b) harrowing	hectare	0.025	$38.61	$1
(c) tilling	hectare	0.025	$38.61	$1
Interest on operating capital	$	6%	$1,571	$94
Total Operating Cost				**$1,666**
FIXED COSTS				
Land lease	hectare	0.025	$49.42	$1
Interest on avg. investment (excl. land)	$	10.00%	1041.67	$104
Depreciation: (a) irrigation equipment	hectare	0.025	$257.40	$6
(b) other equipment	hectare	0.025	$12.87	$0
(c) well	hectare	0.025	$72.08	$2
(d) other	hectare	0.025	$5.15	$0
Total Fixed Cost				**$114**
PRE-TAX RETURNS (total revenue - total operating costs - fixed cost)				**$16,580**
BREAK-EVEN PRICE PER KILOGRAM =				**$1.94**
(at current production level) = ([total fixed costs / kgs sold] + [operating cost per kilogram])				
NET PRESENT VALUE (PRE-TAX) OF A 20-YEAR LEASE UNDER THIS PRODUCTION SYSTEM (AT 5%):				**$206,626**

Cymbopogon* - *Moringa **Intercrop**

.025 hectare unit

Item	Unit	Qty.	Price ($)	Amt.
SALES				
Sale of fresh lemongrass from .025 ha	kg	559.7	$20.00	$11,194
Moringa Powder sales	kg	34.25	$7.33	$251
Total Revenue				**$11,445**
OPERATING COSTS				
Seedlings	plants	480	$0.15	$72
Fertilizer (20 - 20 - 20)	bags	0.7	$23.60	$16
Herbicide and Insecticides (Azetin™, Dipel™, and Mpede™)	package	1	$245.15	$245
Drip irrigation lines	layout	1	$300.00	$300
Water	m^3	13.5	$4.49	$61
Labor: (a) irrigation (set-up & repair)	hours	9.3	$6.25	$58
(b) planting	hours	5.5	$6.25	$34
(c) fertigating and weeding	hours	83.4	$6.25	$521
(d) harvesting (including weighting & bunching)	hours	74.2	$6.25	$464
Machinery: (a) plowing	hectare	0.025	$154.44	$4
(b) harrowing	hectare	0.025	$38.61	$1
(c) tilling	hectare	0.025	$38.61	$1
Interest on operating capital	$	6%	$1,777	$107
Total Operating Cost				**$1,884**
FIXED COSTS				
Land lease	hectare	0.025	$49.42	$1
Interest on avg. investment (excl. land)	$	10.00%	1041.67	$104
Depreciation: (a) irrigation equipment	hectare	0.025	$257.40	$6
(b) other equipment	hectare	0.025	$12.87	$0
(c) well	hectare	0.025	$72.08	$2
(d) other	hectare	0.025	$5.15	$0
Total Fixed Cost				**$114**
PRE-TAX RETURNS (total revenue - total operating costs - fixed cost)				**$9,447**
BREAK-EVEN PRICE PER KILOGRAM (Lemongrass) =				**$3.57**
BREAK-EVEN PRICE PER KILOGRAM (Moringa) =				**$58.34**
(at current production level) = ([total fixed costs / kgs sold] + [operating cost per kilogram])				
NET PRESENT VALUE (PRE-TAX) OF A 20-YEAR LEASE UNDER THIS PRODUCTION SYSTEM (AT 5%):				**$117,730**

Assumptions:

1. Total revenue and costs are rounded off to the nearest dollar.
2. Replanting not required due to natural regeneration.

Data Source:

1. Input and yield data: UVI-AES experimental plots; production data are for 2002/2003.
2. Depreciation rates: Previous UVI-CES enterprise budgets.
3. Selected costs and prices: VI Dept. of Agriculture and previous UVI-CES enterprise budgets.
4. Output price: Informal survey of local growers, farmers market and supermarket. Moringa powder price from WWW search.

Estimated Costs and Returns at Current Market Prices, St. Croix, USVI, 2002-2003

Ocimum Sole-crop

.025 hectare unit

Item	Unit	Qty.	Price ($)	Amt.
SALES				
Sale of fresh basil from .025 ha	kg	656.4	$20.00	$13,128
Other sales				$0
Total Revenue				**$13,128**
OPERATING COSTS				
Seedlings	plants	1200	$0.15	$180
Fertilizer (20 - 20 - 20)	bags	0.7	$23.60	$16
Herbicide and Insecticides (Azetin™, Dipel™, and Mpede™)	package	1	$245.15	$245
Drip irrigation lines	layout	1	$300.00	$300
Water	m^3	12.0	$4.49	$54
Labor: (a) irrigation (set-up & repair)	hours	9.3	$6.25	$58
(b) planting	hours	10.0	$6.25	$63
(c) fertigating and weeding	hours	83.4	$6.25	$521
(d) harvesting (including weighting & bunching)	hours	30.0	$6.25	$188
Machinery: (a) plowing	hectare	0.025	$154.44	$4
(b) harrowing	hectare	0.025	$38.61	$1
(c) tilling	hectare	0.025	$38.61	$1
Interest on operating capital	$	6%	$1,630	$98
Total Operating Cost				**$1,728**
FIXED COSTS				
Land lease	hectare	0.025	$49.42	$1
Interest on avg. investment (excl. land)	$	10.00%	1041.67	$104
Depreciation: (a) irrigation equipment	hectare	0.025	$257.40	$6
(b) other equipment	hectare	0.025	$12.87	$0
(c) well	hectare	0.025	$72.08	$2
(d) other	hectare	0.025	$5.15	$0
Total Fixed Cost				**$114**
PRE-TAX RETURNS (total revenue - total operating costs - fixed cost)				**$11,286**
BREAK-EVEN PRICE PER KILOGRAM =				**$2.81**
(at current production level) = ([total fixed costs / kgs sold] + [operating cost per kilogram])				
NET PRESENT VALUE (PRE-TAX) OF A 20-YEAR LEASE UNDER THIS PRODUCTION SYSTEM (AT 5%):				**$140,648**

Ocimum - Moringa Intercrop

.025 hectare unit

Item	Unit	Qty.	Price ($)	Amt.
SALES				
Sale of fresh basil from .025 ha	kg	429.3	$20.00	$8,587
Moringa Powder sales	kg	34.25	$7.33	$251
Total Revenue				**$8,838**
OPERATING COSTS				
Seedlings	plants	960	$0.15	$144
Fertilizer (20 - 20 - 20)	bags	0.7	$23.60	$16
Herbicide and Insecticides (Azetin™, Dipel™, and Mpede™)	package	1	$245.15	$245
Drip irrigation lines	layout	1	$300.00	$300
Water	m^3	13.5	$4.49	$61
Labor: (a) irrigation (set-up & repair)	hours	9.3	$6.25	$58
(b) planting	hours	9.5	$6.25	$59
(c) fertigating and weeding	hours	83.4	$6.25	$521
(d) harvesting (including weighting & bunching)	hours	66.2	$6.25	$414
Machinery: (a) plowing	hectare	0.025	$154.44	$4
(b) harrowing	hectare	0.025	$38.61	$1
(c) tilling	hectare	0.025	$38.61	$1
Interest on operating capital	$	6%	$1,824	$109
Total Operating Cost				**$1,933**
FIXED COSTS				
Land lease	hectare	0.025	$49.42	$1
Interest on avg. investment (excl. land)	$	10.00%	1041.67	$104
Depreciation: (a) irrigation equipment	hectare	0.025	$257.40	$6
(b) other equipment	hectare	0.025	$12.87	$0
(c) well	hectare	0.025	$72.08	$2
(d) other	hectare	0.025	$5.15	$0
Total Fixed Cost				**$114**
PRE-TAX RETURNS (total revenue - total operating costs - fixed cost)				**$6,790**
BREAK-EVEN PRICE PER KILOGRAM (Basil) =				**$4.77**
BREAK-EVEN PRICE PER KILOGRAM (Moringa) =				**$59.79**
(at current production level) = ([total fixed costs / kgs sold] + [operating cost per kilogram])				
NET PRESENT VALUE (PRE-TAX) OF A 20-YEAR LEASE UNDER THIS PRODUCTION SYSTEM (AT 5%):				**$84,622**

Assumptions:
1. Total revenue and costs are rounded off to the nearest dollar.
2. Two plantings.

Data Source:
1. Input and yield data: UVI-AES experimental plots; production data are for 2002/2003.
2. Depreciation rates: Previous UVI-CES enterprise budgets.
3. Selected costs and prices: VI Dept. of Agriculture and previous UVI-CES enterprise budgets.
4. Output price: Informal survey of local growers, farmers market and supermarket. Moringa powder price from WWW search.

Estimated Costs and Returns at Current Market Prices, St. Croix, USVI, 2002-2003

Stachytarpheta Sole-crop

.025 hectare unit

Item	Unit	Qty.	Price ($)	Amt.
SALES				
Sale of fresh worrywine from .025 ha	kg	865.2	$20.00	$17,304
Other sales				$0
Total Revenue				**$17,304**
OPERATING COSTS				
Seedlings	plants	600	$0.15	$90
Fertilizer (20 - 20 - 20)	bags	0.7	$23.60	$16
Herbicide and Insecticides (Azetin™, Dipel™, and Mpede™)	package	1	$245.15	$245
Drip irrigation lines	layout	1	$300.00	$300
Water	m^3	12.0	$4.49	$54
Labor: (a) irrigation (set-up & repair)	hours	9.3	$6.25	$58
(b) planting	hours	5.0	$6.25	$31
(c) fertigating and weeding	hours	83.4	$6.25	$521
(d) harvesting (including weighting & bunching)	hours	20.0	$6.25	$125
Machinery: (a) plowing	hectare	0.025	$154.44	$4
(b) harrowing	hectare	0.025	$38.61	$1
(c) tilling	hectare	0.025	$38.61	$1
Interest on operating capital	$	6%	$1,446	$87
Total Operating Cost				**$1,533**
FIXED COSTS				
Land lease	hectare	0.025	$49.42	$1
Interest on avg. investment (excl. land)	$	10.00%	1041.67	$104
Depreciation: (a) irrigation equipment	hectare	0.025	$257.40	$6
(b) other equipment	hectare	0.025	$12.87	$0
(c) well	hectare	0.025	$72.08	$2
(d) other	hectare	0.025	$5.15	$0
Total Fixed Cost				**$114**
PRE-TAX RETURNS (total revenue - total operating costs - fixed cost)				**$15,657**
BREAK-EVEN PRICE PER KILOGRAM =				**$1.90**
(at current production level) = ([total fixed costs / kgs sold] + [operating cost per kilogram])				
NET PRESENT VALUE (PRE-TAX) OF A 20-YEAR LEASE UNDER THIS PRODUCTION SYSTEM (AT 5%):				**$195,117**

Stachytarpheta - Moringa Intercrop

.025 hectare unit

Item	Unit	Qty.	Price ($)	Amt.
SALES				
Sale of fresh worrywine from .025 ha	kg	488.2	$20.00	$9,763
Moringa Powder sales	kg	34.25	$7.33	$251
Total Revenue				**$10,014**
OPERATING COSTS				
Seedlings	plants	480	$0.15	$72
Fertilizer (20 - 20 - 20)	bags	0.7	$23.60	$16
Herbicide and Insecticides (Azetin™, Dipel™, and Mpede™)	package	1	$245.15	$245
Drip irrigation lines	layout	1	$300.00	$300
Water	m^3	13.5	$4.49	$61
Labor: (a) irrigation (set-up & repair)	hours	9.3	$6.25	$58
(b) planting	hours	5.5	$6.25	$34
(c) fertigating and weeding	hours	83.4	$6.25	$521
(d) harvesting (including weighting & bunching)	hours	58.2	$6.25	$364
Machinery: (a) plowing	hectare	0.025	$154.44	$4
(b) harrowing	hectare	0.025	$38.61	$1
(c) tilling	hectare	0.025	$38.61	$1
Interest on operating capital	$	6%	$1,677	$101
Total Operating Cost				**$1,778**
FIXED COSTS				
Land lease	hectare	0.025	$49.42	$1
Interest on avg. investment (excl. land)	$	10.00%	1041.67	$104
Depreciation: (a) irrigation equipment	hectare	0.025	$257.40	$6
(b) other equipment	hectare	0.025	$12.87	$0
(c) well	hectare	0.025	$72.08	$2
(d) other	hectare	0.025	$5.15	$0
Total Fixed Cost				**$114**
PRE-TAX RETURNS (total revenue - total operating costs - fixed cost)				**$8,123**
BREAK-EVEN PRICE PER KILOGRAM (Worrywine) =				**$3.88**
BREAK-EVEN PRICE PER KILOGRAM (Moringa) =				**$55.24**
(at current production level) = ([total fixed costs / kgs sold] + [operating cost per kilogram])				
NET PRESENT VALUE (PRE-TAX) OF A 20-YEAR LEASE UNDER THIS PRODUCTION SYSTEM (AT 5%):				**$101,225**

Assumptions:

1. Total revenue and costs are rounded off to the nearest dollar.

Data Source:

1. Input and yield data: UVI-AES experimental plots; production data are for 2002/2003.
2. Depreciation rates: Previous UVI-CES enterprise budgets.
3. Selected costs and prices: VI Dept. of Agriculture and previous UVI-CES enterprise budgets.
4. Output price: Informal survey of local growers, farmers market and supermarket. Moringa powder price from WWW search.

Estimated Costs and Returns at Current Market Prices, St. Croix, USVI, 2002-2003

Verbesina Sole-crop

.025 hectare unit

Item	Unit	Qty.	Price ($)	Amt.
SALES				
Sale of fresh inflammation bush from .025 ha	kg	121.2	$25.00	$3,030
Other sales				$0
Total Revenue				**$3,030**
OPERATING COSTS				
Seedlings	plants	600	$0.15	$90
Fertilizer (20 - 20 - 20)	bags	0.7	$23.60	$16
Herbicide and Insecticides (Azetin™, Dipel™, and Mpede™)	package	1	$245.15	$245
Drip irrigation lines	layout	1	$300.00	$300
Water	m^3	12.0	$4.49	$54
Labor: (a) irrigation (set-up & repair)	hours	9.3	$6.25	$58
(b) planting	hours	5.0	$6.25	$31
(c) fertigating and weeding	hours	83.4	$6.25	$521
(d) harvesting (including weighting & bunching)	hours	30.0	$6.25	$188
Machinery: (a) plowing	hectare	0.025	$154.44	$4
(b) harrowing	hectare	0.025	$38.61	$1
(c) tilling	hectare	0.025	$38.61	$1
Interest on operating capital	$	6%	$1,509	$91
Total Operating Cost				**$1,599**
FIXED COSTS				
Land lease	hectare	0.025	$49.42	$1
Interest on avg. investment (excl. land)	$	10.00%	1041.67	$104
Depreciation: (a) irrigation equipment	hectare	0.025	$257.40	$6
(b) other equipment	hectare	0.025	$12.87	$0
(c) well	hectare	0.025	$72.08	$2
(d) other	hectare	0.025	$5.15	$0
Total Fixed Cost				**$114**
PRE-TAX RETURNS (total revenue - total operating costs - fixed cost)				**$1,316**
BREAK-EVEN PRICE PER KILOGRAM =				**$14.14**
(at current production level) = ([total fixed costs / kgs sold] + [operating cost per kilogram])				
NET PRESENT VALUE (PRE-TAX) OF A 20-YEAR LEASE UNDER THIS PRODUCTION SYSTEM (AT 5%):				**$16,406**

Verbesina - *Moringa* Intercrop

.025 hectare unit

Item	Unit	Qty.	Price ($)	Amt.
SALES				
Sale of fresh inflammation bush from .025 ha	kg	63.8	$25.00	$1,596
Moringa Powder sales	kg	34.25	$7.33	$251
Total Revenue				**$1,847**
OPERATING COSTS				
Seedlings	plants	480	$0.15	$72
Fertilizer (20 - 20 - 20)	bags	0.7	$23.60	$16
Herbicide and Insecticides (Azetin™, Dipel™, and Mpede™)	package	1	$245.15	$245
Drip irrigation lines	layout	1	$300.00	$300
Water	m^3	13.5	$4.49	$61
Labor: (a) irrigation (set-up & repair)	hours	9.3	$6.25	$58
(b) planting	hours	5.5	$6.25	$34
(c) fertigating and weeding	hours	83.4	$6.25	$521
(d) harvesting (including weighting & bunching)	hours	66.2	$6.25	$414
Machinery: (a) plowing	hectare	0.025	$154.44	$4
(b) harrowing	hectare	0.025	$38.61	$1
(c) tilling	hectare	0.025	$38.61	$1
Interest on operating capital	$	6%	$1,727	$104
Total Operating Cost				**$1,831**
FIXED COSTS				
Land lease	hectare	0.025	$49.42	$1
Interest on avg. investment (excl. land)	$	10.00%	1041.67	$104
Depreciation: (a) irrigation equipment	hectare	0.025	$257.40	$6
(b) other equipment	hectare	0.025	$12.87	$0
(c) well	hectare	0.025	$72.08	$2
(d) other	hectare	0.025	$5.15	$0
Total Fixed Cost				**$114**
PRE-TAX RETURNS (total revenue - total operating costs - fixed cost)				**-$98**
BREAK-EVEN PRICE PER KILOGRAM (Inflammation Bush) =				**$30.46**
BREAK-EVEN PRICE PER KILOGRAM (Moringa) =				**$56.79**
(at current production level) = ([total fixed costs / kgs sold] + [operating cost per kilogram])				
NET PRESENT VALUE (PRE-TAX) OF A 20-YEAR LEASE UNDER THIS PRODUCTION SYSTEM (AT 5%):				**-$1,217**

Assumptions:

1. Total revenue and costs are rounded off to the nearest dollar.
2. Replanting not required due to natural regeneration.

Data Source:

1. Input and yield data: UVI-AES experimental plots; production data are for 2002/2003.
2. Depreciation rates: Previous UVI-CES enterprise budgets.
3. Selected costs and prices: VI Dept. of Agriculture and previous UVI-CES enterprise budgets.
4. Output price: Informal survey of local growers, farmers market and supermarket. Moringa powder price from WWW search.

APPENDIX B
ECONOMIC ANALYSIS VARIABLES

Allium schoenoprasum (Chives)

1. The mean yield per plant (wet weight) from each block of the control (area = 37.5 m^2, N = 157) was 0.13 kg. In 250 m^2 there would be 1800 plants on 20.3 cm (8") drip line (120 plants per line * 15 lines), therefore yield from 250 m^2 can be expected to be = 0.13 kg * 1800 = 235.8 kg / 250 m^2. The mean yield per plant (wet weight) from each block of the treatment (area = 37.5 m^2, N = 155) was 0.06 kg. In 250 m^2 intercrop there would be 1440 plants on 20.3 cm (8") drip line (120 plants per line * 12 lines), therefore the yield from 250 m^2 can be expected to be = 0.06 * 1440 = 87.8. This is the yield from 2 harvests.

2. Market price of \$22 kg^{-1} for fresh chives was determined from previous AES enterprise budgets and informal surveys of St. Croix and St. John markets.

3. Average yield (wet weight) of *Moringa* cuttings from harvest 1 was 0.64 kg. Dry weight equaled 35.8%. Average yield dry *Moringa* powder per tree from harvest 1 was therefore 0.64 kg * 0.36 = 0.23 kg. Average yield (wet weight) of *Moringa* cuttings from harvest 2 was 2.13 kg. Dry weight equaled 25.1%. Average yield dry *Moringa* power per tree from harvest two was therefore 2.13 kg * 0.25 = 0.53 kg. In three, 25-meter long alleys with in-row spacing of 1.75 meters, there would be 15 trees per row, for 45 trees total. Total *Moringa* powder yield for 250 m^2 would be 45 trees * 0.23 + 45 trees * 0.53 = 34.25 kg.

4. *Moringa* powder was estimated to be \$7.33 per kg based on web searches for *Moringa* powder products, which yielded a minimum retail price of \$22 per kg (Moringa Farms, 2003), assuming farmers could capture 33% of this price.

5. Chives are an annual that require replanting in subsequent years. \$0.15 per plant is the price per seedling from the Virgin Islands, Department of Agriculture, Kingshill, St. Croix.

6. Fertilizer (20-20-20) used for the research field (370 m^2) was one bag, at \$23.60. One species occupied 37 m^2 so fertilizer required per species is one bag / 10 * 6.67 (250 m^2 / 37 m^2 = 6.67) = 0.67 bags for 250 m^2.

7. Herbicide and insecticides used were Azatin® (\$174.75 per quart), Dipel® (\$15.60 per bag), and Mpede® (\$54.80 per 2.5 gallon bottle). Precise amounts were not available, so price per unit is used.

8. Drip irrigation for a sole-crop covering 250 m^2 would require 375 meters (15 lines x 25 m = 375 m or 1200 feet) drip tape at $0.80 per meters, 45 meters of polyhose at $0.32 per meter, 15 "T's" at $1.25 each and 15 endcaps at $0.85 each. Drip irrigation for the intercrop covering 250 m^2 would require 300 meters (960 feet) drip tape, 116 meters of polyhose, 15 "T's", 15 endcaps, 45 emitters at $0.75 each and one emitter hole punch at $10.

9. 12 m^3 of water at the UVI rate of $4.49 / m^3. Basil water usage of 12 m^3 was determined by dividing total gallons (4773.4 for each 24" species) by 10 (2 treatments and 5 species) and multiplying by 6.67 (for 250 m^2) then converting from gallons to m^3 (3.79 m^3 / 1000 gallons). *Moringa* water usage was 1.49 m^3 (295.2 gallons / 5 * 6.67 = 393.62 gallons).

10. Going rate of labor on St. Croix is $6.25 per hour.

11. Irrigation setup and repair was 9.3 hours per species per treatment for the season (14 hrs / 10 * 6.67 = 9.3 hours).

12. Planting time required for the sole-crop is 10 hours (3 plants / minute * 1800 plants = 600 minutes / 60 = 10 hours) and 8 hours for the intercrop (1440 plants). *Moringa* hedgerows require 1.5 hours to establish and replant.

13. Fertigating and weeding was 83.4 hours (125 hours / 10 * 6.67 = 83.38).

14. Harvesting and bunching estimated to be 4 plants per minute per harvest, which equals 15 hours for the 1800 chive plants in the sole-crop (1800 plants / 4 plants per minute * 2 chive harvests / 60 minutes = 15 hours) and 12 hours for the intercrop (1440 plants). *Moringa* harvesting and drying estimated to require 42.2 hours to process yield from 250 m^2 per season.

15. Plowing is estimated to be $154.44 per ha ($60 / ac from 1999, adjusted by * 1.04167, the rate of inflation, to $62.50 * 2.471 ac / ha = $154.44). Harrowing and tilling were estimated to be $38.61 per ha ($15 / ac from 1999, adjusted by * 1.04167 to $15.63 * 2.471 ac / ha = $38.61).

16. Interest on operating capital equal to 1% per month.

17. Land lease from the Virgin Islands Department of Agriculture = $20 / acre * 2.471 acre / ha = $49.42 / ha.

18. Interest on average investment (excluding land) = $1000 (1999 rate) adjusted by 1.04167 to $1041.67.

19. Depreciation on irrigation = $100 * 1.04167 = $104.17 * 2.471 acres/ha = $257.40; on other equipment = $5 * 1.04167 = $5.21 * 2.471 acres/ha = $12.87; on well = $28 * 1.04167 = $29.17 * 2.471 acres/ha = $72.08; on other = $2 * 1.04167 = $2.08 * 2.471 = $5.15.

Coriandrum sativum (Cilantro)

20. The mean yield per plant (wet weight) from each block of the control (area = 37.5 m^2, N = 70) was 0.20 kg. The yield from 250 m^2 can be expected to be = 0.20 kg * 1800 = 363.6 kg / 250 m^2. The mean yield per plant (wet weight) from each block of the treatment (area = 37.5 m^2, N = 44) was 0.08 kg. The yield from 250 m^2 can be expected to be = 0.08 * 1440 = 120.96. This is the yield from 3 harvests.

21. Market price of \$22 kg^{-1} for fresh cilantro was determined from informal surveys of St. Croix and St. John markets.

22. Cilantro is an annual that would require replanting in subsequent years.

23. Planting time required is 10 hours for the sole-crop and 8 hours for the intercrop. Moringa hedgerows require 1.5 hours to establish and replant.

24. Harvesting and bunching estimated to be 22.5 hours for cilantro (1800 plants / 4 plants per minute * 3 cilantro harvests / 60 minutes = 22.5 hours) and 18 hours for the intercrop (1440 plants). *Moringa* harvesting and drying estimated to require 42.2 hours to process yield from 250 m2 per season.

Cymbopogon citratus (Lemongrass)

25. The mean yield per plant (wet weight) from each block of the control (area = 37.5 m^2, N = 72) was 1.53 kg. The yield from 250 m^2 can be expected to be = 1.53 kg * 600 = 918 kg / 250 m^2. The mean yield per plant (wet weight) from each block of the treatment (area = 37.5 m^2, N = 72) was 1.17 kg. The yield from 250 m^2 can be expected to be = 1.17 * 480 = 559.7 kg / 250 m^2. This is the yield from 4 harvests.

26. Market price of \$20 kg^{-1} for fresh lemongrass was determined from informal surveys of St. Croix and St. John markets.

27. Lemongrass is a perennial that if managed properly, once established, would not require replanting.

28. Lemongrass planting time required is 5 hours for the sole-crop and 4 hours for the intercrop. *Moringa* hedgerows require 1.5 hours to establish and replant.

29. Harvesting and bunching estimated to be 40 hours for lemongrass (600 plants * 1 minute * 4 lemongrass harvests / 60 minutes = 40 hours) and 32 hours for the intercrop (480 plants). *Moringa* harvesting and drying estimated to require 42.2 hours to process yield from 250 m^2 per season.

<u>*Ocimum basilicum* (Basil)</u>

30. The mean yield per plant (wet weight) from each block of the control (area = 37.5 m^2, N = 72) was 1.09 kg. A 250 m^2 field, 25 m long with 15 lines spaced 71 cm apart would have 40 plants on each 61 cm (24") drip line for a total of 600 plants (40 plants per line * 15 lines = 600 plants). Therefore yield from 250 m^2 can be expected to be = 1.09 kg * 600 = 656.4 kg / 250 m^2. The mean yield per plant (wet weight) from each block of the treatment (area = 37.5 m^2, N = 72) was 0.89 kg. A 250 m^2 field with two, five meter alleys and six lines in each, would have 480 plants (40 plants per line * 12 lines = 480 plants) and the yield can be expected to be = 0.89 kg * 480 = 429.3 kg / 250 m^2.

31. Market price of \$20 kg^{-1} for fresh basil was determined from informal surveys of St. Croix and St. John markets.

32. Basil was replanted once so 1200 plants are required for the sole-crop and 960 plants are required for the intercrop.

33. Planting time required for the sole-crop is estimated to be 10 hours (≈2 plants / minute * 600 plants = 300 minutes / 60 = 5 hours * two plantings). Planting time required for the intercrop is estimated to be 8 hours (480 plants). *Moringa* hedgerows require 1.5 hours to establish and replant (45 trees * 2 minutes to plant / tree = 90 minutes).

34. Harvesting and bunching estimated to be 1 minute per plant per harvest, which equals 30 hours for the sole-crop (600 plants * 1 minute * 3 basil harvests / 60 minutes = 30 hours) and 24 hours for the 480 basil plants in the intercrop. *Moringa* harvesting and drying (15 hours required to harvest and process samples from 2 harvests, N = 8) = 15 / 16 = 0.94 hours per tree * 45 trees = 42.2 hours to process yield from 250 m2 per season.

<u>*Stachytarpheta jamaicensis* (Worrywine)</u>

35. The mean yield per plant (wet weight) from each block of the control (area = 37.5 m^2, N = 72) was 1.44 kg. The yield from 250 m^2 can be expected to be = 1.44 kg * 600 = 865.2 kg / 250 m^2. The mean yield per plant (wet weight) from each block of the treatment (area = 37.5 m^2, N = 72) was 1.02 kg. The yield from 250 m^2 can be expected to be = 1.02 * 480 = 488.2 kg / 250 m^2. This is the yield from 3 harvests.

36. Market price of \$20 kg^{-1} for fresh worrywine was determined from informal surveys of St. Croix and St. John markets.

37. Worrywine is an annul that would require replanting in subsequent years.

38. Planting time required is 5 hours for the sole-crop and 4 hours for the intercrop. *Moringa* hedgerows require 1.5 hours to establish and replant.

39. Harvesting and bunching estimated to be 20 hours for worrywine control (600 plants * 1 minute * 2 worrywine harvests / 60 minutes = 20 hours) and 16 hours for the intercrop (480 plants). *Moringa* harvesting and drying estimated to require 42.2 hours to process yield from 250 m^2 per season.

Verbesina alata (Inflammation Bush)

40. The mean yield per plant (wet weight) from each block of the control (area = 37.5 m^2, N = 53) was 0.20 kg. The yield from 250 m^2 can be expected to be = 0.20 kg * 600 = 121.2 kg / 250 m^2. The mean yield per plant (wet weight) from each block of the treatment (area = 37.5 m^2, N = 50) was 0.13 kg. The yield from 250 m^2 can be expected to be = 0.13 kg * 480 = 63.8 kg / 250 m^2. This is the yield from 3 harvests.

41. Market price of $20 per kilo for fresh inflammation bush was determined from informal surveys of St. Croix and St. John markets.

42. Inflammation bush is an annual, though if managed properly once established would not require replanting, since it produces numerous seeds which germinate rapidly.

43. Planting time required is 5 hours for the sole-crop (≈2 plants / minute * 600 plants = 300 minutes / 60 = 5 hours) and 4 hours for the intercrop (480 plants). *Moringa* hedgerows require 1.5 hours to establish and replant.

44. Harvesting and bunching estimated to be 30 hours for inflammation bush sole-crop (600 plants * 1 minute * 3 inflammation bush harvests / 60 minutes = 30 hours) and 24 hours for the intercrop (480 plants). *Moringa* harvesting and drying estimated to require 42.2 hours to process yield from 250 m^2 per season.

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BIOGRAPHICAL SKETCH

Brian Becker was born into a military family living in Okinawa, Japan, in 1970. Returning to the United States with his family he lived in Louisiana, Georgia, Michigan, and Texas before settling in Kansas where he completed his bachelor's degree in anthropology and wildlife biology with a secondary major in natural resources and environmental sciences at Kansas State University. His work with non-timber forest product management, including medicinal and aromatic plants (MAPs), began with a Peace Corps assignment with Nepal's Community Forest Program, and continued to include the United States' Appalachian Mountains, southeastern costal plain and the US Virgin Islands. His research interests include the biometrics, management, production and marketing of non-timber forest products. He is currently a research coordinator with the School of Forest Resources and Conservation's Phytoremediation and Short Rotation Woody Crops Program at the University of Florida, Gainesville, Florida.