Innovation and Transition in Family Farming: How Dairy Farming is Emerging in the Coffee Agroforestry Systems of Central Kenya

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Abstract

Emerging challenges to farming drives farming systems to have three strategies; intensification options optimizing resources and technological innovations, firm diversification orchestrating interdependencies among sectoral boundaries, and transition to new system and trajectories. The trajectory shift emphasis on how new sectoral systems (dairy sector) emerges, and what is the link with the previous sectoral system (coffee) in terms of impact pathway. This paper, therefore, presents (1) how the transition from coffee to dairy based farming system in the coffee agroforestry systems of Murang'a County, central Kenya is taking place? (2) What derives for the transition from coffee to dairy based systems? And (3) what contributes the transition from intensified coffee based to dairy based farming system on household food security? Our data collection consists of three sources. Household survey (120), focus group discussions (9 FGDs) and stakeholders' interview (15 interviews). Coffee production in Kenya has declined by 65% in the last 30 years, and as much as 5 times in Murang'a County, a major coffee producing area. The dairy sector is, however, in opposite visualizing sharp increase in volume of production and price. The study finds that innovation process and actors' interaction differs for the coffee and dairy based systems. Actors in the coffee are limited, the system is highly centralized with limited options to farmers to process and market their product while the dairy sector is less informally controlled by demand based business, comparatively numerous actors with limited government intervention, various options to process and marketing products. Exponential increase in production cost which is a function of coffee diseases and institutional failure (financial and none financial) of the coffee sector while strong public and private intuitions are emerging in the dairy sector is the other driver of the transition.

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1. Introduction

Smallholder agricultural development in developing countries faces challenges and constraints related to climate and weather events (IPCC, 2001). In sub-Saharan Africa, for instance, projections predict a loss of 10-20 million hectares of land suitable for double cropping and 5-10 million hectares of land suitable for triple cropping (Fischer et al. 2005). This yields persistent food insecurity, food price volatility, food safety and sustainability concerns (McCullough et al., 2008) particularly to the resource poor smallholder farmers. Consequently, farmers are forced to shift from a system of high risk or less economic return to more stable socioeconomic and environmental benefits.

This could have three options. A first option is the optimizations of resources to specialize or intensify on specific commodities through developing technical innovations such as adoption of new varieties that can avoid or survive with the current or expected challenges. (Vineyards et al. 2010) demonstrated intensification on technical innovation practices notably irrigation supplementation and varietal innovations in the viticulture industry provide rapid direct responses to changes in berry composition as one of the impacts of climate change. Technological innovation of the sector through intensification and specialization such as coffee variety innovations and small-scale community irrigation development (Kabubo-mariara & Karanja 2007) adapts to climate and at the same time improves farmers' income. The second strategy is orchestrating links and interdependencies among sectoral boundaries (the livelihood options, activities or products diversification such as crop-livestock integration) which are not fixed, but changes over time (Malerba 2002) that provides force and trigger mechanisms of growth and innovation. Diversification options and strategies influence the rate and specific types of innovative competence through mitigating core rigidities and path dependencies, and accelerate the rate of invention to enhance income and food security. Such diversification can be defined as the diversity in the knowledge system and principles underlying the nature of products and their methods of production (Garc´ıa and Velasco, 2008). This illustrates sectors probabilities of emergence, expansion and interdependence due to environmental, socio-economic, policy and political factors. Third group has emphasized change towards transition in sectors. This strategy is the option to a discontinuous shift towards a new system and trajectory(Geels 2004).

The rapid system transition in many African countries such as the agroforestry systems of Kenya is derived along with the changes in environmental, socioeconomic and policy environments. The difficulty in understanding the drivers of the transition, however, holds back the development of concrete policy in Africa. Even in areas of proved impacts of recent transition, such as the transition from coffee to dairy and other food crops in Kenya, the success of various policy proposals has been limited, reflecting a difficulty in linking policy studies to real farmers decisions to change (García de Jalón et al. 2015; Opiyo et al. 2015. To advance understanding of how African farmers respond to challenges, this paper reports the motivations and drivers to innovate in response to change. We frame this analysis in an area where social and climate pressures are already major issues, where all climate scenarios project further temperature constraints, and where farmers contribute to almost 65% of the local economy and contribute directly to the country food security.

We contribute to an understanding of farmers' transition towards adaptation in view of current climate and economic pressures and in view of their perception of climate change. First, while there is a considerable literature on attitudes of the African needs to innovation(Fisher et al. 2015; Sutcliffe et al. 2015; Ifejika & Imme 2013; Mertz et al. 2009) these studies have depended on the rationales behind the need for innovation. Second, national surveys have reported coffee production decline and farmers reduced motivation to coffee production(Thuku 2013a). However, the limitation of these studies is that insufficient evidence on the drivers for the farmers reduced motivation on coffee and coffee production decline. There is no evidence also what is emerging at the expense of decline in coffee production and productivity. Our study bridges how and why coffee is declining and what is emerging at the expense of the declined system aiming to support public policy. Furthermore, we wish to provide evidence on what results the shifting in livelihood options to the food security of the farming community which was left a black box by researchers so far.

2. The Murang'a case study in Central Kenya

The study was conducted in Muranga County, one of the complicated and diversified physical environments (Republic of Kenya, 2015; Ovuka & Lindqvist 2000), climatic and ecological extremes(Parry et al. 2012) with altitudes varying from bellow 1000 (arid and semi-arid agroecology) to over 2000 meters above sea level. Despite the current climatic extremes and physical environmental diversity, the region was potential for agriculture where coffee farming was dominated the rural economy and foreign exchange. Historically, coffee was under the control of the colonial settlers. After independence in 1963, the large coffee estates subdivided to smallholders and coffee production increased by 6% due to the uplifting of the unfavorable laws to native inhabitants and subdivision to smallholders (Akiyama, 1987). This led the national coffee production to increase from 43,778 metric tonnes in 1663/64 to 140,000 metric tonnes in 1987/88 (Republic of Kenya, 2007). Regarding quality and demand of Kenyan coffee at the international market, its beans are popular for blends and buyers have specific volume requirements (Ponte, 2002). On average, Kenya's coffee makes a 10% premium over standard Arabica coffees from Central America and Colombia (Carsan et al. 2014). Despite coffee plays a dominant role in the national economy and was on an increasing trend until 1987/88, it has been on a constant decline over the past three decades (1988/89-2014/15). Production has declined and stagnated at about 50,000 metric tonnes (KNBS, 2013). Exports fell from 2.1 million bags in 1987 to 0.9 in 2007 (Thuku 2013) and world market share has declined from 3.2% in 1987 to 0.6% in 2006 (Mude 2006). Yields have declined from 600 kg/ha to below 400 kg/ha which is very low compared to average yields in neighboring countries such as 1160 kg/ha in Rwanda and 995 kg/ha in Ethiopia (Damianopoulos, 2005).

The factors attributed to such threat ranges from the local production constraint to international market, i.e., (1) The production confound of environmental dynamics and climate change (Davis et al. 2012; (Waha et al. 2013), (2) The weak internal coffee marketing and supply chain (Thuku, 2013; Mude, 2006), and (3) the global coffee crises of free market period (1989 to 1993 and 1999 to 2004) of low price levels (Thuku 2013). The dairy sector development is, however, in opposite to the coffee sector visualizing a sharp increase in volume of production and price. The specialized coffee farms are being transformed either to specialized dairy or diversified coffee-dairy farms. Unlike the coffee system development, the dairy sector is private

sector derived. Mobilizing communities for enabling innovation remains a challenge in most countries, including Kenya(Rajalahti et al. 2008). This was raising questions for centuries about the role of the government sector intermediary domain, to initiate such a sustainable solution in the agricultural intensification.

3. Data and Methods

3.1. Conceptual Framework

The proposed framework for analyzing farmers' innovation in transition from specialized coffee to dairy is outlined in Figure 1. The farmers' choices (options for households' to adapt the changes) are categorized into three, i.e., (1) specialization in coffee intensifying resources, practices and using new varieties, (2) diversification to dairy orchestrating links between the two sectoral systems, and (3) switching coffee and shift and transit to a new system of dairy production. The choice of strategies depends on the effects of current climate pressure and climatic variability, the effects of current economic pressures on the farm, and the changes in household characteristics or institutional reform. The choices that farmers currently make are derived from the consultation process (several focus groups, a household survey and stakeholders' interview) and will be described below. These choices are affected by a large set of explanatory variables (indirect drivers) related to individuals' socio-demographic and environmental characteristics, resource endowment, institutional setting, climate change perception, information on climate and forecasting, farm management and agroecological zone).

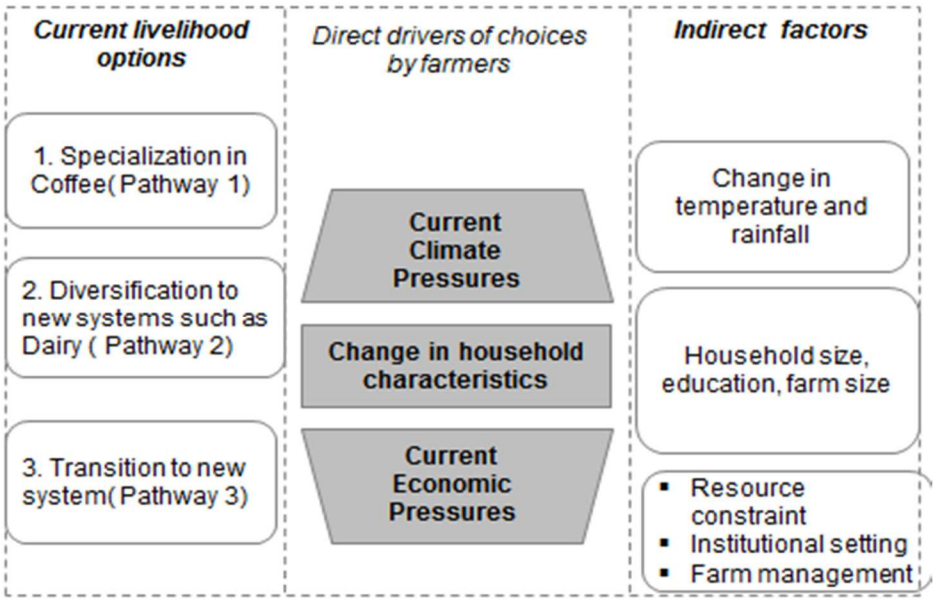

Figure 1: Conceptual Framework

Farming systems transitions are commonly classified based on the objective of the typology and the specific context of the study area. Typologies can be based on farmer strategies towards diversification (Bell & Moore 2012; Valbuena et al. 2008;, Steeg et al. 2010), based on the main agricultural activities the agroecology permits (Daskalopoulou & Petrou 2002) or towards other determinants such as increase in family size and decrease landholding size, adapting the changing climate through transition from more vulnerable system to less vulnerable system (Jones & Thornton 2009; Seo 2010; Seo & Mendelsohn 2008). In this study, farming systems are characterized based on farm characteristics especially reflecting how the transition from one system to another is changed. The level of integration and specialization in crops such as coffee and dairy as dominant systems is considered. Indicators for this diversity or specialty considers land size ownership, level of offarm participation of the household head, family characteristics, introduction of different cropping and animal systems such as coffee, food crops(maize, beans, banana) and dairy. This considers how the household starts farming, develops farming or exits from farming looking in to the farm history using farm history visual timeline (Figure 2).

Land size	**Off-farm**	**Family**	**YEAR**	**Coffee**	**Crops**	**Animals**
Initial land inherited/ bought, inherited/bought additional land, sold/ shared to children or brothers	Participation begun, change in intensity and attention, participation ceased	Change in marital status, family size,	**T_0: start farming**	Coffee farming started/ new management introduced/ neglected/uprooted/ replanted/ added new trees	New crops introduced/ different management introduced/ changed to different cropping	Rearing begun/ new animals introduced/ herd size/ better management/ stop rearing/
			T_0			
			Today (2015)			

Figure 2: A framework to organize concepts, collect data and interpretation guide.
Source, authors own representation, 2014

The criteria used for the classification reflect the level of past farming system and what they actually owned today and how the transition has happened. But generally, the farming systems was 30% coffee specialized and 43.8%coffee food crop diversified systems where no farmer owned dairy system that account more than 20% of total income and 26.3% of dairy specialized. Though the transitions are wider to contain minor

systems changes, our aim is to analyze the institutional innovations and community or private sector derived innovations in the farming systems. We therefore, limit our analysis to the following three options of pathways.

1. Pathway 1: coffee specialized systems (the households produces commercial coffee at high rate of intensification and coffee contemplates at least 80 per cent of the household's annual income)
2. Pathway 2: coffee-dairy diversification systems (either the household's attention is to both systems and households annual farm income is almost equally from coffee and dairy).
3. Pathway 3: dairy specialized systems (where at least 80 percent of farm household's income is from dairy and practicing a commercial dairy as a business but not supplemental.)

3.2. Sample and data collection

Primary data was collected by means of three qualitative and quantitative social research methods used in sequence: focus group discussions, household survey and stakeholders' interview. The household survey was conducted via face to face during June-October, 2014. The sample consists of 220 farm households equally stratified to coffee farmers (120 surveys in the higher altitude coffee area of the county) and food crop farmers (120 surveys in the food crops area of the county). The questionnaires were completed through interviews with the household head or in his/her absence, the most senior member of the household responsible for the farm. Prior to the household survey, nine focus group discussions were conducted with about twelve farmers per group. Discussions with three focus groups per each of the following areas were conducted; coffee specialized, coffee- dairy diversified, and dairy specialized farmers respectively. The aim was to understand the community wide problems and choices on view of climate change and to ensure the surveys were well worded and relevant to them while stakeholders' interview (15 interviews) for understanding the contribution of stakeholders in the transition and innovation process.

4. Results and Discussion

4.1. Characteristics of the Technology Adopting Farmers, Coffee Based and Dairy Based Specifically

Based on household characteristics four distinct farming systems are determined for the year 1980s where farmers start farming with. Table 1 gives an overview of the number of farmers per farming system when farmers introduced farming until the 1980s. Majority of the farmers (54.2%) had intensified coffee with/without limited food crops. Dairy was practiced by 25.98% of farmers but with almost no attention. The cows used were of the large humped local zebu breeds. But supplemental crops such as beans and maize were practiced by some farmers (Table 1). Table 2, on the other hand, presents current farming system of the households after different processes of transition from one system to another. The current farming systems are classified in three categories. A total of 43.80% of the farmers currently practice diversified coffee-dairy enterprises while 26.30% of the farmers have shifted fully to a specialized and commercialized dairy farms (Table 2). A description of the current farming systems with specific household characteristics is given in Table 3. For each farming system the average size of the family is indicated, the number of years of education of the farmer, the average land size, the percentage of land on which is used for coffee, the percentage of land with food and with cash crops, and access to different institutions such as credit and extension. Even in farming systems classified as having limited dairy activities, the farmers often have one cow (Table 1, 2, 3). These farming systems have per household a milk production of less than 1000 L/ha. Cattle intensification is a direct consequence of the usage of fodder and concentrates and is indicated by the milk production per hectare of a household. Farming systems with major dairy activities have a significant higher milk production per hectare, suggesting commercial activities. Dairy farmers are found to be characterized with higher credit and irrigation use, capacity to higher daily and annually laborers, innovative and bitterly informed about climate and weather conditions while they are low in public extension use (Table 3). Many smallholders integrate dairy production with crops (for food and cash) to diversify risks from dependence on a single crop or livestock enterprise. The percentage of cash crops is an important factor to differentiate farming systems. Farms with a high percentage of cash crops are classified as intensified farmers or export cash crop farmers. Export cash crop farmers cultivate more cash crops than the other farmers, but even these farmers cultivate food crops on a proportion of the land. Fertilizers are used in most farming systems, only subsistence farmers hardly use any fertilizer. Manure is only used to maintain soil fertility and crop production in the case intensified dairying is part of the production system.

Table 2: Farming system of the households used in 1980s

Nr.	Farming system	Description	Percent of farmers
1	Intensified coffee farmers with no food crops and dairy	Farm household income was totally from coffee	15.32
2	Intensified coffee farmers with limited food crops	At least 80 percent of household income is from coffee	54.20
3	Food crop dominant farmers with limited coffee	Food crops contributed for income	4.50
4	Food crop or coffee farmers with limited dairy for household consumption	Food crops such as maize and beans are dominant sources income	25.98

total	100.00

Source: Survey data, 2014

Table 3: current farming system of the households

Nr.	Farming system	Description	Percent of farmers
1	Intensified coffee farmers with limited dairy or food crop	At least 80 percent of household income is from	30.00
2	Diversified coffee-dairy farmers	Coffee and dairy contributes income almost equally	43.80
3	Specialized dairy farmers with limited/no crops	Dairy is dominant sources of livelihood to the household or dairy is commercialized	26.30
total			100.00

Source: Survey data, 2014

Table 3: Percentage correlation of household characteristics and the current farming system

Household characteristics	Pathway 1	Pathway 2	Pathway 3
Gender, I if the head is male	79.2	54.3	76.3
Marital status, 1 if the head is married	75.0	74.3	90.5
Education level of the head in years (mean)	6.0	6.2	9.0
Access to irrigation, 1 if there is access	25.0	45.7	42.9
Access to credit, 1 if there access	76.2	60.0	83.3
Access to public extension, 1 if there is	54.2	51.4	38.1
Capacity to higher labor, 1 if capable	66.7	48.6	79.2
Innovativeness, 1 if the head is innovative	29.2	8.6	38.6
Information on climate, 1 if there is information	48.6	62.5	71.4

Source: Survey data 2014

4.2. Defining Trends in Coffee and Dairy Production of the Study Area

Like the other areas in Kenya, coffee production in Murang'a County was in an increasing trend (1963-1987). Since 1987/88, however, coffee was in a continuous decline (figure 1).

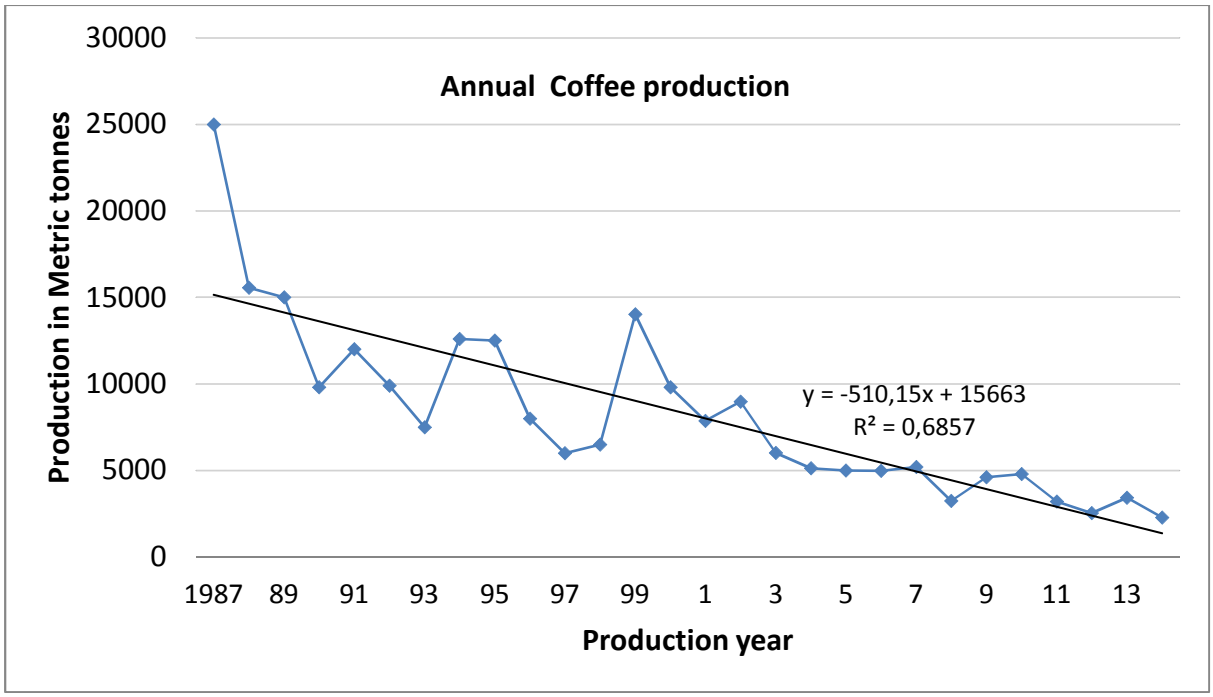

Figure 3: Coffee production trends of Murang'a County (1987-2013)

Source: Murang'a County Cooperatives and Cooperatives Union, 2014

The coffee production and productivity decline of Murang'a County (Figure 3) brought the system to have three dimensions. Specialization in coffee systems using improved coffee management innovations, diversification with dairy and food crops and shift to a fully specialized commercial dairy business. The comparison whether farmers are intensifying to coffee, diversifying to dairy or shifting from an intensified coffee to specialized dairy is compared in terms of farm size acreage allotted to the different enterprises, yield of coffee and dairy, percentage of farmers participation, and the level of management at different time periods (Table 4). Generally average farm size ownership has decreased by 52.8% for the last 30 years where 26% of farm was not used for cultivation. In 1980s, coffee share was 65% of the total farm size but currently coffee share is reduced to less than 40% of the total farm size owned by households. Coffee productivity has declined from 735 kg/ha to less than 275 kg/ha. Similarly, new plantations to replace dieback or infected or old coffee trees have decreased while percentage of farmers uprooting coffee trees is increasing. Average number of coffee trees per farmer for the diversified farmers is reduced to less than 500 coffee trees while at the specialized coffee farmers is reduced to less than 800 coffee tress. The mean number of coffee trees per farm is 280. The dairy sector (figure) on the other hand, is increasing overtime. Multi-cropping practices are widespread among coffee farmers. Indeed, in large portion of the plots, coffee is associated with other crops. Number of new coffee trees planted in new land, replacement of dieback, new management systems introduced such as percentage of farmers introduced manure use, compost use and mulching with special attention to coffee.

System of diversification: percentage of farmers put food crops such maize, beans, and banana. Percentage of farmers planted Napier grass and introduced cow, number of farmers introduced trees and fruits in coffee farms. Numbers of farmers totally or partly uproot coffee, percentage of farmers cutting the coffee trees to use for other crops, percentage of farmers neglected coffee with no management are some of the criteria that differ farmers to be assigned in different systems.

Table 4: Farm allocation to coffee and dairy production at different periods in Murang'a County

Description	1980	1990	2000	2010	2015
Average farm size in acres	4.92	4.6	3.01	2.75	2.6
Percentage of land under cultivation	76	91	96	100	100
Average ha of land under coffee	3.2	3.6	2.05	1.43	1.03
Average coffee yield in kgs/hectare	735	567	368	275	254
% of farmers planted new coffee, replace dried or infected coffee	34.61	23.20	3.06	9.05	11.7
% of farmers uproot coffee	-	-	36.3	50.01	49.05
% of farmers left coffee unmanaged	-	-	39.65	34.00	26.47
% ha of land allocated to pasture	34.00	9.02	34.64	54.50	54.67
Average milk production per year in Hectoliter	-	2,506	9,206.5	36,689.5	50,689.5
Average livestock per household	3.2	1.9	2.01	3.05	3.05
Percent of farmers with dairy cow	25.98	33.56	67.05	80.01	81.7

Source: Survey data 2015

The dairy sector on the other hand, is on an increasing trend. Share of farmland allocated to feed production has increased from 34% (including uncultivated land for free grazing) to 54.67% (intensified feed production). The total cow holding per household did not increased but the production and productivity has increased due to improvements in cow breeds and increasing of the number of households who have cows.

The average milk production increase is due to the improvements in cow breeds and high number of farmers introduced cow in the farming.

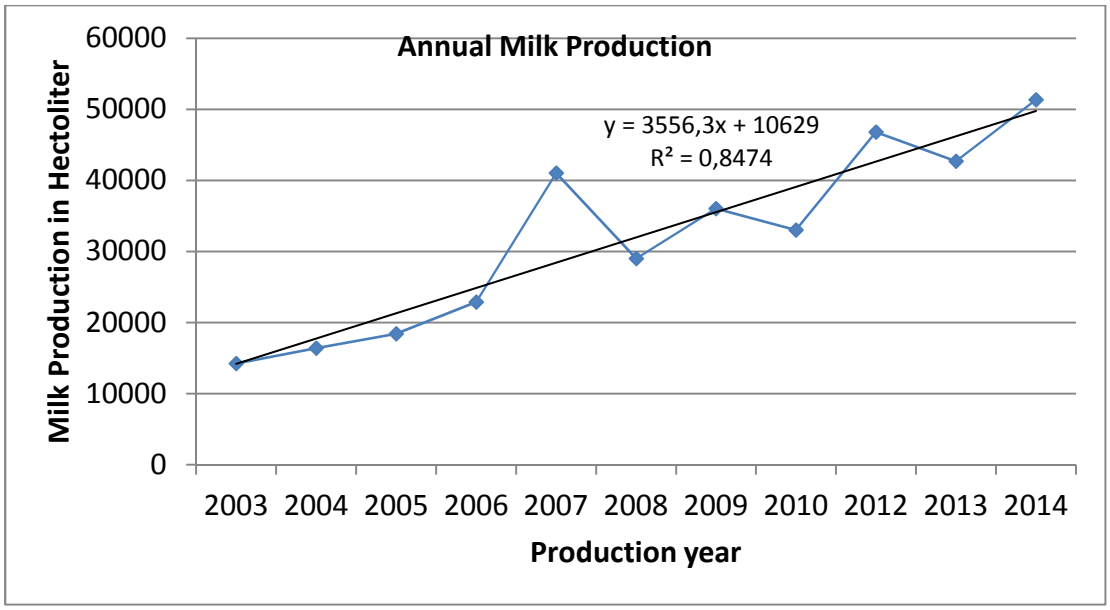

Figure 3: Milk production trends in Murang'a County (2003-2014)

Source: Murang'a County cooperative and Cooperative union. 2014

4.3. Drivers of Transition to Dairy Farming

The drivers are categorized in three categories. Current climate pressure and variability (perception of farmers on climate change, information on climate changes, information on forecasting, indigenous forecasting, change in temperature, change in rainfall, (2) Household characteristics(household size, age, gender, education, marital status), (3) Current economic pressure (farm income, offarm income, livestock holding, access to resources, access to institutions. Characterize the coffee farmers and dairy farmers considering the household characteristics(age, gender, marital status, household size, labour availability at the household, labour requirement, education level of the household head, access to irrigation, cooperative membership, distance to input and output market, livestock ownership, land size, TLU ownership), incomes(On farm, offarm and remittances), food security level, cost-benefit analysis, decision to take price on own produce, knowledge of market price of the produce. The detailed results will be included in the presentation and final manuscript which will be submitted early May, 2016.

4.4. Stakeholders Paradigm Shift in the Mandates and Contributions to Coffee and the State of Household Food security for the Different Systems

The coffee union, the sole and monopoly organization in the coffee development was the strong institution in

financial, administrative, technical services to the smallholders and coffee estates until the coffee liberalization. As of the coffee liberalization, however, this case took two ways. The coffee estates who are capable of strong financial and administration undertaking all the technical, administrative and other activities by themselves supported financial capacity by the banks such as Equity, and others while the smallholder coffee production is left weak where input prices are higher and accessed through private dealers. The coffee union changed its income sources to real estates (detail), other cooperatives such as dairy (details). One of the reasons to change the attention is the weaking of its power by the government at the time of coffee liberalization. Second stiff competition from other organizations that have similar mandates in providing financial and technical services.

4.4.1. Food Security and Farming Transition

Food security can be measured using different strategies such as proxy system using income, energy intake or dietary diversity. This has to consider the access, utilization and sustainability. For the time being we presented a compares of current household income for the three types of households (a detailed analysis will be included in the presentation and final manuscript). Farmers' decision on adoption of given farming system could have two purposes; either for expected profit or avoiding risk. Evidences from (Aslihan 2010) revealed that adoption of climate smart strategies enhances maize productivity and then improves farmers' income in Zambia. Similar to this, adopters of any form of dairy farming in this study were found to be better off compared to the other farming options, showing higher income in all cases. Staple food crop farmers were found to have less annual income by 704.25 US Dollars (USD) compared to specialized dairy households. This is when it is compared with the strategy with a minimum return of 1,492.86USD from a combined adoption of improved crop-livestock diversification. The comparison also revealed that although the packages in combination and separately have significant and positive effect on household income, adoption of combination of packages benefits farmers more than single strategy. This is indeed found similar with results from (Teklewold et al. 2013) in Ethiopia for an analysis of maize-legume rotation, conservation tillage, and modern maize seed and four combinations of the three key variables.

5. Limitation Conclusions and recommendation

Dairy sector is in upward increasing trend while the coffee sector is in a declining downward trend. The main question here is what makes the dairy development to grow while coffee shrinks? The farmers' perception and information on climate change, the economic pressure on the farm such as over sub division and getting squeezed of the land size per household, other household characteristics such as education and awareness raise are among the top reasons. The innovation process and actors interaction differs for the research based coffee development and farmers and private sectors initiative dairy development. Actors in the coffee sector are limited, the system is highly centralized and controlled with top down approach with limited options to farmers to process and market their product while the dairy sector is less informally controlled by demand based business, comparatively numerous actors involved in less formal way with limited government control, various options to process and marketing.

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