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Sustainable Agricultural Intensification: The Role of Cardamom Agroforestry in the East Usambaras, Tanzania

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Abstract

The East Usambaras, located in northeast Tanzania, are a tropical biodiversity hotspot where unsustainable agricultural management practices pose threats to landscape conservation and development objectives. Promoting Sustainable Agricultural Intensification (SAI) would improve long term productivity and reduce pressures on forest reserves. This study assesses adoption of soil fertility investments using farm and household data to evaluate profitability and feasibility of scaling up SAI. A cross sectional design and mixed methods approach were used to compare the profitability of common farming systems and the effects of various household characteristics on adoption of soil improvement practices. Focus groups were used to classify three common farming systems and a fourth model was developed to estimate the relative profitability of incorporating fallow, organic inputs and non-timber forest product activities. Next, household surveys (144) and a logit regression analysis were used to evaluate the effects of socioeconomic characteristics, physical and financial assets, tenure risk and plot specific attributes on the soil fertility investments specified in the model. Findings showed that the SAI model was financially competitive but would likely incur opportunity costs to labor. The logit results showed that marital status, household size, remittances, credit access, and tenure security significantly influenced adoption. Perceived fertility and distance to plots were also significant at plot level. The potential for developing synergies to promote and scale up SAI require stronger policy and institutional support.

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1. Introduction

Low agricultural productivity in sub-Saharan Africa (SSA) threatens food security, compromises health and nutrition, and undermines poverty alleviation efforts (Pretty et al., 2011; Diao et al., 2010). Agricultural practices influence levels of food production and, more broadly, the state of the global environment (Tilman et al., 2002). Population pressures have reduced land availability and led to a breakdown of natural fallow systems that were used to replenish soil fertility (Ajayi, et al., 2007). The removal of subsidies has increased fertilizer costs, making them largely unaffordable (FAO, 2011) and opportunities to extensify are limited due to gazetting of protected areas in the tropics (Reardon et al., 1999). As farmers turn to cultivation of marginal lands, including steep mountain slopes, increased soil erosion and reduced water availability negatively affect long term agricultural productivity (Maertens et al., 2006). Unsustainable intensification has been identified as a prominent driver of land use change and biodiversity loss in tropical regions (Sala et al., 2000 Wright, 2005). Soil fertility investments to improve productivity are needed to accelerate sustainable agricultural intensification (Place et al., 2004; Pretty, 2008).

Sustainable agricultural intensification (SAI) relies on natural, social and human capital assets and the use of available technologies and inputs to minimize or eliminate harm to the environment (Pretty, 2008). The goals of SAI include improving agricultural productivity, household food security, and rural livelihoods while simultaneously mitigating environmental degradation (Lee et al., 2006). SAI increases output and reduces negative environmental impacts while contributing to natural capital and the flow of environmental services (Pretty, 2008; Conway & Waage, 2010; Godfray et al., 2010). Labor and capital inputs can affect the long term sustainability of intensification processes. Labor led intensification refers to the emphasis on labor to improve short term agricultural productivity by cropping more densely, weeding, and harvesting more frequently (Clay et al., 1998). Capital led intensification relies on the substantial use of capital to enhance soil fertility (Reardon, et al., 2001) and includes adoption of land conservation investments, such as agroforestry (AF) (Garrett et al, 2000; Nair et al., 2008), fallowing, and adding organic matter (Clay et al., 1998; Reardon & Vosti, 1995). Although indigenous AF practices are widespread in Africa, (Franzel and Scherr, 2002) abandonment is high (Pattanayak et al., 2003) and adoption of capital inputs to improve soil productivity is generally low (Tenge et al. 2004; Jansen et al. 2006; Kassie et al. 2009; Wollni et al. 2010; Ajayi et al., 2007; Pretty et al., 2003).

The East Usambaras, located in northeast Tanzania, are a tropical biodiversity hotspot where unsustainable agricultural management practices pose threats to landscape conservation and development objectives. Few farmers invest in soil replenishment practices, despite growing population pressures and land scarcity concerns. Promoting SAI would improve long term agricultural productivity and reduce pressure on forest reserves. This study assesses adoption of soil fertility investments using farm and household data to evaluate profitability and feasibility of scaling up SAI in the area. A cross sectional design and mixed methods approach was used to compare the profitability of common farming systems and the influence of various household characteristics on adoption of soil improvement methods was measured. Focus groups were used to classify three common farming systems and a fourth model was developed to estimate the relative profitability of incorporating SAI capital investments, specifically fallow, organic inputs and non-timber forest product (NTFP) activities. Next, household surveys were used to evaluate the roles of socioeconomic characteristics, physical and financial assets, tenure risk and plot specific characteristics on the soil fertility investments specified in the model. Logit regression analyses highlighted household factors that signify where opportunities or challenges to adoption exist. The remainder of the paper is organized into four sections. The first section describes the study area and farming system and household data collection. Next, descriptive data, profitability and logit model results are presented and discussed in terms of their implications for creating financial incentives to adopt SAI. The paper is concluded with policy recommendations for how to promote and scale up SAI in the East Usambaras and other areas of high conservation importance.

2. Methodology

2.a Study Area

The East Usambara Mountains lie within the Eastern Arc Mountains, a chain of 13 mountain blocks and coastal forests in Tanzania and Kenya that support approximately 3300 km^2 of montane forests (Burgess et al., 2007) (Figure 1). The Eastern Arcs are classified as a Biodiversity Hotspot by Conservation International (Mittermeier et al., 1999, 2004; Burgess et al., 1998). They support the highest ratio of endemic flora and fauna per 100 km2 of all biodiversity hotspots in the world: 35% of the plants (e.g., 40 tree species) and more than 25% of animal species (e.g., 80 vertebrate species) are endemic (Burgess et al. 2007). At least 70% of the area's natural forest habitat has been lost, increasing the risk of extinction for many species (Newmark 1998, 2002; Burgess et al., 2007).

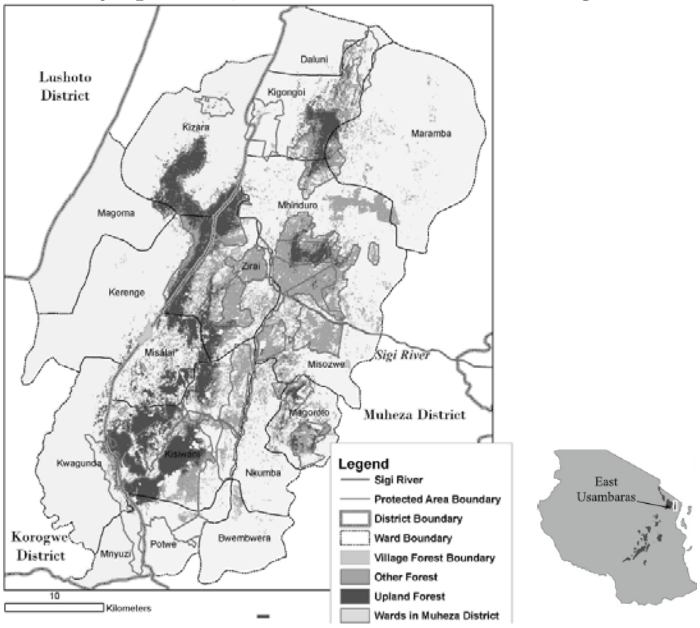

Figure 1 East Usambaras forest cover (2000) and district wards (Hall, 2008)

Settlement of the Usambara Mountains dates back to 100 C.E. (Schmidt, 1989). Activities from the 1960s to the present, such as commercial logging, estate farming, the expansion of smallholder agriculture, and conservation initiatives, have influenced the landscape (Rantala & Vihemäki, 2011; Conte 2004). Semi subsistence farming is the main livelihood for most people in the highlands. Favorable agroecological conditions support diverse food and cash crop production, including high value horticultural products such as spices. Many farmers also manage livestock and dairy cows to sell milk to a local cooperative.

Conservation attention increased in the early 80s (Rodgers and Homewood, 1982). The East Usambara Conservation and Development (EUCD) project began in 1987 and linked conservation of biodiversity with economic development (Conte, 2004). Despite promotion of soil and water conservation, tree planting, and the use of organic manure (Engh, 2011), adoption has been low (EUCAMP 2002; Reyes, et al., 2010). Productivity is threatened by poor soils, heavy rainfall, and generally poor and unsustainable farming methods (ANR New Management Plan, 2009). Conservation regulations limit traditional shifting cultivation practices (Reyes, et al., 2010) and population growth pressure and land scarcity threaten remaining natural forests (Reyes et al. 2005). Losses of productive land and inefficient farm management motivate clearance and cultivation on marginal lands, including steep slopes (Reyes et al., 2005).

2.a.i Cardamom Agroforestry

Cardamom is a perennial shrub commonly grown in highland AF systems. Cardamom (*Elettaria cardamomum)* was first introduced in the 1890s by German settlers (Reyes, 2008) and later promoted by the Tanzanian government in the 1980s as part of its export diversification strategy. The number of households estimated to cultivate cardamom range from 60-90% (Reyes, 2008; Sah, 1996; author's fieldwork). Cardamom sales comprise approximately 30% of household income and more than half of the total cash crop income (Reyes et al., 2006). Cardamom cultivation in the East Usambaras has been identified as one of the primary threats to natural forests outside of protected reserves (CEPF, 2005; Newmark, 2002; Reyes, 2008; Stocking and Perkin, 1991) However, cardamom production, relative to other crop systems, conserves more trees on farms (Woodcock, 1995). Other AF species grown under indigenous or semi-natural forests that have been recognized for their role in maintaining trees on private farms include cocoa and coffee. Maintaining trees on farms outside reserves reduces pressures on natural forests (Huang et al.) and has potential to improve landscape ecosystem functioning.

However, in the East Usambaras, labor led intensification practices undermine the potential of Cardamom AF as a long term, sustainable farming system. Approximately fifty percent of the tall canopy trees are removed and the entire understory is cleared (Reyes et al., 2005; 2008). Initially, species and structural diversity in the agroforest canopy is high (Hall et al., 2010) but, labor intensive management steadily reduces shade tree density and diversity (Rappole et al., 2003; Perfecto et al., 1996). Cardamom is densely intercropped with cash and subsistence crops, including several varieties of banana and cocoyams (*Xanthosoma* sp.). Continuous cropping accelerates fertility declines that lead to poor cardamom production after seven years (Stocking and Perkin, 1991). At this point farmers often convert Cardamom AF to second stage farming systems that support annual sun grown crops (Reyes, Stocking and Perkin, others) such as (sugarcane, *Saccharum officinarum*; maize, *Zea mays*; and cassava, *Manihot esculenta*) (Reyes). Natural fallowing, or withdrawal of land from cultivation to permit natural vegetation to grow, is rare (Reyes, 2008). Under current intensification regimes, land is barren and unproductive after a mere 17 years (Stocking and Perkin, 1991) further exacerbating problems associated with productivity and land availability. Cardamom AF, if deliberately managed using SAI practices, could be an effective landscape scale strategy to sustain productivity outside reserves and contribute to landscape conservation objectives.

2.b Data Collection

Data was collected during field visits made in 2008-2010. Villages were purposively selected using district reports: Kwezitu, Zirai, IBC Msasa and Kizerui were selected for high cardamom production. Mixed methods, including household questionnaires, interviews and focus group discussions (FGD) were used to gather information about farming systems and household characteristics that influence adoption of capital investments to improve soil productivity.

2.b.i Farming Systems

Focus group discussions (FGD) and personal interviews were used to gather farming system data. A total of sixteen FGDs were conducted in four villages. FGDs were decided upon as the optimal method to solicit financial data due to low record keeping and poor individual recall. Similarities across reported figures confirmed that results were reliable. A snowball sampling approach was used to select five to seven male and female farmers to participate in each focus group. Men and women were interviewed separately. FGD participants characterized cropping systems into stages and provided labor, tradable inputs, and revenue figures for each crop in each system on a per acre basis, the local commonly used unit of labor. Figures were later converted to measure on a standard per hectare basis.

Common land establishment activities in all farming systems include clearing trees, and slashing vegetation. Revenues from conversion activities were not accounted for since burning of residues is common during land preparation. Primary and secondary products included fruits, poles and fodder collected during the productive phase (year 1-13). The alternative model, Improved AF, was developed using both primary and secondary data. All second stage farming systems were analyzed for 13 years to compare financial returns evenly. Second stage system productivity may extend past the years that were analyzed in this study.

Seasonal crop variations and yield changes over the system life-span were solicited in FGDs. Final figures in the accounting matrix were based on averages. Figures were reported in local currency (Tsh) and converted to US$ based on the nominal exchange rate of Tsh 1355 = US$ 1 in July 2009. Crop selling price was the annual average for point of sale in the village for the previous year, 2008-2009. Data feedback sessions held in three villages were used to validate final accounting matrix figures.

Annual tradable inputs costs included tools, seeds, planting materials and labor. Replacement tool costs were accounted for the system lifespan. Labour costs are based on eight hours of work, or one-person day (ps-day). Family and hired labour were valued at the local daily farm wage rate in 2009 of Tsh 2000/day (US$ 1.50/day). Labour activities were disaggregated into land preparation, maintenance tasks (weeding and mulching), planting and harvesting tasks. Transportation labour was not included because of high variability of distances travelled between households and farms. Land costs were also not accounted due to price variability based on plot specific attributes.

A 10% discount rate (Gittinger, 1982) was applied to estimate profits and calculate Net Present Value (NPV). The NPV sums the discounted annual costs and revenues over the system lifespan of each system. A sensitivity analysis assessed the impact of changed assumptions and errors on NPV values. Changes in price and yield were applied uniformly to all products in each system. Similarly, wage rate changes were applied to all labour activities.

2.b.ii Household Surveys

Household surveys were used to assess the feasibility of scaling up adoption of SAI practices included in Improved AF, namely fallowing and adding organic inputs, i.e. manure. Households from three villages and five sub-villages were randomly selected using village registers. The survey was pretested and translated into Swahili. Trained enumerators administered the survey, which lasted approximately one hour. The head of household's responses (144) were used since many of the variables were measured at household level and thus did not significantly differ between husband and wife based on Chi Square tests. Many adoption studies have relied on logit models to analyze dichotomous adoption decisions in which the dependent variable is binary (Mercer 2004). A total of four models were run and independent variables were categorized into 1. Socioeconomic characteristics, which included measures of human capital 2. Physical and financial capital as wealth indicators, 3. Tenure risk and 4. Plot specific characteristics. Variables with variance inflation factor (VIF) >5 were excluded from the model to minimize multicollinearity effects. The hypothesized influence of independent variable are illustrated in Table 2.

Table 1 Factors affecting SAI adoption practices

Variable	Unit	Level of measurement	*A priori* sign	
			Fallow	Organic Inputs
1. Socioeconomic Characteristics				
Single HH	Single= 1	Binary	+	-
Household Gender	Male = 1	Binary	-	-
Age	Years	Continuous	+	-
Years Settled	Years	Continuous	+	+
Household Size	# of members in HH	Continuous	-	+
Education	1 = Primary Education	Binary	+	+
Farm Training	Training= 1	Binary	+	+
2. Physical and financial assets				
Total Plot	No. Plots	Continuous	+	+
Total Land	Acres	Continuous	+	+
Livestock	Livestock=1	Binary	+	+
Cattle	Ownership=1	Binary	+	+
Sufficient Land	Sufficient= 1	Binary	+	+
Off farm income	Off farm = 1	Binary	+	-
Remittances	Remittances= 1	Binary	+	-
Loan access	Access= 1	Binary	+	+
Loan Receipt	Received= 1	Binary	+	+
Loan for farm activities	Used for farm= 1	Binary	+	+
3. Tenure security				
Land taken for conservation	Land taken= 1	Binary	-	-
4. Plot characteristics[4]				
Distance	Minutes	Continuous	+	+
Plot Age	Average years per plot	Continuous	+	+
Fertility	Low =1 Average =2 High= 3	Ordinal	-	-
Acres	Average # of acres per plot	Ordinal	+	-

In the category of socioeconomic indicators, *Single Headed Household* status is predicted to positively influence fallow adoption based on labor shortages. Since adding organic inputs is relatively more labor intensive it is hypothesized that adoption is negatively influenced by single headed household status. *Gender of Household Head* is predicted to be

[4] For continuous variables the variable was calculated as an average of total plots to generate one score

significant in adoption since extension systems are biased towards male farmers (Gladwin et al., 1997), in which case female headed households are less likely to adopt improved practices. *Age* is significant because younger farmers are more progressive and likely to adopt new practices (Mabuza et al., 2013; Sanni, 2008). *Years Settled* is assumed to play a significant role since farm plots that have been in use longer require soil fertility investments. Thus, both fallow and organic inputs are predicted to be positively influenced by higher numbers of years settled. *Household Size* is a proxy for labor availability. Less family labor availability positively influences fallow adoption. Labor intensive capital investments such as adding manure correlate with larger household size (Tiwari et al., 2008).

A dimension of the socioeconomic variable includes human capital. Education facilitates learning, which instills a favorable attitude towards the use of improved farm practices (Singh, 2000; Nkamleu & Manyong, 2005). *Education* in this case is a binary measure in which primary school attendance equals one. *Farm Training* is a measure of social capital, which Reyes et al. (2010) found to explain low adoption practices in the study area. Receipt of farm technology training is hypothesized to positively influence adoption of soil fertility practices.

Physical and financial capital indicators were included as proxies of wealth. Households with higher wealth are more likely to adopt new technologies because of their economic position and ability to manage risk (Phiri et al., 2003; Ajayi et al., 2003). Better off households may also allocate labour to off farm sector activities, thereby reducing negative intensification effects (Lee, et al., 2006). *Total Plot* refers to the number of plots managed. Higher number of plots can increase crop diversity and productivity based on scattered plots' locations in various agroclimatic conditions. Owning more plots is hypothesized to coincide with higher levels of adoption of capital investments. *Total Land* size influences farmer's technology adoption decisions (Gosh, 2010). Farmers with more land under cultivation are better able to practice fallow, while smaller farmers must intensify and invest in maintaining productivity to meet household needs (Clay et al., 1998). Higher total land size is hypothesized to be associated with adoption of SAI practices. The perception based measure that a household has *Sufficient Land* to meet household needs is also anticipated to favorably influence adoption of soil replenishment.

Cash sources such as off farm income may lead to neglect of labor intensive forms of soil conservation activities (Ellis, 2000). *Off Farm Income* positively influences fallow but has negative effects on labor intensive organic input adoption. Remittances play a significant role in overall household income (Mabuza et al., 2013) and it is hypothesized that *Remittances* will have adoption effects similar to off farm income. Livestock ownership is positively related to household incomes and wealthier households are more likely to use manure than poorer ones (Mekuria and Waddington, 2002). Households who own *Livestock*, a proxy for wealth, are hypothesized to fallow due to greater ability to manage risk. Cattle ownership is also predicted to positively influence organic input additions based on availability and access to manure.

Access to credit significantly influences adoption of soil improvement technologies (Tiwari et al., 2008). Three aspects of loans were analyzed: *Access to Loan*, which specific to formal microcredit institutions, *Receipt of Loan*, from formal and informal sources, and *Loan for Farm Activities*, in which case the loan was used to hire labor for farm related tasks. We assumed that access to credit will exert a positive influence on adoption (Paudel and Thapa 2004).

Tenure security was deemed important since each of the sampled villages' population was affected by the establishment of Derema Corridor and Nilo Forest Reserve. Most recently, the creation of Derema in the 1990s led to farm evictions, in which case hundreds of smallholder farmers were displaced and compensation was provided to some (Rantala and

Vihemaki, 2011). Defining the terms and the form of compensation were sources of frustration to those who lost farms and threats were made by farmers that they would slash vegetation in the corridor (ibid). Given the contentious history the indicator *Land Taken for Conservation* was included in the model and predicted to negatively influence SAI capital investments.

Plot characteristics exhibit great spatial and biophysical variability however, bio-physical variables are commonly not included in AF adoption studies even though they often impart a statistically significant effect (Pattanayak et a., 2003). Questions concerning plot level data and specific details for distance (estimated minutes), age, perceived fertility, and acres were collected. An average score was created for each indicator and included in the regression model. Higher average *Distance* from household was assumed to favorably influence fallow while plots located farther from the household were assumed to negatively influence labor intensive organic input adoption. *Plot Age* is significant because plots that have been cultivated longer would require soil replenishment investments and thus positively influence adoption of both SAI practices. Perceived fertility levels influence soil fertility investments (Reyes et al., 2010; Franzel, 1999). Higher perceived *Fertility* would negatively influence adoption since the farmers would not see the need to adopt soil conservation measures. Higher average plot size, represented by *Acres*, is hypothesized to positively influence fallow, but negatively influence organic inputs since spreading manure over large areas is labor intensive.

3. Results and discussion

3.a Farming System Descriptions

Farm level analysis was used to assess the profitability of adopting SAI investments to prolong Cardamom AF productivity. Focus groups and later, household surveys, confirmed that Cardamom AF is the first stage land use system. The system is managed for 13 years and subsequently converted to second stage systems *Grevillea* AF or Spice Perennials. Table 1 details the products that were valued in the accounting matrix for each farming system.

Table 2 Common cropping systems and financially valued products

Cropping system	*Stage*	*Products valued in accounting matrix*
Cardamom AF	1	Cardamom, bananas, cocoyams, avocados, jack fruits, building poles, timber, fuelwood, fodder, ropes
Grevillea AF	2	*Grevillea robusta* timber, beans, maize, cassava, bananas, fodder
Spice Perennials	2	Cloves, cinnamon, cassava, maize, beans
Improved AF	2	Cardamom, bananas, cocoyams, avocados, jack fruits, building poles, fuelwood, fodder, ropes, *Allanblackia* nuts, butterfly farming

First stage Conversion: Cardamom AF

Cardamom cultivation is the first stage of forest conversion when tall canopy tree cover is reduced by 40-60% (Reyes, author’s observation). The entire understory is cleared and cardamom and other cash and subsistence crops, banana varieties and cocoyams (*Xanthosoma* sp.), are planted under the remaining trees. Shade tree species include endemic species *Allanblackia stuhlmannii*, *Cephalosphera usambarensis*, *Ficus* species, *Milicia* *excelsa,* and fruit trees like avocados (*Persea americana*) and jack fruit (*Artocarpus heterophyllus).* Exotic species such as *Maesiosi eminii* have also been documented (Hall et al., 2010).

Cardamom begins producing after 2.5 years (Reyes, 2008; author's observation) and is harvested three times a year (seasonal yield changes were accounted in the matrix). Two crop rotations produce for a total of 11 years. First rotation yields peak in year six. In year nine the second rotation of cardamom is planted at a lower density and mixed in with the older plants. Combined production from first and second rotation boosts yields in year 11. Bananas are grown as a permanent crop and harvested throughout the year. Cocoyams are harvested and replanted annually. Secondary products utilized in the household or sold locally include fuelwood, small timber poles, logs and wild grasses used for fodder. Cardamom AF is converted to *Grevillea* AF or Spice Perennials when cardamom yields decline in year 13.

Second Stage Option 1: *Grevillea* AF

Grevillea AF is a second stage cropping system that follows Cardamom AF. *Grevillea robusta* is commonly planted to delineate and secure land tenure (Woodcock, 2002: 83) or intercropped with maize, beans and cassava that are mainly grown to meet household subsistence needs. Establishment requires clearing trees remaining from the previous Cardamom AF stage, which leads to an estimated 10-25% of tree cover compared to a natural forest. *Grevillea* timber is harvested every seven to ten years. Leaves provide fodder for cattle and small branches are used for fuelwood. Beans, maize (*Zea mays sp.*), and cassava (*Manihot esculenta*) are intercropped and planted on a rotational basis. Beans and maize are row planted together every two years. Maize is harvested once a year and time to maturity can take seven months due to highland agroecological conditions. Beans are harvested twice annually. Cassava is harvested per based on an as needed basis. This system may be extended beyond 13 years using rotational fallowing, however farmers reported that yield declines over time.

Second Stage Option 2: Spice Perennials

Alternatively, farmers may establish Spice Perennials following Cardamom AF. Cloves (*Eugenia caryophyllata*) and cinnamon (*Cinnamomum zeylanicum*) are grown together with food crops until the trees shade out the annual crops, between four to seven years. Land preparation includes slow and steady tree clearance since spices perform optimally in full sunlight. Approximately 10% tree cover, compared to natural forest, is retained. Cloves start producing after seven years and production increases annually by approximately 12 kg per tree. Yields are highly variable due to losses that result from poor harvesting practices. Cinnamon is harvested after a minimum of four years and the timber is used as firewood. The remaining stump coppices and four to seven stems are harvested in four-year intervals. As cloves and cinnamon mature the system tends towards a monocropped and permanent plantation.

Second Stage Option 3: Improved Agroforestry

Improved AF is a farming model developed to calculate the relative profitability of adding capital investments to replenish soil fertility and extend productivity of first stage Cardamom AF. Rather than conversion and following the typical labor intensification pathway, fallowing, organic inputs, i.e. manure, and income from commercialized NTFPs are included in the model.

Land preparation requirements are low since tree cover from Cardamom AF is maintained and fallow is practiced for the first three years. Less intensive management and lower planting densities maintain the system's financial productivity. Organic inputs, i.e. cattle manure, are added to the soil prior to planting in lower densities (50% of the conventional first stage Cardamom AF) in year four. Two rotations of intercropped cardamom, cocoyams and bananas are planted every three years after natural fallowing. Management tasks includes less intensive weeding and clearing to allow regeneration and seedling development of canopy tree species and understory layers, which may improve forest health and the potential for regeneration of certain forest species (Ashton et al., 2001).

Revenues from commercialized NTFPs, *Allanblackia* fruits and butterflies, are included in the model. Local market development for *Allanblackia* fruits that contain oil-producing seeds has raised the value of the seeds as a source of household income. Fruits mature once or twice per year and may yield up to 150 fruits or up to 50 kg of fat per year (Mwaura and Munjuga, 2007). Average household income was estimated to be approximately $100USD but household incomes vary widely based on access to productive trees on private and common lands. Sales of butterfly pupae are the second source of NTFP income. The Amani Butterfly Project assists people to farm butterflies and markets them to live butterfly exhibits in the United States and Europe (Morgan-Brown et al., 2010). Sales of butterfly pupae generated a total of approximately US$ 44,000 in revenue for 300 farmers in 2010 (Morgan-Brown T., 2009, pers. communication). Farmers source butterflies from natural forests and AF systems. Pupae are bred in a cage constructed of local materials and purchased mesh. Maintenance tasks average one to two hours per day. Improved AF is proposed as a permanent land use that incorporates capital investments to sustain long term production.

3.b Profitability Analysis

Conversion of forest or semi-natural forests to Cardamom AF is profitable, as demonstrated by cash flows (Figure 2). Cash flow declines that result from fertility losses motivate conversion in year 13. *Grevillea* AF cash flows peak and fall sharply as a result of annual harvesting cycles; the longer term cash flow trend decreases over time as a result of intensive, continuous planting regimes that reduce soil fertility in the long term. Returns are generally lower when compared to cash crop returns such as Perennial Spices. Farmers intercrop food crops and perennials to offset income losses as trees mature. Clove production begins in year seven and generates significant revenues thereafter. Improved AF is competitive until year six, at which point fallow and lower yields depress revenues. Commercialized NTFPs account for 22% of the total revenue to the system.

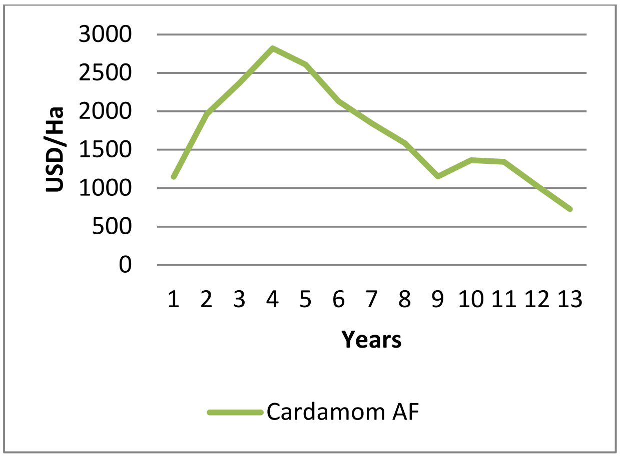

Figure 2 Cardamom AF Discounted Cash Flow (USD per ha/year)

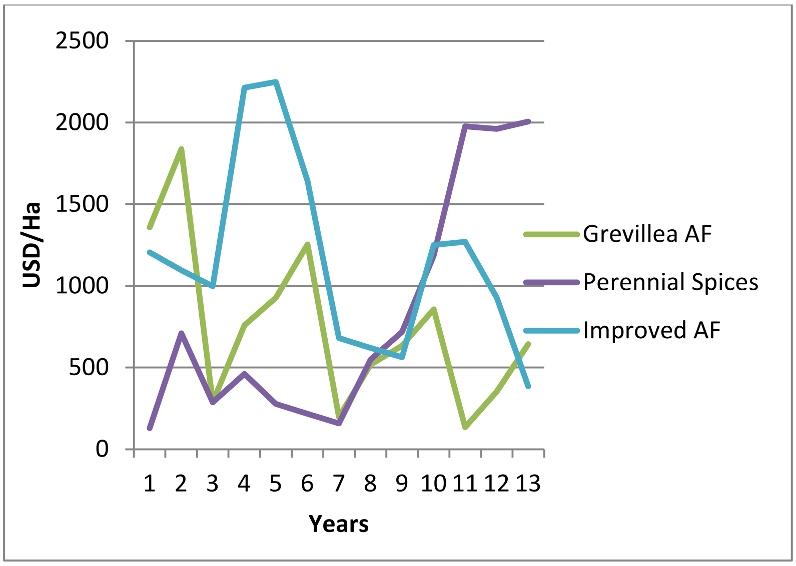

Figure 3 Discounted Cash Flows from Second Stage Systems (USD/Ha)

Establishment and production costs for second stage systems are compared in Table 3. During establishment Spice Perennial's labor and total costs are the highest, followed by *Grevillea* AF and Improved AF. Improved AF NPV and revenues for the productive phase (years 1-13) outperform the common farming systems. Total discounted and labor costs in *Grevillea* AF and Spice Perennials are comparatively lower. Improved AFs total discounted costs are twice as much as *Grevillea* AF. Over the system lifespan of 13 years daily returns to labor are lowest for the Improved AF model, which is, in part, a result of high labor costs associated with NTFP activities. In the Spice Perennials system labor costs associated with farm maintenance decrease over time.

Table 3 NPV and Discounted labor, Costs, and Revenue (USD/ha)

Stage	**1**	**2**		
	Cardamom AF	***Grevillea* AF**	**Spice Perennials**	**Improved AF**
Year 0 (Establishment)				
Total labour	320.9	353.7	*375.4*	126.7
Total Costs	809.2	470.6	486.6	230.5
Years 1-13				
NPV	15,659.5	6480.2	7680.1	8542.0
Total Discounted Revenue	22,075.4	9759.2	10,632.5	15,093.5
Total Discounted Labour Costs	5,678.5	2752.6	2,646.0	5664.8
Daily Returns to Labor	3.89	3.55	4.02	2.66
Total Discounted Costs	6,415.9	3279.0	2,952.4	6,551.5

Each system was re-run to assess sensitivity to changes of key factors were discount rate, price, yield, and wage changes (Appendix). Lowering the discount rate to 5% increased Improved AF's NPV, but effects were highest for Perennial Spices, a 66% increase. The most significant positive change in NPV accrued to *Grevillea* AF and Improved AF when 25% increase in crop prices were applied, which raised NPV by 38% and 30%.

Farm profitability analysis revealed that while financial benefits of adopting the Improved AF model exist, high labor costs relative to other second stage systems could affect adoption rates. The Improved AF model is profitable based on NPV when compared to other common second stage systems over a 13 year period. Other studies similarly indicated positive returns associated with adoption technologies (Place et al., 2002; Mekuria and Waddington, 2002). NTFP activities were included in the model to offset profit losses during the fallow periods. Pattanayak and Sills (2001) found that NTFP collection had an income smoothing response that mitigated agricultural losses. However, NTFP inclusion in the Improved AF model raised labor costs relative to other second stage systems. Activities associated with butterfly maintenance incurred the highest labor cost (18%), followed by firewood collection (11%). Organic input investments, specifically manuring, were comparatively lower (2%). Additionally, lower daily returns to labor raise the opportunity costs of adopting SAI practices as modeled in this scenario. Extending the analysis and measuring long term returns from continuous cropping schemes that deplete soil fertility, such as *Grevillea* AF, would make Improved AF more financially attractive as a land use option since yields, and consequently income, are sustained.

3.c Logit model results

Household surveys were used to assess feasibility of adoption of the soil replenishment investments included in the Improved AF model. Sample characteristics are presented in Table 4. Seventy-five percent of respondents manage Cardamom AF plots. Household survey data confirmed that the system is productive for 13 years, at which point the system is converted. Eighty-one percent of households manage *Grevillea* AF, and 92% planted cloves in the past 5 years. Adoption of capital investments is low. Thirty-five percent of households practice fallow on an average of 1.3 plots for 3.2 years. Eighteen percent add manure to their farms, which may be due to low supply since only 16% percent own cattle. Ten percent of households adopt fallow and organic inputs. Nearly half of the respondents perceive their land as sufficient to meet household needs. Fourteen percent of households have access to formal microcredit institutions. Eight percent used a loan to hire labor for farm activities. Approximately half of the respondents had land taken to create forest reserves.

Table 4 Sample Household Characteristics

	Mean ±std	N =144, %
1. Socioeconomic Characteristics		
Household Gender		Male: 90.3%
Single HH		Single: 11.8%
Age	47.5, 15.7	
Years settled	35±16.3	
Household Size	5.8, 2.5	
Education		90.3%
Farm Training		21.5%
2. Physical and Financial Assets		
Total Plot	3.2, 1.4	
Total Land	7.24, 7.02	
Livestock		86.8%
Cattle		16%

Sufficient Land		45.1%
Off farm income		14.6%
Remittances		21.5%
Loan Access		13.9%
Loan Receipt		13.2%
Loan for farm activities		7.6%
3. Tenure Security		
Land taken for conservation		49.3%
4. Plot characteristics[5]		
Perceived Distance	35.1, ±35.8	
Plot Age	13.3, 11.6	
Fertility		1 = 15.9% 2=58.3% 3= 22.9%
Acres	2.6, 2.03	

Four logit models were estimated to predict the probability of adoption of capital investments at $p < 0.05$ (Table 5). A total of seven out of 22 indicators explain adoption of fallow and organic investments. Logit results were validated using backward step logistic regression procedures. Among indicators in the socioeconomic category those that were significant were *Single headed household* status, which positively influenced fallow adoption, and *Household Size*, which positively influenced organic input adoption. The odds ratio for single headed household status was also very high, 31.4. Fallow and organic inputs, manuring in this case, differ in terms of their labor requirements. Labor related indicators are central to evaluating the viability of promoting SAI practices (Lee et al., 2006) and constraints have been a major factor limiting farmer's interest in adoption of AF technologies (Adesina and Coulibaly 1998, Tripp 2005). In this case, labor availability is constrained in single headed households and thus lowers the amount of land under cultivation, which is favorable for SAI. Labor constraints also lower adoption of organic inputs. The extent of fallowing is limited both due to land scarcity and household's needs for food and cash income. Nkamleu and Manyong (2005) reported similar results concerning impacts of household size on adoption. Such findings raise concerns about the feasibility of different types of capital investments based on household labor availability. Gender of household head and education were not significant. Other studies have similarly found that gender does not play a significant role in AF adoption practices (Pattanayak et al., 2003) and conservation agriculture practices (Clay et al., 1998).

In our model physical assets, i.e. land and livestock, were not significant. The impacts of farm size on adoption are inconclusive due to the mixed observations of positive, negative and insignificant correlations (Knowler and Bradship, 2006). Labor allocation towards activities associated with cattle have also revealed tradeoffs between crops and livestock production that help to explain low correlation of adoption (Mugonola et al., 2012; Nkonya et al, 2005). Dairy cattle in the East Usambaras are typically stall fed and labor activities include collecting fodder, a labor intensive activity that appears to interfere with manuring activities.

Cash and credit access indicators were significant (see Tiwari et al, 2008; Hazarika and Alwang, 2003). *Remittances* negatively influenced fallow and *Loan Access* negatively influenced organic input adoption. These findings suggest that farmers are intensifying

[5] For continuous variables the variable was calculated as an average of total plots to generate one score

through labor led strategies that entail hiring labor, rather than turning to less labor intensive off farm activities. Low cash investments in soil replenishment practices are also a consequence of low numbers of household receiving extension services (22%). Similar studies have shown that off farm income negatively affects adoption of conservation practices (Mbaga-Semgalawe and Folmer, 2000; Pattanyak et al., 2003). In our study only fifteen percent of households access off farm income, which suggests that the opportunity cost of allocating labor towards farm intensification is relatively low since off farm employment opportunities are few, a trend common to remote rural areas (Ruben et al., 2006).

One dimension of tenure security that was measured included *Land Taken for Conservation*, which significantly and negatively influenced adoption of organic inputs. Fifty percent of households had farms confiscated to create Derema Corridor or Nilo Forest Reserve. Total average land size and number of plots did not differ significantly between the households so intensification is not a result of cultivating smaller farms. Land tenure systems place constraints on long term investment in land (Msikula 2003) and leads to maximization of short term investment (Barbier, 1990) at the expense of long term productivity.

At plot level, perceived *Fertility* positively influenced fallow adoption and *Distance* negatively impacted adoption of organic inputs. Other studies found that farmer's perceptions of low fertility and soil erosion motivated household adoption of soil conservation measures (Scherr and Hazell, 1994; Mbaga Semgalawe and Folmer, 2000). Farmers in the East Usambaras mostly perceive soil fertility to be adequate (Reyes et al., 2010). Unlike other studies that measured labor intensive soil and water conservation investments, fallow does not require significant labor allocation, which may explain why farmers are more inclined to practice fallow despite the perception that soil fertility is adequate. The effects of distance on adoption of labor intensive practices have similarly been shown in Brown (2006). The anticipated effects of other plot level characteristics, such as age and plot size were insignificant.

Table 5 Model Results

	Fallow					Organic Inputs			
Variable	ß	S.E.	Sig.	Odds ratio (e^{β})		ß	S.E.	Sig.	Odds ratio (e^{β})
Single Headed	3.448	1.528	*.024	31.448		-1.136	1.625	.484	.321
Age	.004	.018	.829	1.004		-.005	.024	.845	.995
Gender of HH head	-1.727	1.411	.221	.178		-1.453	1.583	.358	.234
Years in village	.029	.016	.078	1.029		-.022	.022	.311	.978
HH Size	.008	.092	.928	1.008		.232	.120	*.054	1.262
Education	-054	.755	.943	.947		2.774	1.692	.101	16.017
Training	-.122	.592	.837	.885		-.498	.685	.467	.608
Total plots	.268	.177	.129	1.307		.143	.205	.487	1.153
Total Land	-.001	.041	.979	.999		.089	.056	.113	1.093
Livestock	-.363	.769	.636	.695		.358	.972	.713	1.431
Cattle	.464	.599	.439	1.591		-.631	.636	.321	.532
Sufficient land	-.505	.458	.271	.604		.065	.575	.911	1.067
Off farm	.125	.610	.837	1.133		2.173	1.218	.074	8.789

Remittances	-1.895	.579	*.001	.150		.170	.774	.826	1.185
Loan access	-1.062	.848	.210	.346		-1.901	.884	*.032	.149
Loan receipt	1.836	1.327	.167	6.274		-.192	1.181	.871	.826
Loan for farm	-.066	1.509	.965	.936		1.876	7.497	.210	6.527
Land taken for Conservation	-.419	.446	.347	.657		-1.395	.623	*.025	.248
Constant	-3.327	2.009	.098	.036		-4.141	2.923	.157	.016
Log-Likelihood: 147.884 Percentage of correct prediction: 76.2% Hosmer & Lemeshow: .294						Log-Likelihood: 99.621 Percentage of correct prediction:83.9% Hosmer & Lemeshow: .564			
Distance mins	.000	.005	.926	1.00		-.034	.013	*.011	.967
Years (Ave)	.003	.017	.862	1.003		-.018	.021	.388	.982
Fertility (Ave)	1.563	.381	*.000	4.771		.283	.354	.424	1.327
Acre (ave)	-.209	.113	.064	.811		.015	.105	.888	1.015
Constant	-3.308	.852	.000	.037		-.923	.828	.265	.397
Log-Likelihood: 163.391 Percentage of correct prediction: 72.2% Hosmer & Lemeshow: .991						Log-Likelihood: 127.808 Percentage of correct prediction: 81.3% Hosmer & Lemeshow: .228			

4. Conclusion

This study assessed the potential of scaling up adoption of sustainable agricultural intensification practices in the highlands of the East Usambaras, a biodiversity hotspot located in Tanzania. Adoption potential was evaluated using farm and household characteristics to estimate farm profitability and feasibility based on the influence of household characteristics on adoption of soil replenishment investments. A cross sectional design and mixed methods were used to conduct a financial analysis of farming systems, followed by a survey of 144 households to investigate the effects of socioeconomic, cash and credit access, tenure, and plot specific characteristics on soil improvement investments in three villages.

Focus group data confirmed that labor led intensification is the most common pathway of land use management and occurs primarily in two stages. Following Cardamom AF conversion *Grevillea* AF incorporates continuous cropping and leads to long term soil fertility decline. The other option is Spice Perennials, which is managed to become small scale plantations of cloves and cinnamon. From a profitability standpoint the Improved AF model generates competitive returns to farmers, but at a higher labor cost relative to common second stage farming systems. The household survey revealed that labor constraints hindered adoption of more labor intensive investments, i.e. spreading organic inputs. Land tenure perceptions also lowered adoption of capital investments to improve fertility.

Although adoption of soil replenishment investments is low in the East Usambara highlands, efforts to enhance uptake and scale up SAI should be made. Many farmers recognize the benefits of AF, as evidenced by the high number of farmers who manage Cardamom AF, 75%. Agroforestry products contribute to household needs and income, including fuelwood, fruits, and *Allanblackia* nuts. Agroforestry stabilizes soil on steep slopes and thus is a more practical land use than cultivating annuals, which require intensive soil tillage. People typically invest more labor on high income crops (Pretty et al., 2008). Since cardamom generates higher income on smaller plots of land relative to food crops (Hamilton and Bensted Smith 1989) SAI practices that are more labor intensive could be perceived more favorably. Deliberate management has the potential to lower extensification to marginal lands. Lastly, management of multiple plots, as is common in the study area, affords farmers greater flexibility to manage labor and risk at different production stages. The multiseasonalcharacter of AF make it an appropriate mechanism to reduce risk and uncertainty by diversifying smaholders portfolios (Franzel and Scherr, 2002).

Further research to investigate the sustainability of Improved AF from a biological and biodiversity perspective is needed (Hall et al., 2010). Additionally, the implications of gendered labor divisions in different SAI scenarios (Kiptot and Franzel, 2012) would provide more insight into devising strategies to manage farming systems that generate equitable livelihood benefits.

Sustainable agricultural growth is central to many developing countries' goals of improving food security, rural employment and economic growth, and poverty alleviation (Lee et al., 2006; Reardon et al, 1999). Efforts to achieve these goals will often require tradeoffs among objectives that vary based on distinct agroecological and economic conditions (ibid). This study contributes to identifying where the potential to enhance synergies exist and where policy emphasis should be focused to scale up sustainable agricultural intensification practices. Widespread adoption of agroforestry is strongly influenced by the policy and institutional contexts (Ajayi and Place, 2012). Farmers must receive satisfactory economic benefits from the resources they invest (Rasul & Thapa, 2004), in which case the opportunity costs of allocating scarce household labor towards capital investments in SAI practices must be addressed. Policy investments to improve production and market value chain development for crops grown in agroforestry systems has thus far created financial incentives to retain *Allanblackia*, an indigenous tree species, on farms, for example. Extending such initiatives to include cultivated crops, like cardamom, could stimulate stronger farmer interest and investment in prolonging Cardamom AF production versus labor led strategies that reduce tree diversity on farms. Secondly, current low employment and availability of off farm income sources lowers the opportunity cost of labor led intensification in the highlands. Poor extension has been identified as a key constraint to increasing household production and income in the area (Reyes et al. 2005). Social capital formation through the promotion of extension services and technological advice would raise awareness of capital investments to improve fertility and subsequently shift the labor led intensification strategies towards more sustainable and longer term productive land uses.

Farmers' decisions concerning short and long term economic choices are influenced by wider institutional and policy environments. Additionally, their decisions concerning farm system management have wider, landscape scale implications for meeting conservation and rural development objectives. Strengthening institutions to improve financial returns from agroforestry products and working with farmers to develop strategies that are appropriate to specific agroecological and socioeconomic conditions will improve efforts to scale up sustainable agricultural intensification in locations recognized for their conservation importance.