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ADAPTATION TO RISING POPULATION DENSITY: VOICES FROM RURAL KENYA

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By

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Abstract

This study provides empirical evidence on the link between population density and agricultural intensification and other strategies that rural communities use to adapt to increasing population density. The qualitative data used in this study were collected through Focus group discussions (FGDs) among experienced community members who provided historical accounts on the dynamics of rural communities and transitions in agriculture that can be linked to scarcity of land associated with population density growth. The results generated by this study offer some insights on the link between population density growth and agricultural development. The study finds evidence of a Boserupian type of agricultural transformation in rural Kenya. Rural communities mainly responded to scarcity of land through agricultural intensification, migration and off farm diversification. Unsustainable land fragmentation, decline in agricultural outputs and incomes and deterioration in soil quality were cited as key phenomena accompanying the strategies adopted in response to population density growth. From the results we draw some policy implications that can provide insights to policy makers to guide sustainable agricultural development in the densely populated areas which include reversal of land fragmentation, improved market access, proper use of fertilizers and land policies that encourage migration into scarcely populated areas.

Keywords: *population density; agricultural intensification; sustainable*

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Acronyms

DAP	Di-Ammonium Phosphate
DFID	Department for International Development
FAO	Food and Agriculture Organization of the United Nations
FGD	Focus group discussion
GISAIA	Guiding Investments in Sustainable Agricultural Intensification in Africa
HYVs	High Yielding Varieties
IGA	Income Generating Activities
KNBS	Kenya National Bureau of Statistics
MSU	Michigan State University
TAPRA	Tegemeo Agricultural Policy Research and Analysis
USAID	United States Agency for International Development

1. Introduction

Farming systems in Sub-Saharan Africa have undergone substantial transition in the past five decades. This transition has been attributed to increased population density, urbanization and weather related factors (Tiffen et al.1994; Murton 1997) making the population density-food production nexus an issue of phenomenal policy importance. Early research on this topic was informed by the Malthusian theory which asserted that population growth would lead to inevitable land degradation. Malthus predicted a slow growth in food production relative to population growth which in return would lead to food scarcity (Malthus, 1798). In his argument, Malthus indicated that increased demand for food would push food production to marginal areas, eventually leading to a terminal decline in food production due to mass land degradation. However, this assertion was challenged by the seminal work by Boserup (1965) who postulated that increased demand for food as a result of population growth would stimulate agricultural intensification. In support of the Boserupian hypothesis, a study by Tiffen et al. (1994) titled *More People less Erosion*, presented the 'Machakos miracle' where increasing population density was found to have been accompanied by environmental recovery. The Tiffen et al. (1994) study found that population growth was a key driver of improved land management. The authors showed that in the midst of population driven scarcity of land, farmers generally intensify their production systems, for example adopting new technologies, to respond to emerging market opportunities.

After the publication of this influential study, many similar studies have been conducted in Machakos and elsewhere to test the 'More People less Erosion' hypothesis. For example, Murton (1997, 1999) assessed whether the sustainable agricultural intensification reported in Machakos also translated to improved livelihoods. These studies found that agricultural intensification in Machakos did not necessarily lead to improved output per capita and better livelihoods but rather to a long term vicious cycle of agricultural productivity decline for poor farmers. A similar study by Zaal and Oostendorp (2002) assessed the relative importance of population growth, among other factors, as a driver of agricultural intensification and improved land management. The study found mounting population density to be a key factor driving agricultural intensification beside strong urban linkages, high cash crop (coffee) prices and drought. Other studies (Murton, 1997; Carswell, 1997) found capital availability (probably from off-farm employment and sale of high value crops) and the ability to hire labor as key drivers of intensification.

Although earlier studies found population density to be a key driver of agricultural intensification recent studies have revealed that there is a limitation to the extent to which population density growth can drive agricultural intensification without substantial changes in production technology. Muyanga and Jayne (2014) confirmed the theoretically expected inverse relationship between population density and the size of land holdings, land under cultivation and fallow land but found a population threshold beyond which intensification declines. The authors found that the intensity of purchased external inputs and households' farm income per hectare planted increase with population density up to a population density of about 600 persons/Km^2 and then declines. A study carried out in Malawi by Ricker-Gilbert et al. (2014) obtained similar findings.

However, results from a study by Rashid et al. (2014) in Bangladesh fail to confirm the existence of a population density threshold contrasting the results in the African studies. It seems there are certain conditions under which the linear relationship between agricultural intensification and population density disappears.

Against this backdrop and given the important role of agricultural led development in a country where a substantial percentage of rural dwellers still live on agriculture, the current paper revisits Machakos county to reassess the *More People Less Erosion* hypothesis, 20 years after the Tiffen et al. (1994) study. Previous studies have alluded to the potential confounding effect of urban proximity and argued that the sustainable intensification might have been driven more by urban influence rather than population density alone (for example see Zaal and Oostendorp, 2002). To control for urban linkages, our study also incorporates two sub-counties in Kisii County. Machakos and Kisii counties are similar in many aspects, such as their geographical and climatological conditions, farming systems and population densities. These similarities provide an opportunity for comparing the two counties. The only major difference is that Machakos is close to Nairobi, a major urban center, which allows us to control for urban influence on agricultural development in the midst of population density growth.

Our study documents historical accounts on the response of rural agriculture to population density growth as narrated by elderly community members who have witnessed the changes first hand. Specifically, the study seeks to address the following research questions: (1) What are the most important strategies through which rural communities respond to population

density pressure and what are the key drivers of changes in rural agriculture? (2) How have rural farmers' livelihoods and agricultural productivity been affected by the adaptation strategies?

To address these questions, qualitative data were collected using Focus Group Discussions (FDGs) involving elderly and experienced community members who gave their perspectives based on first hand historical accounts. The FGD participants shared their knowledge and observations on how local communities have responded to population growth for a period spanning over 40 years. This information will be vital to explain trends in agricultural intensification and other livelihood strategies in response to population pressure rural Kenya.

2. Conceptual Framework

The conceptual framework for this study as presented in Figure 1 was adapted from Jayne et al. (2014). Population growth is one of the major pressing issues facing humanity today besides climate change, food insecurity and economic crises. As population grows, societies gradually confront 'land frontiers' that force them to seek adaptive mechanisms (Lipton, 1989). Population growth and demographic transitions over time are usually part of an endogenous system involving urbanization, migration, and changes in birth and mortality rates. According to the demographic transition theory, higher incomes drive improvements in living standards, health and life expectancy and a decline in fertility and mortality rates (Notestein, 1945). These demographic processes are a consequence of government policies and/or exogenous factors such as natural calamities, war, famine and other pestilences as predicted by Malthus (Malthus, 1798). Some past incidences of natural population control include the first and second world war, the Vietnamese famine of 1945 (2 million dead), the North Korean famine of 1994-1998 (3 Million dead) and the great Chinese famine of 1958-1961 (43 million dead) (Dikötter, 2010; Gunn, 2011).

Despite these catastrophes that have previously curtailed population growth, the world has also witnessed several advances in child mortality control and healthcare improvements that have increased population growth through improved fertility and maternal health. The net effect has therefore been increased population density in many parts of the world, accompanied by scarcity of land. Scarcity of land results from the fact that more people imply higher demand for food and shelter. However, population density is not the sole driver for scarcity of land. Changes in market conditions, land reforms and infrastructural development may also contribute to scarcity of land. In response to scarcity of land, communities have historically engaged in diverse strategies such as agricultural intensification, permanent migration, and off-farm diversification (Figure 1).

Through agricultural intensification, farmers can respond to declining farm sizes and emerging market opportunities given that urban and rural population growth drives demand for food. Common forms of agricultural intensification include the adoption of high yielding varieties, reduction in fallow periods, increased use of inorganic fertilizers, increased capital input and increased labor input per unit of land. However, depending on how these strategies

are implemented, intensification may turn out to be sustainable or unsustainable. Sustainability is achieved when agricultural intensification is also accompanied by environmental protection and improvement in the quality of land leading to persistent increase in agricultural productivity as land to labour ratio increase. On the other hand, indicators of unsustainable intensification include reduced fallows, continuous use of inorganic fertilizers causing soil acidity and declining crop productivity. Agricultural intensification creates demand for labour with a potential for creating employment opportunities in the rural areas. However, for agriculture to attract substantial labour force, the sector must competitive wages. Infrastructural development and market access may also drive agricultural intensification. Mounting population growth increases infrastructure development through reduced cost of infrastructure per person, facilitating intensification through reduced transportation costs. Also, improved infrastructure opens up remote rural areas to both input and output markets by reducing the average time to reach markets, average transport cost and transaction costs. The latter would be as a result of an increase in the access to (market) information.

Permanent migration may be triggered by scarcity of land that can be attributed to population density. As land gets scarcer, individuals are likely to seek land in sparsely populated areas. Migration affects rural agricultural economies through the possibilities for land redistribution and adjustments in farm sizes. If rural immigrants move to sparsely populated areas, there is a possibility of easing population density pressure on the areas they migrate from.

Off-farm employment in both urban and rural areas is another common strategy to deal with swelling population. Urbanization, which is both a cause and a consequence of off-farm diversification, plays an important role in this process. If urban centers are economically dynamic and create growing job opportunities, then proximity to major urban centers can draw labor out of agriculture and hence relieve the pressures of rural population growth. However, an individual's choice of either to engage in agricultural employment as compared to non-agricultural employment will depend on the trade-off between returns to agricultural labor and returns to non-farm employment. Off-farm diversification also offers a possibility of urban-rural transfers (remittances), which can be invested in agricultural intensification therefore facilitating productivity growth (Murton, 1999) .

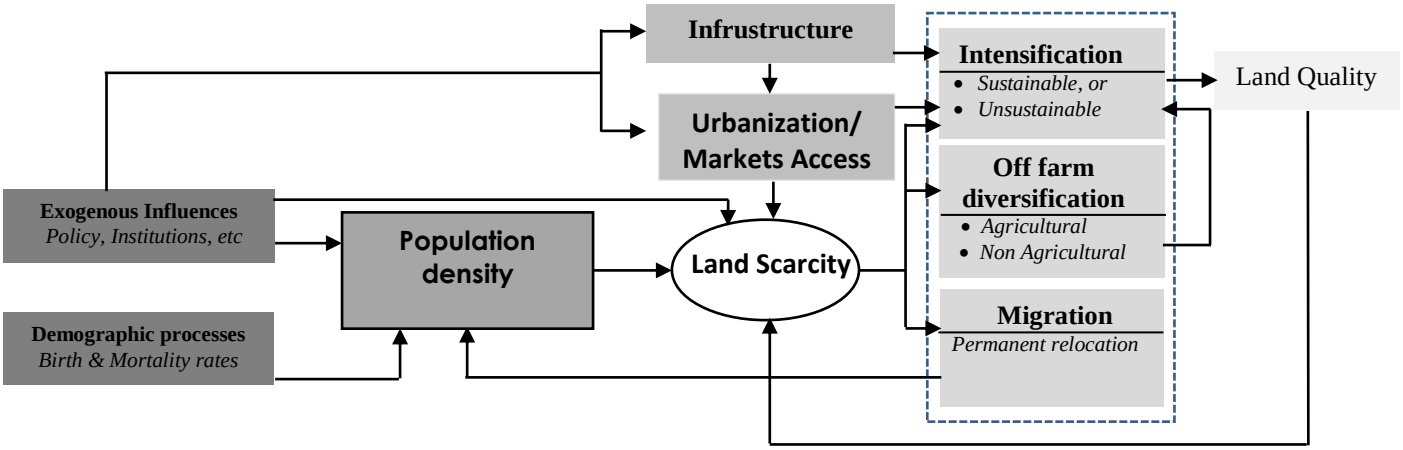

Figure 1: Conceptual Framework ; *Source*: Adapted from Jayne et al. (2014)

3. Methodology

3.1. Sampling, Data Collection and Analysis Methods

The data used in this study were collected through Focus Group Discussions (FGDs) conducted in six villages in Machakos and Kisii counties. Six sessions (three in each county) were held between March 17 and April 10, 2014. Participants in the FGDs included members of the community who are over 70 years of age and had lived in the community for at least 40 years and therefore were well versed with the history of the area. Random sampling was done at two stages. In the first stage, one village was selected from each Sub-location where the research team was conducting household surveys using simple random sampling. In total, six villages were selected.

Participants were then selected from the villages through stratified random sampling. All people in each target village who satisfied the inclusion criteria were listed with the help of village elders. The required sample was then drawn using stratified random sampling, where gender was the strata to ensure representation from both genders. In total 23 male and 7 female participants were selected. The number of respondents drawn from each village was proportional to the population of people who met the criteria for inclusion in the village. The discussions were held in two languages: Kiswahili (in Kisii) and Kikamba (in Machakos). The moderator was fluent in both languages and therefore there was no language barrier that could otherwise distort the results.

The discussions were moderated by the researcher guided by a check list that contained open ended questions[2]. Following a similar approach to that used by Davis, (2007), the participants were asked to narrate the changes in agricultural production that they had witnessed in the past and how these changes could be related to different phenomena in the community such as population density growth and increased government interventions. Further, they shared their opinion on some of the strategies that people in their localities had adopted in response to the changes. Finally, the discussion was centered on the implications of these strategies on people's livelihoods and crop productivity.

In each case, the entire discussion was documented through detailed notes taken by the moderator and his assistant, diagrams and maps. All nonverbal gestures and behavioural responses were noted and followed up where possible. The notes were later analyzed

[2] The check list and accompanying protocols are available upon request.

qualitatively to identify key points, patterns and similarities using the coded key word approach (CPRC, 2010).

3.2. Description of Study Sites

Machakos County borders Nairobi City County and has four sub-Counties, namely, Machakos, Kangundo, Mwala and Yatta. The county is approximately 6,208 Km^2 with an estimated population of 1,098,584 persons according to the 2009 Kenya population and housing census (KNBS, 2010). Rural population density in the County ranges between 35.7 persons/Km^2 in Ngelani sub-Location and 1,199 persons/Km^2 in Lower Kiandani sub-Location. The current study was carried out in Kangundo and Machakos sub-Counties (Figure 2), whose population densities ranged between 587 and 1,017 persons/Km^2 (Table1).

Table 1: Population data for GISAIA research areas in Machakos

Sub-county	Sub-Location	Male	Female	Households	Area (Km^2)	Density
Kangundo	Muisuni	3,151	3,053	1,687	6.1	1,017
	Maiuni	2,303	2,418	1,090	5.8	822
Machakos	Iveti	1,688	1,776	747	5.9	587
	Kasinga	4,169	4,324	1,934	12.6	675

***Source*:** KNBS, (2010b**)**

The County has a bimodal rainfall pattern, averaging between 500 and 900 mm per year, which is received in October-December (short rains) and March-May (long rains). Machakos is mainly an agricultural county where farmers produce both export (coffee, fruits, vegetables) and food crops (maize, beans, cow peas and green grams) mostly in mixed farming systems. Off- farm income generating activities such as micro-enterprises and urban employment also contribute substantially to the incomes for the people of Machakos (Murton, 1999).

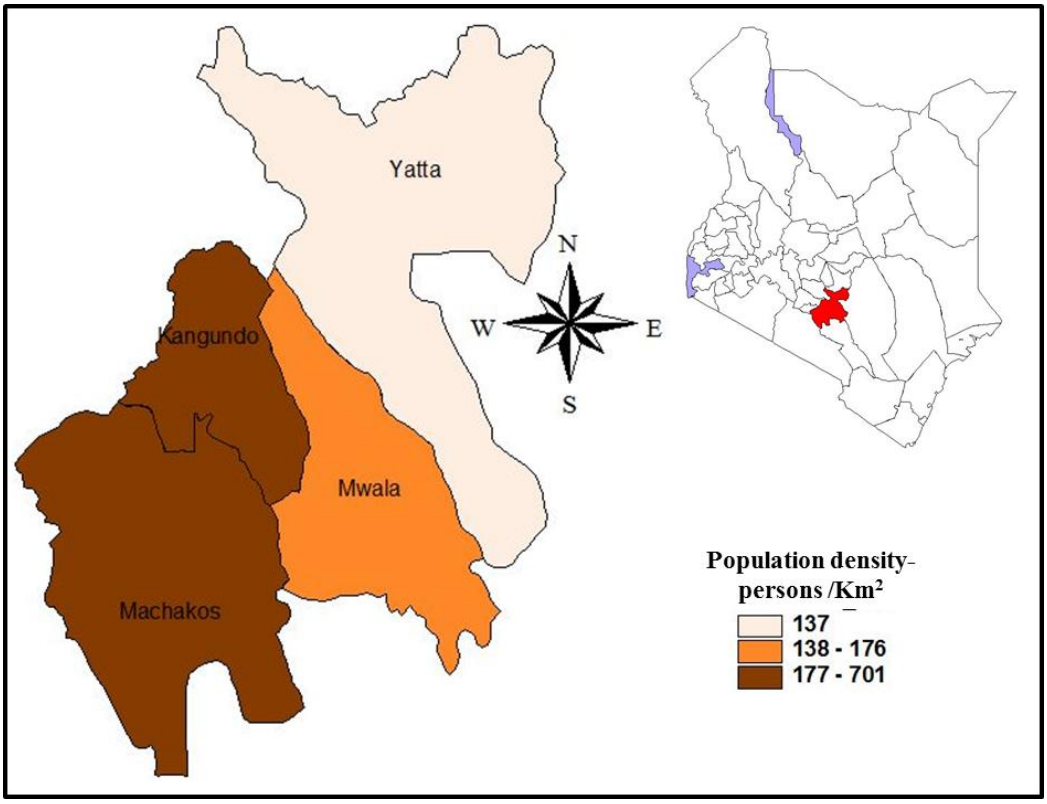

Figure 2: Map of Machakos County Showing Mean Population Densities
Source: Drawn by the authors based on Population data from KNBS 2009 Census data (Republic of Kenya, 2010)

The county is mainly inhabited by the Akamba community, a *Bantu* ethnic group that settled in the upper parts of Machakos County (Kangundo, Machakos Central and Kathiani) towards the end of the 19th century (Munro, 1975). Their initial farming systems where characterized by crop and livestock production mainly on shifting basis, a system that allowed land to lie fallow for at least two years. The community later transformed into sedentary mixed farming. At the onset of colonialism, the Akamba were forced into reserves. Concentration of Kamba farmers in fewer locations asserted a lot of pressure on land, and this was the major cause of the land degradation that was reported in Machakos in 1930s (Tiffen et al., 1994). Currently, farming in the community is highly diversified through mixed farming systems, intercropping and ownership of multiple parcels of land in different parts of the county by the same household.

Kisii County is located South East of Lake Victoria and covers an estimated area of 1,317 Km^2. According to the 2009 Kenya population and housing census, the County had a population of 1,152,282 persons translating to an average population density of 874 people per Km^2. Between 1979 and 2009 the population increased from 869,512 to 1.75 million, recording an average annual population growth rate of 3.4%. Over the same period,

population density rose from 392 persons/Km^2 to 789 persons/Km^2. The current study was carried out in Bobasi and Kitutu Chache sub-Counties, where population density ranges between 739 and 910 (Figure 3 and Table 2).

Table 2: Population data for GISAIA research areas in Kisii

Sub-county	Sub-Location	Male	Female	Households	Area (Km^2)	Density
Kitutu Chache	Sensi	2,736	3,214	1,336	8.1	739
Bobasi	Riosugo	4,496	5,078	2,069	10.5	910
	Bosansa	3,681	4,271	1,665	9.7	820

***Source*:** KNBS, (2010b**)**

The County is inhabited by the *Gusii* people, also a *Bantu* ethnic group and is located on the western Kenya highlands. Owing to the highland equatorial climate, the county experiences rainfall almost through-out the year, but with two distinct seasons occurring in March-May and October-November. The County receives on average about 1500 mm of rainfall per annum.

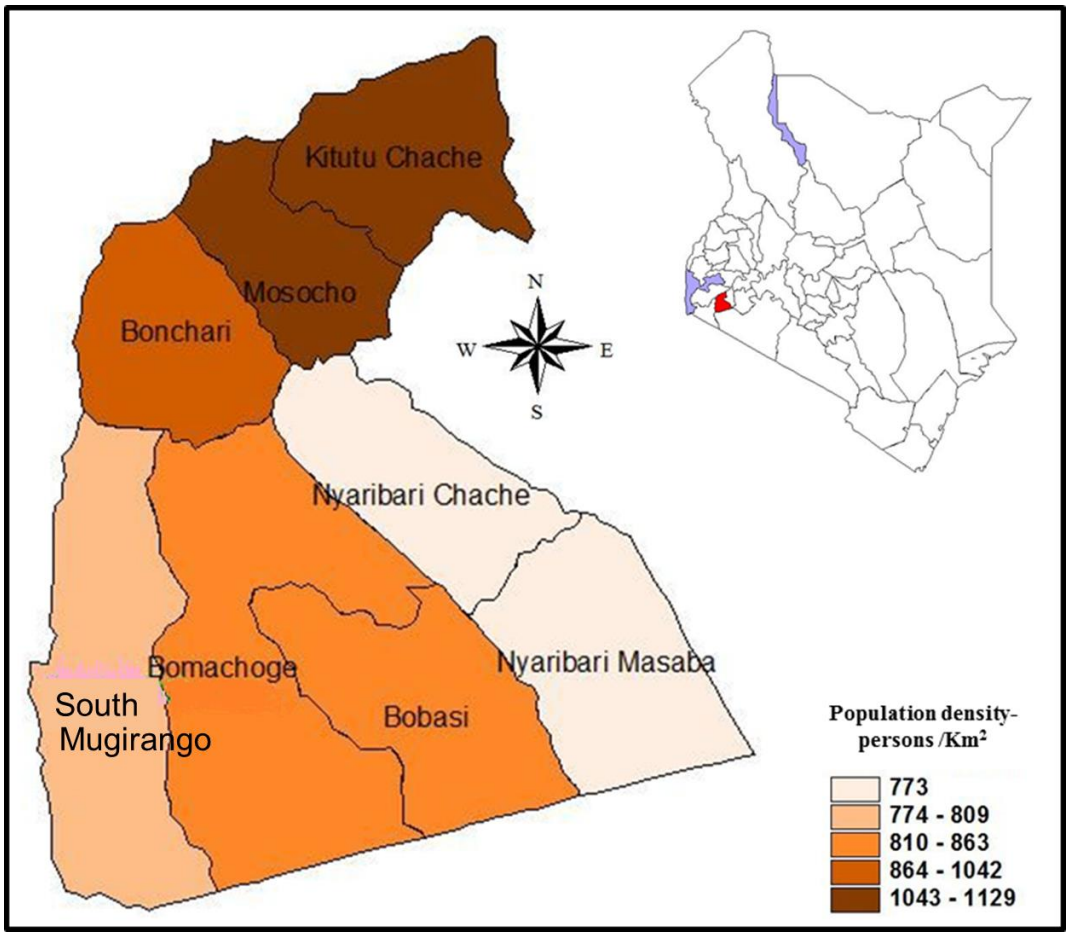

Figure 3: Map of Kisii County showing mean population densities (Persons/Km^2)
Source: Drawn by the authors based on Population data from KNBS 2009 Census data (Republic of Kenya, 2010).

This weather condition enables the production of a wide range of agricultural commodities such as tea, coffee, pyrethrum, bananas, avocado, maize, beans, millet, sweet potatoes and sugar cane. The history of human settlement in Kisii County dates back to 1755 AD when the first Gusii immigrants from Western Kenya settled in the area. However, substantial agricultural developments started towards the end of the 19th century. Initial settlements were in the valleys, where agricultural production was limited to food crop (sorghum, millet, maize and pumpkins) production and extensive livestock rearing systems (goats, sheep, cattle and donkeys). Initially, the hilly areas were mainly uninhabited and were covered by a rain forest, dominated by broad leaved indigenous trees mixed with scrubs. However, population growth eventually led to expansion of crop land to the previously unsettled areas.

4. Results and Discussions

This section summarizes the results emerging from the FGDs. Section 4.1 starts by outlining the challenges associated with population growth as witnessed by the FGD participants. Both Kisii and Machakos counties have experienced general positive population growth in the past decades. The mounting population growth has had multiple implications on rural agricultural development as evident in the transformation in agricultural systems witnessed in the past decades. For example, as reported by Tiffen et al. (1994), Machakos had a major transformation between 1930 and 1990, which saw the reversal of land degradation. When the Machakos Miracle was reported in the 1990s, the population density in Machakos was 400 persons/km^2 and sustainable intensification was possible at that time. However, as it emerges in our study, the population dynamics are likely to cause substantial changes in agriculture.

Section 4.2 presents results on the strategies that communities in the study areas have engaged in to cope with the increasing population density, again, as witnessed by the participants. Guided by the conceptual framework presented in Figure 1, we classify the coping mechanisms into three categories: (i) agricultural intensification; (ii) off-farm diversification, and (iii) migration. The section discusses these strategies in detail in light of their implications on agricultural development in rural areas.

4.1. Challenges Associated with Population Growth

4.1.1. Scarcity of land and Shrinking Average Farm Sizes

FGD participants observed that farm land has increasingly become scarce in both Machakos and Kisii as indicated by the general decline in farm sizes and increase in the rental and purchase price for land in the counties, a finding that is consistent with that of a study in other areas of Kenya by Muyanga, (2013). In the Machakos case, the average farm size per household in 1940's was 8.4 hectares but declined to 1.3 hectares in 1997 (Murton, 1999) and further to less than one hectare currently. One of the key drivers for land fragmentation is the cultural practice in Machakos and Kisii where every male child is entitled to a share of his parent's land. Land fragmentation is also driven by frequent land subdivision through land sales given that land markets have recently become active, partly as a result of population pressure. The widespread scarcity of land has been accompanied by biomass fuel shortage and decline in pastures as indicated by growth in farm forestry and intensive livestock production systems.

The transition into intensive livestock production systems has the following implications: (i) further decline in crop land as some land is allocated to fodder production, particularly Napier grass (*Pennisetum purpureum*); (ii) increased use of crop residues as livestock feed, reducing the quantity of residues that could be integrated back to the soils to improve the soil organic matter; (iii) increased labor demand for the intensive livestock production systems; (iv) decline in the supply of farm yard manure resulting from the decline in cattle numbers; and (v) decline in supply of animal traction. The decline in draught power and farm yard manure availability has had some negative implications on agricultural productivity among the rural poor. Animal traction was the most cost effective, affordable and reasonable form of agricultural mechanization given the shrinking farm sizes while farm yard manure was the readily available source of fertilizer. A study by Onchere, (1982) reports that the use of animal traction contributed to higher crop productivity in Machakos and Kitui. Another study by Murton (1999) reports that between 1965 and 1996, the number of farmers who owned ploughs in Machakos declined from 25% to less than 2%. Limited agricultural mechanization implies that productivity per unit of labor has to decline as population densities increase.

4.1.2. Decline in Crop Productivity and Farm Incomes

In the 1990s, the story by Tiffen et al. (1994) painted a picture of sustainable intensification in Machakos that was attributed to institutional support that facilitated access to quality inputs (fertilizer and seeds), information and markets. Higher prices imply substantial surpluses that can be used to invest in fertilizers and other external inputs that enhance crop productivity. For example in Machakos where farmers received higher coffee prices compared to those in Kisii, coffee productivity was reported to be higher. Institutional support in terms of provision of inputs and technical support offered through government extension service providers and cooperative societies facilitated better management of crops hence higher productivity.

Most FGD participants were of the opinion that recently, crop productivity has been declining in both Machakos and Kisii. This observation is consistent with evidence from a household survey in Machakos by Murton (1999) who noted that maize yields in Machakos had declined from 1.3 tons/ha in 1940 to 1.1 tons/ha in 1996. FGD participants attributed the decline in crop productivity to poor crop management strategies, overuse of inorganic fertilizers, use of poor quality seeds and emerging pests and diseases. The practice of using recycled hybrid seeds which is very common among the farmers also depresses yields. Further, given that hybrid maize varieties are more responsive to fertilizers, it is usually highly recommended

that farmers should use of inorganic fertilizers. However, farmers have adopted a norm of continuous blanket application of acidic fertilizers such as Di-Ammonium Phosphate (DAP) without proper soil analysis to determine farm specific nutrient requirements. The situation is aggravated by reduction in fallow periods and unavailability of organic fertilizer due to a decline in cattle populations.

Although some studies (for example Ünal, 2008) support the inverse yield-area relationship, findings from this study show that land fragmentation has had a negative effect on agricultural productivity. The FGD participants were of the opinion that small farms are not necessarily more efficient and productive than medium-scale and large-scale farms as traditionally believed. Similar findings by Deolalikar (1981) and Kimhi (2003) assert that the yield-area inverse relationship is not unequivocal but will only exist under certain conditions. Jayne et al. (2010) and Muyanga and Jayne (2014) find that small land units are an impediment to technology application and productivity. Advantages associated with intensive use of modern technology (e.g. mechanization, precision farming) available to medium-scale farms are reversing the inverse farm size-productivity relationship.

Owing to productivity declines, land fragmentation and declining rural farm economy, the contribution of agricultural income to total household income has declined, as also reported by Murton (1999). Currently, off farm income generation activities contribute a higher percentage of household income. Farmers in Machakos noted that the only time they generated substantial surpluses from agricultural production was during the coffee boom of the 1970s, after which farm incomes have been on the decline.

4.1.3. Soil Degradation

The decline in crop productivity reported in the previous section can be attributed to soil degradation among other factors. Results indicate that land degradation in the form of decline in soil fertility, reduced soil organic matter, increased acidity and depletion of micro and macro nutrients is a common trend in both Machakos and Kisii. Given that shifting cultivation and fallowing practices are no longer possible owing to scarcity of land, most farms have continuously (unsustainably) been cropped for over 100 years. As Drechsel et al. (2001) notes, all year round cultivation combined with poor land management practices leads to depletion of soil micro-nutrients and acidity which affects yields negatively. It appears that contrary to the Mortimore and Tiffen (1994) ‘Machakos miracle’ story of 1990s, there is

evidence that some unsustainable forms of agricultural intensification are creeping in as manifested in soil mining due to continued cultivation and acidity build-up due to inorganic fertilizers overuse in some areas. Consequently, this could be a possible explanation to perceptions on declining crop yields in Machakos and Kisii as reported in the FGDs, despite the widespread soil and water conservation practices.

4.1.4. Population Driven Social Challenges

The FGD participants reported some trends on increased alcoholism, petty theft and general insecurity in the rural areas, a trend they could partly attribute to population density growth. Population growth leads to shrinking farm sizes and excess labor force. Scarcity of land in the context of limited farm and off-farm employment opportunities is creating a pool of unemployed youths who are getting trapped in these social problems. Alcoholism and drug abuse in turn inhibits the capacity of the youths to actively contribute to farming activities. Consequently, the densely populated areas are currently facing a '*scarcity in the midst of plenty'* tragedy whereby, despite high population densities, agricultural labor force is scarce.

The declining employment opportunities in agriculture can be attributed to the fact that the rural farming sector, that is dominated by smallholder farmers is not productive enough to be able to gainfully engage the ever increasing entrants into the labour market. Furthermore, many small-scale farming areas have become enclaves unable to expand because they are surrounded by lands of a different tenure system. It is also unfortunate that, even when opportunities are available, most youths are not likely to be engaged in farming jobs because of their negative attitudes towards farming[3] and reduced capacity as a result of alcoholism and drug abuse.

4.2. Strategies for Coping with Population Pressure in Machakos and Kisii

4.2.1. Agricultural Intensification

Tiffen et al. (1994: pp 29) define agricultural intensification as '*increased average inputs of labour or capital on a smallholding, either on cultivated land alone, or on cultivated and grazing land, for the purpose of increasing the value of output per hectare'*. Four forms of agricultural intensification emerged distinctively in the Kisii and Machakos case: increased

[3] The youth claim that 'farming isn't cool'.

use of inorganic fertilizers, adoption of high yielding varieties, implementation of soil and water conservation practices, and increased capital investment in farming.

Increased use of inorganic fertilizers was driven by the need to enhance crop production on the declining farm sizes. Fertilizer adoption was also necessary following the widespread adoption of cash crops (e.g. coffee in Machakos and tea, pyrethrum and coffee in Kisii). Higher prices generated from cash crops (such as the coffee boom of the 1970s) facilitated further intensification since farmers could invest in more fertilizers and agro-chemicals. Adoption of high yielding varieties such as hybrid maize varieties started in the 1970s and expanded in many parts of rural Kenya. These technologies replaced the traditional varieties which were low yielding and did not depend on external inputs such as pesticides and inorganic fertilizers. Further, emerging market opportunities through increased demand for high value crops (e.g. fruits and vegetables) by consumers in the growing Nairobi city was also a key driver for intensification, and by extension, fertilizer use in Machakos. Proximity to a major airport in Nairobi also provided opportunities for farmers to produce crops for the export market. Such crops are very demanding in terms of inorganic fertilizers, pesticides and irrigation and therefore demanded more capital investment per unit of land.

Despite the fact that inorganic fertilizers increased yields in the beginning, FGD participants noted that the gains were short lived. In most parts of Kisii and Machakos, yield response to fertilizer use has declined; soils have become acidic and lost most of micro-nutrients. These trends were not visible at lower population densities such as when the 'Machakos miracle' was happening. Respondents also attributed the decline in yields to the fact that adoption of fertilizers and HYVs were not accompanied by appropriate technical advice and therefore farmers have continuously been applying the same type of inorganic fertilizers. The application of either wrong fertilizers or the same type of fertilizer for a long period is a factor that Muyanga (2013) associates with deterioration of crop yields, also leading to increasing soil acidity (Jayne et al. 2014). Even in cases where correct fertilizers are applied, the application rates have generally been below optimum levels as also reported in a recent nation-wide study by Sheahan et al. (2013).

Soil and water conservation was one of the earliest forms of agricultural intensification, driven by the realization that agricultural land was increasingly getting degraded as a result of intensified cropping in hilly areas. In Machakos, intensive soil conservation efforts started in the 1930s when soil degradation was identified as a serious challenge that threatened food production in Machakos (Tiffen et al. 1994). Initial soil conservation efforts were driven by

government efforts to restore degraded land but later the practices spread voluntarily, as farmers experienced the positive benefits. Soil and water conservation was a great success in the Machakos region as indicated in the Machakos Miracle (Tiffen et al. (1994), whereby in 1990, farmers had managed to reverse the widespread soil degradation trends witnessed in Machakos in the 1930s. The fact that many farms in densely populated areas are highly conserved is consistent with findings from previous research that has found an inverse relationship between farm size and the intensity of soil conservation (Willy and Holm-Mueller, 2013). As farms get smaller, they are likely to be well conserved, since the incentives to conserve are higher. The most common soil and water conservation practices in the Machakos are bench terraces, contour farming, *Fanya juu* terraces, mixed cropping, grass strips and farm forestry. Farm forestry is dominated by exotic species like Sydney blue gum (*Eucalyptus saligna*), Mexican cypress (*Cupressus lusitanica*), black wattle (*Acacia mearnsii*), silky oak (*Grevillea robusta*) and whistling pine (*Casuarina equisetifolia*).

As for Kisii, terraces are not common but farm forestry and mixed cropping are the dominant soil and water conservation practices. Given the extremely small farm sizes, farm forestry in Kisii is done mainly through boundary establishments unlike in Machakos where woodlots are common. Despite the widespread soil conservation efforts, results indicate that this has not necessarily translated to higher yields. This is consistent with previous findings that soil conservation has indeterminate influence on crop productivity depending on the practice in question, the opportunity costs involved and the fertility status of the soil prior to implementation of the practice (Willy et al. 2014). In the marginal lands which were highly degraded prior to implementation of the measures, it is likely that soil conservation will have substantial positive effects on yields. However, in cases where conservation measures are likely to take a larger proportion of the total land there might be a decline in production. As scarcity of land bites, farmers are also likely to convert some of the land previously under soil conservation practices (such as *Fanya Juu* terraces) back to crop production, causing productivity declines in the long run.

Capital investment was needed to finance all the above mentioned forms of agricultural intensification. Capital enabled financing of inorganic fertilizers and pesticides and also hiring of additional labor needed to implement the labor-intensive soil conservation practices such as bench terracing.

4.2.2. Off Farm Diversification

Our FGD reveals that off-farm diversification was driven by both 'push' and 'pull' forces. Land fragmentation and declined farm productivity associated with population density growth drove individuals to pursue non-land dependent income generating activities. Some of the most frequently mentioned off-farm income generation activities included seeking employment in urban centers, engagement in micro enterprises in rural areas and employment in commercial farms.

It is the authors' opinion that off-farm diversification depends on education level, gender and proximity to urban centers. Education increases the opportunity cost of being employed in agriculture and also the prospects of acquiring better paid off-farm employment. Even for the uneducated youths, poverty and the 'urban opportunities mirage' pushes them to urban centers, but most of them end up in low paying menial jobs and petty trade (such as hawking of water, ice cream and sweets in streets). This kind of employment does not generate substantial surpluses that can be transferred to rural areas and therefore has limited impact on agricultural intensification. Owing to culturally prescribed gender roles, women are supposed to remain at home to perform both productive and reproductive roles as home makers while the men are supposed to engage in income generating activities. Proximity to urban centers not only creates demand for agricultural commodities but also provides opportunities for off-farm employment in the manufacturing sector, service industry and public service among other sectors. For example, proximity to the Nairobi city has been a key 'pull' factor for immigrants from Machakos.

Participation in off-farm income generating activities has had two main effects on agriculture in the study areas. *First*, FGD participants reported that income generated from off-farm employment activities provided working capital to finance agricultural intensification through purchase of improved inputs and hiring of additional labor. This was the case especially during the time when the Machakos Miracle was reported, when population density was still low and investment in agricultural intensification could generate substantial returns. This is no longer the case with mounting population densities and declining farm sizes, trends that have suppressed the returns per shilling invested in agricultural intensification. With declining returns to agriculture, investment in agriculture also decreases as also observed by McDowell and de Haan (1997) who note that in some instances, only a small percentage of remittances is usually invested in agriculture. Often, off-farm income is used to accumulate

land (not necessarily for agricultural purposes), construct better houses and avail savings which act as an insurance against unforeseen events such as crop failure and other disasters.

Second, interaction with the 'outside world' by temporary immigrants is a media for technology transfer. As individuals travel, they are likely to borrow new technologies that they can adapt to their regions. FGD participants reported that most of the early adoptions of cash crops, use of the ox-plough and high yielding varieties (HYVs) were spearheaded by individuals who were either working in towns or in white settler farms, or were involved in the first and second World War.

4.2.3. Migration

Permanent out-migrations in Machakos and Kisii are prompted by pressure on land leading to extreme decline in average farm sizes. Theoretically, it is expected that migration is likely to ease pressure on land in densely populated areas. However, results emerging from this study indicate that whether this happens or not will depend on the whether immigrants transfer their land rights and the final destinations of the immigrants. In the Kisii case, it emerged that migrations are biased towards areas that were geographically similar to Kisii in terms of terrain, soil fertility and precipitation. Consequently, immigrants from Kisii seek land in other high potential areas, which also happen to be densely populated. Since government policies usually advocate for migration from densely populated areas to sparsely populated areas, policy incentives may be necessary to encourage migration into less attractive low potential areas. Asked whether they would migrate to low potential areas, respondents indicated that this would be possible only if such areas were improved through the provision of productivity enhancing infrastructure such as irrigation systems. FGD participants reported that out-migration may not necessarily ease land pressure and reduce land fragmentation in Kisii. Immigrants do not relinquish their ancestral land entitlements. This deep cultural attachment to ancestral land is likely to continue posing a challenge to anti-land fragmentation policies.

In the Machakos case, migrations started as soon as the ban instituted by the British colonialists was lifted (Munro, 1975; Kasperson et al., 1995). Unlike the Gusii, immigrants from the Kamba community were willing to migrate to low potential and also less congested areas in the plains. Also, permanent migrations in Machakos were accompanied by relinquishment/transfer of land rights through land sales to those who remained behind. As a result, some land consolidation was possible resulting to relatively larger production units, consequently reversing land fragmentation.

5. Conclusions and Policy Implications

This study presents findings emerging from discussions with experienced community members on agricultural trends in response to population density growth using Machakos and Kisii counties of Kenya as a case study. The findings offer some insights on the link between population growth and agricultural change. The study sought to identify how agriculture has changed in response to population density growth and how these changes have impacted on rural peoples livelihoods: incomes and crop productivity. It is imperative for agricultural policy in Kenya to assess whether farming systems of the study regions can continue producing more and more from cultivated land in response to rising population density or whether diminishing returns might set in at some point given existing farm technologies and agro-ecological conditions.

5.1. Drivers of Agricultural Intensification

In the face of population density increase, communities in the two study Counties have adapted their livelihood strategies to cope with the emerging challenges. Our study reveals that rural communities in Kisii and Machakos have responded to population density growth through multiple coupled adaptive strategies. Further, the outcomes of these strategies on agricultural productivity, livelihoods and the environment are anecdotal and depend on local conditions and interactions of intervening factors. Some of the key drivers of change in the case study areas are summarized in this section.

Our study confirms the hypothesis that population density pressure is a key driver of transformation in agriculture in rural areas. We find a Boserupian kind of transformation in the study areas where scarcity of land and emerging demand for food drove communities into agricultural intensification, off-farm diversification and migration. These responses were mainly conditioned by urbanization, government interventions (markets and infrastructure), culture, and influence from agents of change outside the confines of the rural areas.

Government policies: Government strategies and policies were found to be a key factor that influenced the way people respond to population pressure. Besides determining the availability of off-farm opportunities, the government also influences the set of incentives facing communities. Infrastructural development was found to be a key driver of agricultural intensification. Improved infrastructure ensures that the rural areas are well linked to the urban markets.

Urbanization: Urbanization was a key driver to agricultural intensification and off-farm diversification. Off-farm employment provides a pathway through which community members facing shrinking farm sizes and declining agricultural productivity can diversify their income sources. Further, the income generated from off-farm sources is used to finance agricultural intensification in the rural areas. The other direct link between agricultural intensification and urbanization is the fact that the growth in urban demand offers new opportunities for rural farms to supply food, especially fresh fruits and vegetables, and milk.

*Cultural influence***:** We noted a cultural influence in the way communities cope with population density pressure. Strong cultural attachment to ancestral land restricts land consolidation since even people who migrate to other regions still hold their rights to the highly fragmented parcels in their original homes. Further, people's culture contributes to skewness in migration patterns towards certain areas that are similar to the original settlements. This limits the success of land redistribution policies which are in favour of movement of people from densely populated areas to sparsely populated areas.

External influence: Finally, external influence through interaction with the 'outside world' was noted as a key driver of technology transfer facilitating agricultural intensification. People who had sought off-farm employment in urban areas also brought many technologies to their villages. Contact with British settler farmers and missionaries also tremendously change agricultural production systems in the communities and expanded options for coping with population density pressure.

5.2. The Impact of Adaptation Strategies on Crop Productivity

In the Machakos and Kisii case studies, it emerged that agricultural intensification has had mixed impacts on household livelihoods. To some farmers, the effect has been improved productivity while for others agricultural intensification and improved land management has not necessarily yielded substantial productivity gains. One possible explanation is the vicious cycle of agricultural productivity caused by the endogenous effect of poor agricultural performance. Lower incomes imply that fewer resources are available for subsequent investment in agriculture resulting to a vicious cycle of low productivity as also observed by Murton (1999). The decline in productivity as a result of degraded soils could also be a disincentive against investments in agriculture, since returns to such investment are not guaranteed.

Another important factor is the functioning of land markets. As land holdings per households decline with increasing population pressure, land markets offer an opportunity for farmers to compensate for the ‘‘lost’’ land through renting of additional land such that operated land remains the same over time. This however has not been the case in rural Kenya where according to a study by Muyanga (2013), land markets are either non-existence or highly distorted. Further, it emerged from this study that in most cases even migrations do not ease the pressure on land since immigrants still maintain land ownership in their original areas. A study by Murton (1999) reveals a skewed distribution of land in rural Machakos. Land assets accumulate among wealthy households who use surplus resources earned off the land to accumulate more land in their villages. This creates a majority of poor community members who are highly depended on agriculture and controlling less land in the midst of fewer wealthy land owners, most of whom hold land for speculative purposes (Muyanga, 2013).

Finally, improper implementation of agricultural technologies and lack of technical support has been a major cause for low productivity gains in the process of agricultural intensification. Improper utilization of fertilizers has led to massive soil micro and macro nutrient depletion with serious implications on crop yields. Improper use of high yielding technologies and failure to invest in accompanying technologies has led to on-farm yields that were well below potential.

Based on the findings, we can draw a number of policy implications. It is obvious that agricultural and food policies targeting rural Kenya cannot ignore the impact of population density on agricultural development, especially when a substantial proportion of the Kenyan population still lives in the rural areas depending on agriculture.

The population driven challenges facing agriculture can be addressed through controlling of land fragmentation and stabilization of farm sizes. One possible way of achieving this is by growing non-farm job opportunities so that they can pull rural people out of agriculture and into non-farm jobs, allowing farm sizes to stop declining. Past trends in rural Kenya indicate that the rate of job growth in urban and rural Kenya has not been fast enough to pull rural labor out of agriculture, thereby resulting in continued increases in labor to land ratios in agriculture (Muyanga, 2013). Farmers are not able to profitably increase their use of capital in agricultural production, so as to increase their capital/land ratios over time. A study by Muyanga and Jayne (2014) documents a trend of declining land holdings and cultivated land across all the population density quintiles, confirming that land fragmentation has been

increasing with population density growth. Land policies that discourage land sub-division beyond a certain level could play an important role in such a situation. Land subdivision into very small uneconomical units pushes people out of agriculture. In that case we are likely to observe declines in the amount of fertilizers used and the amount of money used on purchased inputs.

The other necessary option is to encourage reduction in population density growth. The current situation in Kenya is that although population density growth rates have started to decline, absolute rural population densities are still high beyond sustainable levels. This study finds that migration into the already densely populated areas is the norm. Migration into areas perceived to be low potential can be encouraged by enhancing the productive capacity of land in such areas through infrastructural (transport, financial and irrigation) development.

Finally, to counter the negative impacts of population growth on agricultural productivity, it is necessary that agricultural productivity and therefore incomes stop declining. High population densities in rural Kenya, accompanied by decline in agricultural rural incomes as a result of declined agricultural productivity can act as a disincentive towards investment in purchased agricultural inputs, further pushing productivity down. Policy needs to focus on strategies that enhance crop productivity and foster sustainable forms of agricultural intensification such as increased technical advice on the use of inputs, encouraging of the use of organic manure and fallowing to re-build soil organic carbon. Positive returns to agriculture can be an incentive for investment in farming, especially among the massively unemployed youths, who are likely to increase as population growth bites.

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