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# Intensify or diversify? Agriculture as a pathway from poverty in eastern Kenya

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## Abstract

Rainfed agriculture's potential as a pathway from poverty was explored through a comparative study of Embu and Kitui districts in eastern Kenya. Using survey data from 680 households, livelihood diversification was measured by developing a typology based on the contribution of different sources to household income and by a Herfindahl Index. Intensification was measured by an aggregate adoption index and indicators reflecting the adoption of individual agricultural technologies. More diversified households had higher incomes. Households specializing in farming in Embu earned enough income from agriculture to stay above the poverty line, but not in Kitui. Agricultural intensification appears a potential pathway from poverty in high-potential rainfed agriculture in Embu, while income diversification seems a more realistic strategy in low-potential areas like Kitui. This highlights the importance of agro-ecology and household livelihood strategies in determining the potential uptake of new technology and the benefits from intensification.

***Keywords:*** Livelihood diversification; intensification; technology adoption; poverty; Kenya

**JEL classification**: 013, 014, Q12

# Contents

Abstract ........ 2
Contents ........ 3
1 Introduction ........ 4
2 Material and methods ........ 5
2.1.1 Study site selection and sampling ........ 5
2.1.2 Measurement: Poverty ........ 6
2.1.3 Measurement: Livelihood diversification ........ 6
2.1.4 Measurement: Agricultural intensification ........ 7
2.1.5 Analysis ........ 8
3 Results ........ 8
4 Discussion ........ 18
4.1 Intensification and diversification ........ 18
4.2 Intensification and poverty ........ 19
4.3 Agro-ecology and market access ........ 20
5 Conclusions ........ 20
References ........ 22
Appendix ........ 25

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# 1 Introduction

Agriculture is deemed an important pathway for the rural poor to move out of poverty (World Bank, 2007). At the same time, there appears to be a vicious cycle in which low surplus production constrains the development of markets, reinforcing subsistence agriculture and keeping smallholders poor (Jayne and Muyanga, 2012). A potential exit from this impasse is ‘intensification’, which has become the new war-cry for agricultural research and development in Sub-Saharan Africa (SSA). ‘Sustainable intensification’ is defined as the application of technology that can increase food production from existing farm land, places less pressure on the environment and does not undermine the capacity to continue producing food in the future (Garnett et al., 2013). Widespread adoption of such new technology is viewed as a promising strategy to increase productivity and reduce poverty among African smallholders.

One objection to this strategy is that the process of adoption is not straightforward and may not give the expected results. Determinants of adoption have been studied for decades (Feder et al., 1985; Foster and Rosenzweig, 2010; Sunding and Zilberman, 2001). Even where new technology appears profitable, households may not adopt (Suri, 2011). Moreover, adoption is determined largely by short-term profitability and sustainability is not necessarily an immediate concern for smallholders (Lee, 2005). African agricultural systems are heterogeneous in institutional contexts, socio-economic and agro-ecological conditions, generating multiple routes to intensification (Vanlauwe et al., 2014). This indicates the need for increased attention to barriers and disincentives to the adoption of technologies in SSA (Jack, 2011; Jayne et al., 2010). Furthermore, the evidence that intensification leads to poverty reduction is thin and mixed (Collier and Dercon, 2014; Cunguara and Darnhofer, 2011; Kassie et al., 2011). In particular, doubts have been raised about the potential of rainfed agriculture as a pathway from poverty. Over 80% of farms in SSA are now under two hectare (ha) (Lowder et al., 2014; Nagayets, 2005). On farms below one ha with a single cropping season, the additional income from new technology may be too low for crop production alone to lift smallholders above the poverty line (Harris and Orr, 2014).

A second objection is that, for many rural households, intensification may not be an appropriate strategy. Gone are the days when rural populations were assumed to be simply farmers (Freeman and Ellis, 2005; Sumberg et al., 2004). Instead, diversification is the norm (Barrett et al. (2001). Diversification can be defined as a process by which households construct a diverse portfolio of income generating activities to improve their living standards (Ellis, 1998). Diversification strategies vary widely (Barrett et al., 2005). Poorer households may diversify into low-return non-farm activities to spread risk, while others diversify into high-return non-farm activities as an alternative pathway from poverty (Haggblade et al., 2010; Stifel, 2010). Clearly, the diversification strategy followed by rural households will affect their decision to adopt new technology (Tittonell, 2007). Households with limited resources or the aspiration to step out of agriculture may not adopt new technology even when this is profitable (Tittonell et al., 2010). Moreover, as the share of farming in household income declines, the expected benefits to adoption need to increase in order for a technology to remain attractive (Sumberg et al., 2004). Alternatively, income from diversification into non-farm activities can be re-invested in agriculture to increase income from farming (Freeman and Ellis, 2005; Harris and Orr, 2014; Reardon, 1997). It is thus unclear whether intensification and diversification are competing or complementary livelihood strategies (Sumberg et al., 2004).

The general objective of this study is to assess the relevance of agricultural intensification for poverty reduction in rainfed farming systems where households follow diverse livelihood strategies. Specifically, we try to answer three questions:

1. How important is agriculture as a livelihood strategy?
2. Is intensification compatible with livelihood diversification?
3. Is intensification a potential pathway from poverty?

'Rainfed agriculture' covers many environments that differ widely in their potential for crop production. Generalisations based on a single environment are misleading. We have therefore used a comparative approach, allowing us to compare intensification as a potential pathway from poverty for high-potential and low-potential environments in eastern Kenya.

# 2 Material and methods

### 2.1.1 Study site selection and sampling

For comparison we selected two districts from eastern Kenya: Embu and Kitui. Rainfall across both districts is bimodal and allows two cropping seasons per year (Jaetzold et al., 2006; Tittonell et al., 2010). Maize is the most widely cultivated crop in both study areas (Odame and Muange, 2011). Embu district is sub-humid, with fertile soils, relatively high population density and good market access (Tittonell et al., 2010). Rainfall varies from 900-1800 mm according to altitude (Jaetzold et al., 2006). At higher altitudes, farmers grow coffee, tea and macadamia, while at lower altitudes *miraa* (khat) is the main cash crop. Livestock consists primarily of high-grade dairy cattle. By contrast, Kitui district is semi-arid, with lower and more variable rainfall, particularly in the long rains (Rao et al., 2011). Our study was conducted in central Kitui, which lies on an undulating plateau at about 1100 meters altitude and receives more rainfall (between 750-1150 mm) than the rest of the district (Jaetzold et al., 2006). Livestock consists largely of zebu cattle for ploughing and goats.

The survey formed a baseline for an evaluation of Farm Input Promotions (FIPS) Africa's extension programme in Eastern Kenya (see Zaal et al., 2012). Forty-one villages were purposefully selected in coordination with government extension staff to ensure that intervention and control villages were similar in socio-economic and agro-ecological characteristics. 680 households were randomly selected from household lists compiled by village elders. The aim was to interview 15-20 percent of all village households. Because of the purposeful village sampling strategy our findings are not necessarily representative at district level. However, they give insights into which livelihood strategies generate returns above the poverty line in two contrasting rainfed environments.

Data was collected through a structured questionnaire. This was not a farm survey, based on continuous observation throughout the year and precise measurements of inputs and outputs. Rather, this was a household survey designed to capture the chief sources of household income, the profitability of the main farm enterprises, and whether or not farm households used a range of new technologies. For intensification, data was collected on the full range of on-farm enterprises, which captured the entire crop-livestock system. For diversification, data was collected on off-farm income such as trade, remittances and other forms of paid employment. Because of time and financial constraints, information on household income was collected using a one-off visit. To reduce recall bias and measurement errors implicit in a one-off survey, the survey questionnaire was designed to capture as full a record of household income as possible. In addition, where possible we interviewed both the head of household and their spouse. To aid recall, interviews were timed at the end of the main rainy season (September-October 2013), when information was collected on farm production in both the main rainy season and the previous season (May-June, 2013). Visits were made to farm fields but only where these were nearby. On average, each interview took two hours, which we judged the maximum length for unpaid interviews. In addition, village surveys were administered to collect data on the prices of crops, livestock and inputs, the availability of services, and the presence of agricultural and other interventions. The first author was present throughout the process of data collection.

#### 2.1.2 Measurement: Poverty

Our objective is to assess the relevance of agricultural intensification for poverty reduction. We use the international poverty line of US dollars (USD) 1.25 per day per capita, which is expressed in Purchasing Power Parity (PPP) terms and constant 2005 prices. We realize that the “dollar a day line” is not without criticism, but it has become the standard for measuring extreme poverty in the world (Ravallion et al., 2009). See also Deaton (2010) for a thorough discussion of the measurement of poverty and the role of PPP price indexes.

Following Harris and Orr (2014) we analyse whether total, farm or crop related activities can generate incomes above the international poverty line. Specifically, we converted net household income from Kenya shillings (KES) to USD PPP values, using 2013 conversion rates for household final consumption expenditure extrapolated from the 2011 International Comparison Program (ICP) benchmark year (World Bank, 2015). To inflate the international poverty line to 2013 prices, we computed its equivalent in 2005 KES using 2005 PPP conversion rates. The KES poverty line in 2005 prices was subsequently inflated to 2013 prices using the Kenyan national consumer price index. Conversion of the 2013 KES poverty line into 2013 USD PPP prices translated into an international poverty line of USD 1.49 per day per capita in 2013.

#### 2.1.3 Measurement: Livelihood diversification

Diversification was measured as the vector of income shares associated with different income sources (Barrett et al., 2005). Income sources represent net income as they take into account input and hired labour costs for crop production and livestock rearing, while households were specifically asked to report net off-farm income. Unlike Harris and Orr (2014), we did not measure net returns to specific agricultural technologies, but net returns from agriculture (excluding the cost of family labour) at household level.

We estimated two indicators of livelihood diversification. First, cluster analysis was used to assign households to clusters based on the share of on-farm, farm labour and non-farm income sources. K-means cluster analysis was performed to obtain a predetermined number of clusters to minimize within-cluster variance and maximize between cluster variance following Brown et al. (2006). Since households that engage in farm labour are likely to be poorer, it is important to study this group separately (Barrett et al., 2005; Davis et al., 2010). We therefore increased the number of clusters until it was possible to distinguish a ‘farm-worker’ cluster. This resulted in four clusters: full-time farmer, farm-worker, mixed and non-farm.

Second, we used the Herfindahl Index, defined as the sum of squared shares of on- and off-farm income sources (Barrett et al., 2005). Following Davis et al. (2010) we distinguished three sources of on-farm income (crop sales, value of own crop consumption and livestock income) and four sources of off-farm income (non-farm wage labour, farm labour, self-employment / trade and transfers, such as remittances and pensions). A Herfindahl Index value of 1 indicates complete dependence on one source and 0.14 indicates perfectly equal earning across the 7 income sources.

### 2.1.4 Measurement: Agricultural intensification

To measure intensification we constructed an index of technology adoption. Following van Rijn et al. (2012) and Pamuk et al. (2014) the index is based on the number of technologies adopted. The index captures a range of 15 technologies, which can be grouped in five sub-categories and include methods to improve the management of soil fertility, water resources, crops, post-harvest handling and livestock. The index ranges from 0 to 15 and sums the adoption of agricultural technologies that are applicable across both sub-humid and semi-arid agro-ecological systems and were captured by our survey. The adoption index is derived from observational data and covers the entire crop-livestock farm system, which signifies its relevance as an indicator for agricultural intensification.

We acknowledge that this is a crude index of adoption. First, count data treats widely differing technologies as equivalent. Some authors address this problem by disaggregating the adoption index into sub-categories. For instance, van Rijn et al. (2012), distinguished between a total and an essential innovation index, while Pamuk et al. (2014) divided their analysis into innovation sub-categories. In our case, however, 15 technologies over 5 sub-categories left insufficient variation for a meaningful sub-category analysis. Second, the adoption index does not reflect the extent or intensity of adoption. Again, data limitations prevented us developing such an index. Although we have information on the area allocated to certified maize seed and fertilizer use, this information is not available for natural resource management and post-harvest innovations. Thus, we were unable to compute a weighted adoption index that incorporated the extent of farm system intensification.

On the other hand, any index of adoption that attempts to capture intensification across the entire farm system will run into problems of assumed equivalence. Examples of measuring intensification at the farm level were hard to find. We did encounter a paper where maize system intensification was estimated using factor analysis (Muraoka et al., 2015) while Aguilar-Gallegos et al. (2015) and Dhakal et al. (2015) used the percentage of innovations adopted from within each sub-category as a measure for oil palm and agroforestry innovations respectively. However, these measures focus on specific crops or individual farm system components and do not capture intensification at the level of the farm system. Thus, the general difficulties associated with the estimation of farm system intensification combined with the limitations in our data prevented us developing a more robust index of farm system intensification.

Our approach, therefore, was to retain our admittedly imperfect index of farm level intensification but to check the robustness of this index by comparing the results with those obtained from alternative indicators of intensification that reflect the intensity or extent of adoption. We borrow from a rather extensive body of literature that analyses the relationship between intensification and certain variables of interest, e.g., institutional services

(Gebremedhin et al., 2009), population density (Josephson et al., 2014; Muyanga and Jayne, 2014; Ricker-Gilbert et al., 2014) and land constraints (Headey et al., 2014). We specifically utilized the following indicators of intensification: chemical fertilizer use (kg/ha), certified maize seed use (% maize area), maize yield (kg/ha) as well as land and labour returns (USD / ha or family labour day). These measures avoid concerns around treating technologies as equivalent while providing an indication of the extent of adoption. By comparing differences between the livelihood clusters with respect to these indicators we can further assess correlations between intensification and diversification. In addition, the composite indicators for returns to land and labour indicate the returns to intensification. Of course, these indicators do not reflect intensification at the level of the farm system. Since the general objective of the paper is to assess whether intensification is compatible with livelihood diversification, we have therefore chosen to retain an index of intensification at the aggregate or farm system level.

#### 2.1.5 Analysis

We used a variety of methods to answer our three research questions. First, we assessed the importance of agriculture as a livelihood strategy (research question 1). Differences in on and off-farm income shares as well as the Herfindahl Index were analysed by district and livelihood cluster. In addition, analysis of variance (ANOVA) was performed to compare mean descriptive values across the livelihood clusters. Tests were adjusted using the Bonferroni method to correct for possible spurious inference due to making multiple comparisons between group means and proportions following Brown et al. (2006).

Secondly, we analysed whether agricultural intensification and livelihood diversification are compatible (research question 2). Ordinary least squares (OLS) regression was used to analyse the relationship between diversification and technology adoption. The main variables of interest are the livelihood clusters, with full-time farmers as comparison category, and the Herfindahl Index. The model includes various controls derived from the extensive and longstanding literature on the determinants of technology adoption (e.g., Feder et al., 1985; Foster and Rosenzweig, 2010; Jack, 2011; Lee, 2005; Parvan, 2011; Sunding and Zilberman, 2001). Descriptive statistics for the variables used in the regression models are presented in the Appendix. Because the adoption index consists of count data, Poisson models were estimated to check robustness. We further assessed the robustness of our findings by running the OLS model with alternative indicators of agricultural intensification.

Finally, we explored whether agricultural intensification is a potential pathway from poverty (research question 3). We did this by calculating whether households earned returns above the poverty line using total income per capita, farm income per capita and crop income per capita (per day and in 2013 USD PPP prices). Comparing returns to crop and farm income with total income, provides an indication of agriculture's potential contribution to poverty alleviation.

## 3 Results

How important is agriculture as a livelihood strategy? Table 1 shows income diversification among the sample households.

**Table 1 Share of income by district and livelihood cluster**

| | Kitui | Embu | Kitui | | | | Embu | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Full-time farmer | Farm-worker | Mixed | Non-farm | Full-time farmer | Farm-worker | Mixed | Non-farm |
| | n=335 | n=345 | n=55 | n=32 | n=113 | n=135 | n=125 | n=39 | n=104 | n=77 |
| Herfindahl Index: Income diversification | $.49_a$ | $.47_a$ | $.45_a$ | $.46_a$ | $.36_b$ | $.62_c$ | $.49_a$ | $.44_a$ | $.36_b$ | $.63_c$ |
| Farm income (%) | $40.7_a$ | $56.9_b$ | $84.9_a$ | $33.3_b$ | $51.7_c$ | $15.3_d$ | $90.0_a$ | $38.2_b$ | $54.1_c$ | $16.3_d$ |
| Crop sales (%) | $8.4_a$ | $26.7_b$ | $22.9_a$ | $4.9_{b,c}$ | $9.5_b$ | $2.3_c$ | $44.6_a$ | $17.0_b$ | $23.3_b$ | $7.2_c$ |
| Value own consumption (%) | $22.9_a$ | $16.1_b$ | $40.9_a$ | $21.1_b$ | $30.4_c$ | $9.7_d$ | $21.9_a$ | $15.2_b$ | $16.4_b$ | $6.5_c$ |
| Livestock income (%) | $9.5_a$ | $14.1_b$ | $21.1_a$ | $7.3_{b,c}$ | $11.8_b$ | $3.3_c$ | $23.5_a$ | $5.9_{b,c}$ | $14.4_b$ | $2.6_c$ |
| Off-farm income (%) | $59.3_a$ | $43.1_b$ | $15.1_a$ | $66.7_b$ | $48.3_c$ | $84.7_d$ | $10.0_a$ | $61.8_b$ | $45.9_c$ | $83.7_d$ |
| Farm wage labour (%) | $8.4_a$ | $8.9_a$ | $5.3_a$ | $58.1_b$ | $3.8_a$ | $1.9_a$ | $4.8_a$ | $55.6_b$ | $2.0_{a,c}$ | $1.3_c$ |
| Non-farm wage labour (%) | $29.5_a$ | $21.3_b$ | $5.2_a$ | $3.6_a$ | $22.0_b$ | $51.8_c$ | $2.1_a$ | $2.9_a$ | $23.4_b$ | $58.9_c$ |
| Self-employment / trade (%) | $11.0_a$ | $7.2_b$ | $1.8_a$ | $1.6_a$ | $9.5_a$ | $18.3_b$ | $1.0_a$ | $1.9_a$ | $11.5_b$ | $14.3_b$ |
| Transfers (%) | $10.4_a$ | $5.7_b$ | $2.8_a$ | $3.4_{a,b}$ | $13.1_b$ | $12.8_{b,c}$ | $2.2_a$ | $1.3_a$ | $9.0_b$ | $9.2_b$ |

Note: Values in the same row and sub-table not sharing the same subscript are significantly different at $p < .05$ in the two-sided test of equality for column means / proportions. Tests are adjusted for all pairwise comparisons within a row of each innermost sub-table using the Bonferroni correction.

**Table 2 Analysis of Variance demographics and wealth by district and cluster**

| | | | Kitui | | | | Embu | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kitui | Embu | Full-time farmer | Farm-worker | Mixed | Non-farm | Full-time farmer | Farm-worker | Mixed | Non-farm |
| | n=335 | n=345 | n=55 | n=32 | n=113 | n=135 | n=125 | n=39 | n=104 | n=77 |
| *Demographics and location* | | | | | | | | | | |
| Male head (yes=1, no=0) | $.80_a$ | $.84_a$ | $.82_a$ | $.81_a$ | $.79_a$ | $.81_a$ | $.85_a$ | $.74_a$ | $.83_a$ | $.91_a$ |
| Age household head (years) | $48.98_a$ | $51.31_b$ | $52.58_a$ | $49.44_a$ | $48.95_a$ | $47.43_a$ | $54.56_a$ | $49.97_{a,b}$ | $51.42_{a,b}$ | $46.57_b$ |
| Education head (years) | $7.94_a$ | $7.36_a$ | $6.76_a$ | $6.72_{a,b}$ | $7.96_{a,b}$ | $8.69_b$ | $6.85_a$ | $6.08_a$ | $7.48_{a,b}$ | $8.68_b$ |
| Married head (yes=1, no=0) | $.76_a$ | $.79_a$ | $.80_a$ | $.75_a$ | $.75_a$ | $.76_a$ | $.78_a$ | $.69_a$ | $.76_a$ | $.90_a$ |
| Family size (No.) | $5.27_a$ | $4.27_b$ | $5.44_a$ | $4.97_a$ | $5.44_a$ | $5.12_a$ | $4.44_a$ | $4.51_a$ | $3.79_a$ | $4.52_a$ |
| Dependents (%) | $40.11_a$ | $35.74_b$ | $39.31_a$ | $36.03_a$ | $39.87_a$ | $41.61_a$ | $34.64_a$ | $34.64_a$ | $38.40_a$ | $34.49_a$ |
| Distance to nearest all-weather road (km) | $.71_a$ | $.53_b$ | $.76_a$ | $.96_a$ | $.64_a$ | $.69_a$ | $.60_a$ | $.87_a$ | $.47_a$ | $.33_a$ |
| Access to electricity (%) | $21.5_a$ | $38.3_b$ | $18.2_a$ | $0.0_a$ | $19.5_a$ | $29.6_a$ | $32.8_a$ | $10.3_b$ | $44.2_{a,c}$ | $53.2_c$ |
| *Wealth, credit and savings* | | | | | | | | | | |
| Current asset value (USD) | $1{,}988_a$ | $1{,}668_a$ | $1{,}485_a$ | $806_a$ | $1{,}665_a$ | $2{,}744_a$ | $1{,}463_a$ | $546_a$ | $1{,}731_{a,b}$ | $2{,}483_b$ |
| Current owned land value (USD) | $16{,}394_a$ | $33{,}447_b$ | $19{,}117_a$ | $13{,}060_a$ | $18{,}233_a$ | $14{,}535_a$ | $39{,}097_a$ | $21{,}530_a$ | $31{,}670_a$ | $32{,}710_a$ |
| Land owned (ha) | $1.16_a$ | $.70_b$ | $1.38_a$ | $.78_a$ | $1.29_a$ | $1.06_a$ | $.83_a$ | $.42_b$ | $.65_{a,b}$ | $.70_{a,b}$ |
| Current animal value (USD) | $1{,}075_a$ | $936_a$ | $1{,}287_a$ | $552_a$ | $1{,}239_a$ | $975_a$ | $1{,}130_a$ | $439_b$ | $991_{a,c}$ | $797_{b,c}$ |
| Total current tropical livestock units (TLU) | $2.06_a$ | $1.39_b$ | $2.57_a$ | $1.06_a$ | $2.36_a$ | $1.85_a$ | $1.67_a$ | $.65_b$ | $1.45_a$ | $1.21_{a,b}$ |
| Has credit (%) | $25.4_a$ | $20.6_a$ | $20.0_a$ | $12.5_a$ | $23.9_a$ | $31.9_a$ | $17.6_a$ | $15.4_a$ | $20.2_a$ | $28.6_a$ |
| Has savings (%) | $70.7_a$ | $67.2_a$ | $67.3_a$ | $59.4_a$ | $75.2_a$ | $71.1_a$ | $66.4_a$ | $53.8_a$ | $73.1_a$ | $67.5_a$ |

Note: Values in the same row and sub-table not sharing the same subscript are significantly different at $p < .05$ in the two-sided test of equality for column means / proportions. Tests are adjusted for all pairwise comparisons within a row of each innermost sub-table using the Bonferroni correction.

In Kitui, full-time farmers accounted for just 16% of the sample population, while the majority belonged to the non-farm and mixed livelihood clusters. The share of full-time farmers in Embu was twice as high (36%), but they were still a minority. The Herfindahl Index shows that the households in the non-farm livelihood cluster were less diversified in terms of sources of income (index 0.62, 0.63) than full-time farmers (index 0.45, 0.49). The mixed livelihood cluster was the most diversified, with the lowest Herfindahl Index (0.36). Mixed farmers were less market-oriented than full-time farmers with around half the share of income from crop sales. There were significant differences between districts. The share of off-farm income was higher in Kitui (59%) while in Embu the largest share of income came from agriculture (57%). Households in Embu were also more market-oriented, drawing a higher share of income from crop sales (27%) than in Kitui (8%).

Tables 2 and 3 compare demographics, wealth and farming activities between districts and livelihood clusters. Family size and dependency rates in Kitui were higher than in Embu. Distances to roads were larger in Kitui and there was considerably less access to electricity. Average farm size in both districts was below 1 ha. Although households in Kitui owned more land, land in Embu was more valuable. The value of livestock and other assets did not differ significantly between the two districts. Chemical fertiliser rates, the number of crops planted and the share of households hiring labour were significantly higher in Embu. Returns to land in Embu (3,800 USD/ha) were more than double those in Kitui (1,712 USD/ha), while average returns to family labour were also higher (24 USD/day compared to 14 USD/day). Maize productivity was significantly higher in Embu (2,068 kg/year) than in Kitui (1,737 kg/year). A significantly higher share of households in Embu grew and sold horticultural crops (vegetables) and cash crops (coffee, tea, mirra). Households in Embu were more likely to receive information on agricultural technologies from the state extension service whereas those in Kitui relied primarily on the mass media. In both districts the highest returns to land and labour were achieved by full-time farmers, while returns were lowest for farm-workers. Full-time farmers in Embu were more closely linked to markets, with a higher share selling agroforestry crops (98%) and cash crops (89%) than in Kitui (40% and 6%, respectively).

Adoption of new technology was significantly higher in Embu (Adoption Index = 8.98) than in Kitui (Adoption Index = 7.70) (Table 4). Households in Embu were more likely to adopt irrigation, certified maize seed, chemical fertiliser, non-storage chemicals and post-harvest innovations, whereas households in Kitui were more likely to adopt labour-intensive erosion control and water harvesting technologies and relied on organic fertiliser. Households in Embu were also more likely to own improved animal breeds and buy animal feed, reflecting their engagement in dairy and poultry farming. Within the clusters, full-time farmers had the highest adoption index (8.20, 9.57), although these are not significantly different from the mixed cluster. Non-farm households had a significantly lower adoption index (7.45, 8.38), similar to that of farm-workers. Adoption of new technology by full-time farmers was significantly higher than non-farm households only for post-harvest processing (drying, threshing/shelling and grading) reflecting their greater market-orientation.

**Table 3 Analysis of variance farming activities by district and cluster**

| | | | Kitui | | | | Embu | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kitui | Embu | Full-time farmer | Farm-worker | Mixed | Non-farm | Full-time farmer | Farm-worker | Mixed | Non-farm |
| | n=335 | n=345 | n=55 | n=32 | n=113 | n=135 | n=125 | n=39 | n=104 | n=77 |
| *Land, input and labour utilization* | | | | | | | | | | |
| Area cultivated (ha) | .89$_{a}$ | .64$_{b}$ | 1.02$_{a}$ | .66$_{a}$ | 1.02$_{a}$ | .78$_{a}$ | .77$_{a}$ | .43$_{b}$ | .60$_{a,b}$ | .58$_{b}$ |
| Organic fertilizer (kg/ha) | 1,054$_{a}$ | 1,155$_{a}$ | 1,113$_{a}$ | 695$_{a}$ | 1,030$_{a}$ | 1,136$_{a}$ | 1,272$_{a}$ | 785$_{a}$ | 1,423$_{a}$ | 792$_{a}$ |
| Chemical fertilizer (kg/ha) | 21$_{a}$ | 193$_{b}$ | 58$_{a}$ | 17$_{a}$ | 7$_{a}$ | 18$_{a}$ | 212$_{a}$ | 115$_{a}$ | 181$_{a}$ | 216$_{a}$ |
| Certified maize seed (% maize area) | 67.6$_{a}$ | 86.9$_{b}$ | 66.6$_{a}$ | 64.7$_{a}$ | 63.1$_{a}$ | 72.3$_{a}$ | 85.9$_{a,b}$ | 71.5$_{a}$ | 90.2$_{b}$ | 92.0$_{b,c}$ |
| Crops planted (No.) | 6.8$_{a}$ | 8.7$_{b}$ | 7.8$_{a}$ | 7.1$_{a,b}$ | 7.0$_{a}$ | 6.1$_{b}$ | 9.2$_{a}$ | 8.1$_{a}$ | 8.7$_{a}$ | 8.3$_{a}$ |
| Farm family labour days (days) | 191.7$_{a}$ | 163.6$_{b}$ | 250.6$_{a}$ | 124.1$_{b}$ | 218.0$_{a}$ | 161.8$_{b}$ | 193.7$_{a}$ | 125.1$_{b}$ | 159.3$_{a,b}$ | 139.9$_{b}$ |
| Farm hired labour days (days) | 46.7$_{a}$ | 40.2$_{a}$ | 31.6$_{a}$ | 6.5$_{a}$ | 37.5$_{a}$ | 70.2$_{a}$ | 56.3$_{a}$ | 17.1$_{b}$ | 33.5$_{a,b}$ | 34.9$_{a,b}$ |
| Hires labour (%) | 52.2$_{a}$ | 71.0$_{b}$ | 56.4$_{a,b}$ | 34.4$_{a}$ | 44.2$_{a}$ | 61.5$_{b}$ | 70.4$_{a}$ | 59.0$_{a}$ | 79.8$_{a}$ | 66.2$_{a}$ |
| *Productivity, returns and farm system* | | | | | | | | | | |
| Returns to land (crop income / ha cultivated) | 1,712$_{a}$ | 3,800$_{b}$ | 2,793$_{a}$ | 878$_{b}$ | 1,773$_{a,b}$ | 1,417$_{b}$ | 4,602$_{a}$ | 2,688$_{a,b}$ | 3,961$_{a,b}$ | 2,844$_{b}$ |
| Returns to labour (farm income / fam labour days) | 13.8$_{a}$ | 23.9$_{b}$ | 28.2$_{a}$ | 5.7$_{a,b}$ | 16.7$_{a,b}$ | 7.4$_{b}$ | 32.6$_{a}$ | 9.6$_{a,b}$ | 27.7$_{a,b}$ | 12.0$_{b}$ |
| Annual maize productivity (kg/ha) | 1,737$_{a}$ | 2,068$_{b}$ | 1,890$_{a}$ | 1,191$_{a}$ | 1,801$_{a}$ | 1,751$_{a}$ | 2,245$_{a}$ | 1,419$_{a}$ | 2,242$_{a}$ | 1,874$_{a}$ |
| Grows agroforestry crops (%) | 77.3$_{a}$ | 97.7$_{b}$ | 81.8$_{a}$ | 75.0$_{a}$ | 83.2$_{a}$ | 71.1$_{a}$ | 99.2$_{a}$ | 97.4$_{a}$ | 99.0$_{a}$ | 93.5$_{a}$ |
| Sells agroforestry crops (%) | 26.9$_{a}$ | 90.7$_{b}$ | 40.0$_{a}$ | 25.0$_{a,b}$ | 31.0$_{a,b}$ | 18.5$_{b}$ | 97.6$_{a}$ | 76.9$_{b}$ | 92.3$_{a,b}$ | 84.2$_{b}$ |
| Grows horticultural crops (%) | 33.7$_{a}$ | 79.4$_{b}$ | 43.6$_{a}$ | 28.1$_{a}$ | 38.9$_{a}$ | 26.7$_{a}$ | 80.8$_{a}$ | 59.0$_{b}$ | 86.5$_{a}$ | 77.9$_{a,b}$ |
| Sells horticultural crops (%) | 10.1$_{a}$ | 42.7$_{b}$ | 25.5$_{a}$ | 3.1$_{b}$ | 10.6$_{a,b}$ | 5.2$_{b}$ | 49.6$_{a}$ | 33.3$_{a}$ | 43.3$_{a}$ | 35.5$_{a}$ |
| Grows cash crops (%) | 3.0$_{a}$ | 78.3$_{b}$ | 5.5$_{a}$ | 3.1$_{a}$ | 3.5$_{a}$ | 1.5$_{a}$ | 88.8$_{a}$ | 69.2$_{b}$ | 77.9$_{a,b}$ | 66.2$_{b}$ |
| *Sources of information accessed* | | | | | | | | | | |
| Source: Government extension (%) | 23.6$_{a}$ | 36.5$_{b}$ | 29.1$_{a}$ | 9.4$_{a}$ | 30.1$_{a}$ | 19.3$_{a}$ | 43.2$_{a}$ | 17.9$_{b}$ | 41.3$_{a,b}$ | 28.6$_{a,b}$ |
| Source: FIPS-Africa (%) | 19.4$_{a}$ | 22.0$_{a}$ | 20.0$_{a}$ | 21.9$_{a}$ | 21.2$_{a}$ | 17.0$_{a}$ | 25.6$_{a}$ | 30.8$_{a}$ | 19.2$_{a}$ | 15.6$_{a}$ |
| Source: Farmer group (%) | 16.1$_{a}$ | 23.8$_{b}$ | 27.3$_{a}$ | 21.9$_{a,b}$ | 15.0$_{a,b}$ | 11.1$_{b}$ | 27.2$_{a}$ | 33.3$_{a}$ | 20.2$_{a}$ | 18.2$_{a}$ |
| Source: Mass media (%) | 65.1$_{a}$ | 47.0$_{b}$ | 65.5$_{a}$ | 78.1$_{a}$ | 61.9$_{a}$ | 64.4$_{a}$ | 49.6$_{a}$ | 59.0$_{a}$ | 40.4$_{a}$ | 45.5$_{a}$ |

Note: Values in the same row and sub-table not sharing the same subscript are significantly different at $p < .05$ in the two-sided test of equality for column means / proportions. Tests are adjusted for all pairwise comparisons within a row of each innermost sub-table using the Bonferroni correction.

**Table 4 Technology adoption index by district and livelihood cluster**

| | | | Kitui | | | | Embu | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kitui | Embu | Full-time farmer | Farm-worker | Mixed | Non-farm | Full-time farmer | Farm-worker | Mixed | Non-farm |
| | n=335 | n=345 | n=55 | n=32 | n=113 | n=135 | n=125 | n=39 | n=104 | n=77 |
| Adoption index (No. technologies) | 7.70$_{a}$ | 8.98$_{b}$ | 8.20$_{a}$ | 7.06$_{b}$ | 7.94$_{a,b}$ | 7.45$_{b}$ | 9.57$_{a}$ | 7.95$_{b}$ | 9.11$_{a,c}$ | 8.38$_{b,c}$ |
| Irrigation (%) | 6.3$_{a}$ | 13.6$_{b}$ | 10.9$_{a}$ | 6.3$_{a}$ | 3.5$_{a}$ | 6.7$_{a}$ | 15.2$_{a}$ | 7.7$_{a}$ | 18.3$_{a}$ | 7.8$_{a}$ |
| Erosion control and water harvesting (%) | 93.7$_{a}$ | 63.2$_{b}$ | 92.7$_{a}$ | 100.0$_{a}$ | 96.5$_{a}$ | 90.4$_{a}$ | 68.0$_{a}$ | 53.8$_{a}$ | 63.5$_{a}$ | 59.7$_{a}$ |
| Conservation agriculture (%) | 12.8$_{a}$ | 8.1$_{b}$ | 16.4$_{a}$ | 6.3$_{a}$ | 16.8$_{a}$ | 9.6$_{a}$ | 8.0$_{a}$ | 15.4$_{a}$ | 4.8$_{a}$ | 9.1$_{a}$ |
| Intercropping (%) | 96.7$_{a}$ | 92.8$_{b}$ | 98.2$_{a}$ | 96.9$_{a}$ | 98.2$_{a}$ | 94.8$_{a}$ | 91.2$_{a}$ | 94.9$_{a}$ | 93.3$_{a}$ | 93.5$_{a}$ |
| Certified maize seed (%) | 80.3$_{a}$ | 91.6$_{b}$ | 78.2$_{a}$ | 78.1$_{a}$ | 78.8$_{a}$ | 83.0$_{a}$ | 90.4$_{a,b}$ | 79.5$_{a}$ | 95.2$_{b}$ | 94.8$_{a,b}$ |
| Selectively saves seed (%) | 72.5$_{a}$ | 73.3$_{a}$ | 78.2$_{a}$ | 87.5$_{a}$ | 68.1$_{a}$ | 70.4$_{a}$ | 79.2$_{a}$ | 87.2$_{a}$ | 66.3$_{a}$ | 66.2$_{a}$ |
| Organic fertilizer (%) | 66.6$_{a}$ | 37.1$_{b}$ | 80.0$_{a}$ | 56.3$_{a}$ | 70.8$_{a}$ | 60.0$_{a}$ | 40.0$_{a}$ | 35.9$_{a}$ | 40.4$_{a}$ | 28.6$_{a}$ |
| Chemical fertilizer (%) | 16.7$_{a}$ | 91.9$_{b}$ | 12.7$_{a}$ | 12.5$_{a}$ | 12.4$_{a}$ | 23.0$_{a}$ | 95.2$_{a}$ | 79.5$_{b}$ | 92.3$_{a,b}$ | 92.2$_{a,b}$ |
| Chemicals - excluding pesticides (%) | 8.7$_{a}$ | 23.8$_{b}$ | 16.4$_{a}$ | 12.5$_{a}$ | 4.4$_{a}$ | 8.1$_{a}$ | 24.0$_{a}$ | 15.4$_{a}$ | 26.9$_{a}$ | 23.4$_{a}$ |
| Pesticides - including storage (%) | 87.2$_{a}$ | 79.4$_{b}$ | 80.0$_{a}$ | 78.1$_{a}$ | 90.3$_{a}$ | 89.6$_{a}$ | 82.4$_{a}$ | 69.2$_{a}$ | 84.6$_{a}$ | 72.7$_{a}$ |
| Improved storage (%) | 80.3$_{a}$ | 79.4$_{a}$ | 74.5$_{a,b}$ | 65.6$_{a}$ | 86.7$_{b}$ | 80.7$_{a,b}$ | 85.6$_{a}$ | 69.2$_{a}$ | 78.8$_{a}$ | 75.3$_{a}$ |
| Post-harvest processing (%) | 33.4$_{a}$ | 59.4$_{b}$ | 56.4$_{a}$ | 31.3$_{a,b}$ | 38.9$_{a}$ | 20.0$_{b}$ | 77.6$_{a}$ | 64.1$_{a,b}$ | 50.0$_{b}$ | 40.3$_{b,c}$ |
| Improved animal breeds (%) | 8.4$_{a}$ | 52.2$_{b}$ | 12.7$_{a}$ | 0.0$_{a}$ | 12.4$_{a}$ | 5.2$_{a}$ | 57.6$_{a}$ | 33.3$_{b}$ | 52.9$_{a,b}$ | 51.9$_{a,b}$ |
| Buys animal feed (%) | 26.9$_{a}$ | 53.0$_{b}$ | 27.3$_{a}$ | 12.5$_{a}$ | 31.0$_{a}$ | 26.7$_{a}$ | 57.6$_{a}$ | 20.5$_{b}$ | 61.5$_{a}$ | 50.6$_{a}$ |
| Other animal services (%) | 79.7$_{a}$ | 79.1$_{a}$ | 85.5$_{a,b}$ | 62.5$_{a}$ | 85.0$_{b}$ | 77.0$_{a,b}$ | 84.8$_{a}$ | 69.2$_{a}$ | 81.7$_{a}$ | 71.4$_{a}$ |

Note: Values in the same row and sub-table not sharing the same subscript are significantly different at $p< .05$ in the two-sided test of equality for column means / proportions. Tests are adjusted for all pairwise comparisons within a row of each innermost sub-table using the Bonferroni correction.

Is intensification compatible with livelihood diversification? Table 5 shows regression results for determinants of technology adoption as measured by the adoption index. Model 1 captures the influence of diversification by using livelihood clusters as independent variables while Model 2 uses the Herfindahl Index. Model 1 shows that non-farm and farm-worker households had a significantly lower adoption index than full-time farmers (the comparison category). Mixed cluster households also had a lower adoption index, but this was significant only at the 10% level. Model 1 thus suggests that specialisation in farming is positively related to adoption as both non-farm and farm-worker clusters had consistently and significantly lower levels of adoption. However, full-time farmers adopt only up to one technology more than other clusters, indicating that the effect size is relatively small. Model 2 shows that the coefficient for the Herfindahl Index was negative, indicating that households with a greater variety of income sources were higher adopters. The Herfindahl Index shows that the non-farm cluster was the least diversified. When the Herfindahl Index was replaced by the share of non-farm income (not shown), the coefficient was negative and significant. Together, these results suggest that diversification out of agriculture reduced adoption. The Poisson model largely confirms the findings from the OLS models, though the mixed cluster is no longer significantly different and the Herfindahl Index is only significant at the 10% level. Other significant determinants of adoption included the tropical livestock units owned, the value of assets, distance from an all-weather road and access to electricity, all of which control for the potential effects of wealth and market access. The coefficients for all four sources of information were positive and statistically significant, confirming the importance of information for adoption. Horticulture, agroforestry or cash crop farming, were also positively correlated with adoption. Savings had a significant positive relation but access to credit was not statistically significant. Land ownership was not significantly related to adoption, suggesting that adoption was not biased towards bigger or wealthier farmers.

To test the robustness of our findings we ran the OLS model described in the previous paragraph with various alternative indicators of intensification (Table 6). We report differences between the various livelihood clusters, using the full-time farmer cluster as the category for comparison. In contrast with the insignificant differences reported in Table 3, controlling for alternative determinants of adoption shows that farm-workers and mixed households used significantly less fertilizer than full-time farmers. However, these differences were not large, only -68 kg/ha for farm workers and -36 kg/ha for mixed farm households, compared to full-time farmers, and the percentage of maize land cultivated with certified seed was not significantly different for any of the clusters. However, the difference in maize yields was both statistically significant and large. Maize yields for farm workers were 841 kg/ha lower than for full-time farmers, and maize yields for non-farm households were 461 kg/ha lower. Interestingly, yields for non-farm households were lower despite their similar use of fertilizer and certified seed as full-time farmers, and again in contrast with the insignificant differences shown in Table 3. Moreover, the difference in returns to land and labour between the clusters was both statistically significant and large. Farm-workers and non-farm households generated 1,700 USD/ha less than full-time farmers. Returns to land for mixed households were 900 USD/ha lower. As average returns to land were 2,771 USD/ha (Table 9), full-time farming was considerably more profitable than among the other clusters.

**Table 5 OLS and Poisson Regression - Dependent variable: Adoption Index (No. technologies)**

| Variables | Model 1: OLS | Model 1: Poisson | Model 2: OLS | Model 2: Poisson |
|---|---|---|---|---|
| Male head (yes=1, no=0) | -0.32598 | -0.04544 | -0.35362 | -0.04677 |
| | (0.282) | (0.063) | (0.285) | (0.063) |
| Age household head (years) | 0.00043 | 0.00000 | 0.00121 | 0.00012 |
| | (0.005) | (0.001) | (0.005) | (0.001) |
| Education head (years) | 0.00490 | 0.00057 | 0.00581 | 0.00077 |
| | (0.020) | (0.004) | (0.020) | (0.004) |
| Married head (yes=1, no=0) | 0.63921** | 0.08491 | 0.68648*** | 0.08940 |
| | (0.260) | (0.058) | (0.263) | (0.058) |
| Household size (No.) | 0.01135 | 0.00134 | 0.00681 | 0.00094 |
| | (0.033) | (0.007) | (0.033) | (0.007) |
| Dependents (%) | -0.00551** | -0.00065 | -0.00495* | -0.00059 |
| | (0.003) | (0.001) | (0.003) | (0.001) |
| Access to electricity (yes=1, no=0) | 0.33783** | 0.03676 | 0.32247** | 0.03399 |
| | (0.163) | (0.034) | (0.162) | (0.033) |
| Distance to nearest all-weather road (km) | 0.12077** | 0.01436 | 0.11346** | 0.01332 |
| | (0.057) | (0.012) | (0.057) | (0.012) |
| Current asset value (USD) | 0.00004* | 0.00000 | 0.00004* | 0.00000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Land owned (ha) | -0.04920 | -0.00520 | -0.03871 | -0.00459 |
| | (0.072) | (0.015) | (0.073) | (0.015) |
| Tropical livestock units owned (No.) | 0.16789*** | 0.01927*** | 0.17568*** | 0.02027*** |
| | (0.034) | (0.007) | (0.034) | (0.007) |
| Has credit (yes=1, no=0) | -0.12221 | -0.01685 | -0.13520 | -0.01874 |
| | (0.159) | (0.034) | (0.159) | (0.034) |
| Has savings (yes=1, no=0) | 0.48283*** | 0.05966* | 0.47509*** | 0.05871* |
| | (0.147) | (0.031) | (0.147) | (0.031) |
| Grows horticultural crops (yes=1, no=0) | 0.61302*** | 0.07471** | 0.63142*** | 0.07683** |
| | (0.152) | (0.032) | (0.153) | (0.033) |
| Grows agroforestry crops (yes=1, no=0) | 0.57837*** | 0.08308* | 0.56894*** | 0.08046* |
| | (0.213) | (0.048) | (0.215) | (0.048) |
| Grows cash crops (yes=1, no=0) | 0.43790** | 0.04894 | 0.54112*** | 0.06113 |
| | (0.209) | (0.044) | (0.209) | (0.043) |
| Source: Government extension (yes=1, no=0) | 0.36764** | 0.04313 | 0.44117*** | 0.05276* |
| | (0.146) | (0.030) | (0.147) | (0.030) |
| Source: FIPS-Africa (yes=1, no=0) | 0.56231*** | 0.06463** | 0.54499*** | 0.06338* |
| | (0.161) | (0.033) | (0.162) | (0.033) |
| Source: Farmer group (yes=1, no=0) | 0.38673** | 0.04491 | 0.36390** | 0.04175 |
| | (0.165) | (0.034) | (0.166) | (0.034) |
| Source: Mass media (yes=1, no=0) | 0.64598*** | 0.07837*** | 0.61427*** | 0.07432*** |
| | (0.135) | (0.029) | (0.136) | (0.028) |
| Cluster: Farm-worker (yes=1, no=0) | -0.93649*** | -0.11413** | | |
| | (0.240) | (0.052) | | |
| Cluster: Mixed (yes=1, no=0) | -0.29080* | -0.03024 | | |
| | (0.173) | (0.035) | | |
| Cluster: Non-farm (yes=1, no=0) | -0.67322*** | -0.07854** | | |
| | (0.186) | (0.039) | | |
| Herfindahl Index: Income diversification | | | -1.04557*** | -0.13340* |
| | | | (0.363) | (0.077) |
| District (1=Embu, 0=Kitui) | 0.52444** | 0.06553 | 0.53670** | 0.06682 |
| | (0.215) | (0.046) | (0.216) | (0.046) |
| Constant | 5.85769*** | 1.80033*** | 5.84647*** | 1.80408*** |
| | (0.473) | (0.101) | (0.498) | (0.106) |
| Observations | 680 | 680 | 680 | 680 |
| Adjusted R-squared | 0.365 | | 0.354 | |
| Pseudo R-squared | | 0.0441 | | 0.0427 |

Note: cluster comparison full-time farmer, standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

**Table 6 OLS models utilizing various indicators of agricultural intensification**

| | (1) | (2) | (3) |
|---|---|---|---|
| Models | Cluster: Farm worker (yes=1, no=0) | Cluster: Mixed (yes=1, no=0) | Cluster: Non-farm (yes=1, no=0) |
| (1) Adoption Index (No.) | -0.9365*** | -0.2908* | -0.6732*** |
| | (0.240) | (0.173) | (0.186) |
| (2) Chemical fertilizer (kg/ha) | -68.3937** | -37.5995* | -18.1215 |
| | (27.116) | (19.487) | (20.954) |
| (3) Certified maize seed (% maize area) | -5.9395 | -1.2893 | 3.2445 |
| | (4.909) | (3.528) | (3.794) |
| (4) Maize yield (kg/ha) | -840.7931*** | -201.9022 | -461.1982** |
| | (274.312) | (197.134) | (211.973) |
| (5) Land return (USD / ha) | -1,739.8252*** | -907.9936** | -1,708.2795*** |
| | (525.425) | (377.597) | (406.020) |
| (6) Labour return (USD / day) | -14.4824** | -10.0656** | -25.6750*** |
| | (6.397) | (4.597) | (4.943) |

Note: Columns present results for the livelihood cluster variables with the full-time farmer cluster as comparison category. Rows present regression models with various indicators of agricultural intensification as dependent variables. Row (1) reports, for purposes of comparison, the results found in Table 6 for the adoption index OLS model. Rows (2 - 4) report results for fertilizer and improved certified maize seed use as well as maize productivity while rows (5 - 6) show results for returns to land and labour. Regressions include all explanatory variables from Table 6 and contain 680 observations. Standard errors in parentheses (* p<0.10, ** p<0.05, *** p<0.01).

Is intensification a potential pathway from poverty? Table 7 compares income and poverty across the four livelihood clusters. Income per capita was significantly lower in Kitui than in Embu (USD 1,045 compared to USD 1,391). Consequently, poverty was also higher in Kitui, with 44% of the sample households below the poverty line compared to 33% in Embu. Results for the livelihood clusters show that income per capita was significantly higher for non-farm households in Kitui (USD 1,518) and Embu (USD 1,987). The majority of non-farm households (70%) belonged to the two highest income quartiles. For full-time farm households, income per head was considerably higher in Embu (USD 1,184) than in Kitui (USD 743). In terms of poverty, 60% of full-time farm households in Kitui lived below the poverty line, compared to 38% in Embu. Two thirds of full-time farmers in Kitui (66%) belonged to the two poorest income quartiles compared to approximately half in Embu (54%). The poorest households were farm-workers, with 91% in Kitui and 59% in Embu living below the poverty line.

**Table 7 Analysis of variance income and poverty by district and cluster**

| | | | Kitui | | | | Embu | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kitui | Embu | Full-time farmer | Farm-worker | Mixed | Non-farm | Full-time farmer | Farm-worker | Mixed | Non-farm |
| | (n=335) | (n=345) | (n=55) | (n=32) | (n=113) | (n=135) | (n=125) | (n=39) | (n=104) | (n=77) |
| *Income and poverty* | | | | | | | | | | |
| Household income (USD) | 4,677$_{a}$ | 5,053$_{a}$ | 3,789$_{a}$ | 1,617$_{a}$ | 3,805$_{a}$ | 6,493$_{b}$ | 4,532$_{a}$ | 2,397$_{a}$ | 4,589$_{a}$ | 7,870$_{b}$ |
| Income per capita (USD) | 1,045$_{a}$ | 1,391$_{b}$ | 743$_{a}$ | 391$_{a}$ | 811$_{a}$ | 1,518$_{b}$ | 1,184$_{a,b}$ | 597$_{a}$ | 1,497$_{b,c}$ | 1,987$_{c}$ |
| Poverty - total income (%) | 43.9$_{a}$ | 33.3$_{b}$ | 60.0$_{a}$ | 90.6$_{b}$ | 49.6$_{a}$ | 21.5$_{c}$ | 37.6$_{a,b}$ | 59.0$_{a}$ | 24.0$_{b}$ | 26.0$_{b,c}$ |
| Poverty - net farm income (%) | 85.4$_{a}$ | 55.7$_{b}$ | 67.3$_{a}$ | 100.0[1] | 81.4$_{a}$ | 92.6$_{b}$ | 37.6$_{a}$ | 89.7$_{b}$ | 46.2$_{a}$ | 80.5$_{b}$ |
| Poverty - net crop income (%) | 91.3$_{a}$ | 69.0$_{b}$ | 76.4$_{a}$ | 100.0[1] | 91.2$_{b}$ | 95.6$_{b}$ | 55.2$_{a}$ | 92.3$_{b}$ | 63.5$_{a}$ | 87.0$_{b}$ |
| *Income quartile* | | | | | | | | | | |
| Quartile 1 (%) | 24.8$_{a}$ | 24.9$_{a}$ | 34.5$_{a,b}$ | 62.5$_{a}$ | 26.5$_{b}$ | 10.4$_{c}$ | 27.2$_{a,b}$ | 46.2$_{a}$ | 21.2$_{b}$ | 15.6$_{b,c}$ |
| Quartile 2 (%) | 25.1$_{a}$ | 24.9$_{a}$ | 30.9$_{a}$ | 25.0$_{a}$ | 31.0$_{a}$ | 17.8$_{a}$ | 26.4$_{a,b}$ | 43.6$_{a}$ | 23.1$_{a,b}$ | 15.6$_{b}$ |
| Quartile 3 (%) | 25.1$_{a}$ | 25.2$_{a}$ | 18.2$_{a}$ | 12.5$_{a}$ | 24.8$_{a}$ | 31.1$_{a}$ | 28.0$_{a,b}$ | 7.7$_{a}$ | 31.7$_{b}$ | 20.8$_{a,b}$ |
| Quartile 4 (%) | 25.1$_{a}$ | 24.9$_{a}$ | 16.4$_{a}$ | 0.0[1] | 17.7$_{a}$ | 40.7$_{b}$ | 18.4$_{a,b}$ | 2.6$_{a}$ | 24.0$_{b}$ | 48.1$_{c}$ |

Note: Values in the same row and sub-table not sharing the same subscript are significantly different at $p< .05$ in the two-sided test of equality for column means / proportions. Tests are adjusted for all pairwise comparisons within a row of each innermost sub-table using the Bonferroni correction.

[1] This category is not used in comparisons because its column proportion is equal to zero or one.

# 4 Discussion

## 4.1 Intensification and diversification

Intensification assumes that rural households are willing to adopt new technologies. To some degree, this willingness will depend on their existing livelihood strategies. Rural livelihoods in Kitui and Embu were diverse, with full-time farming a minority occupation. The majority of rural households did not depend on agriculture for their livelihood but drew most of their income from other sources (Table 1). For most rural households, therefore, farming was a part-time occupation. Agriculture remained important to these households, however. All our sample households, irrespective of livelihood strategy, cultivated some land, grew a variety of crops and most received income from crop sales. One-third of household income for farm-worker households came from their own farm (Table 1). Similarly, non-farm households use 140-162 family labour days/year working their own farms. However, the prevalence of part-time farming raises doubts about the relevance of agricultural intensification. How compatible with livelihood diversity is a strategy for poverty reduction based on widespread adoption of new farming technology?

Not surprisingly, the most eager adopters of new technology were full-time farmers. Of the 15 technologies represented in our adoption index, they had adopted eight or nine (Table 4). This supports the argument that farm-based households are more likely to adopt as they are focussed on increasing the profitability of their farm systems (Tittonell et al., 2010). However, part-timers were not far behind. In Kitui, for example, farm-worker households had adopted seven and mixed households eight technologies, while in Embu farm-workers and non-farm households had both adopted eight. Hence, although the difference in adoption between full-timers and part-timers was statistically significant, it was small. In Embu, for instance, adoption rates between full-time farmers and farm-workers differed significantly for only three technologies, all of which required cash investment. The situation was similar for non-farm households, which revealed few significant differences with full-time farmers. This supports suggestions that off-farm income is re-invested in crop production (Freeman and Ellis, 2005; Harris and Orr, 2014; Iiyama et al., 2008; Reardon, 1997). Therefore, intensification seems to be compatible with diversification, even in regions like eastern Kenya where part-time farming is the norm.

Although all households had adopted new technology, they did not enjoy the same level of benefits. Full-time farmers in both districts managed to generate up to twice the returns to land and farm labour compared to the other three clusters. In addition, although all households engaged in agroforestry, horticulture and cash cropping, full-time farmers were more likely to sell them, particularly in Embu. Full-time farmers generated superior returns to land and labour and had higher maize yields despite similar fertilizer use and certified maize seed adoption (Table 6). While a minority of rural households made a living out of agriculture, therefore, others farmed for different reasons (Tittonell, 2007). Better-off non-farm households may feel a cultural attachment to agriculture as a way of life and may be willing to pay to maintain the family farm (Barrett et al., 2001). Others may keep one foot in agriculture to avoid becoming over-dependent on non-agricultural jobs (Banerjee and Duflo, 2007). As part-time farmers, however, the benefits they receive from new technology will be relatively small (Sumberg et al., 2004). Consequently, although technology adoption may be compatible with livelihood diversification, the benefits from adoption will vary according to the household’s level of engagement in farming. As a strategy to increase rural income, intensification is most effective when it targets full-time farmers.

How can the benefits from intensification be increased? One suggestion is farm consolidation, with a large proportion of the rural population becoming farm labourers (Vanlauwe et al., 2014). Farm-workers in Kitui and Embu had the highest poverty rates, a lower adoption index, the lowest returns and maize yields and owned less land and livestock. They persist with farming to utilise their limited assets and ensure some household food security. Increasing their numbers seems a dire prospect given the high prevalence of poverty in this group. Furthermore, because of their greater dependence on agriculture for their income, farm-workers are most vulnerable to agricultural yield fluctuations and price shocks (Barrett et al., 2005). Labour in impoverished households is sold cheaply to wealthier households, reinforcing the gap between rich and poor (Tittonell, 2014). This implies a self-reinforcing circle of unequal distribution of land and non-farm earnings with substantial wealth-differentiated barriers (Barrett et al., 2001). Social protection programmes may be a more effective strategy to assist these households than intensification (Tittonell et al., 2010).

## 4.2 Intensification and poverty

Livelihood clusters showed a welfare ordering with some enjoying higher incomes than others (Stifel, 2010). Farm-worker households had the lowest incomes and were concentrated in the two poorest income quartiles. Mixed cluster households had incomes somewhere between the high-return non-farm and low-return farm-worker clusters. This is caused by their engagement in different income generating activities with varying returns. By contrast, households in the non-farm livelihood cluster had the highest incomes. Over 40% of households in this cluster were in the top income quartile and more than 75% were above the poverty line (Table 7). This confirms the role of diversification into non-farm activities as a primary pathway from poverty (Narayan et al., 2000). Although they diversified out of agriculture, the high value of the Herfindahl Index shows that non-farm households had the least diversified incomes. Higher incomes were thus associated with specialisation into non-farm activities rather than a diversified income portfolio spread across a variety of sources.

Earlier work suggested that agricultural intensification alone could not lift smallholders above the poverty line, unless combined with diversification into non-farm activities (Harris and Orr, 2014). We explore this by comparing the percentage of households above the poverty line based on their total, farm and crop income per day per capita (Table 7). In Embu, 44% of households generated enough farm income (crop and livestock) to cross the poverty line compared with 64% of households if off-farm income was included. In Kitui, only 15% of households would have crossed the poverty line with farm income alone compared with 46% once off-farm income was taken into account. When we include only income from crops, as did Harris and Orr (2014), 31% of households in Embu and 9% percent of households in Kitui earned an income above the poverty line. On average, farm and crop income alone did not generate incomes above the poverty line.

Despite their small average farm size (1.0 ha in Kitui and 0.8 ha in Embu) many full-time farmers were able to generate quite high returns from crop production and livestock. Combined with off-farm income, this was enough for a significant share of full-time farmers to earn incomes above the poverty line. In Embu, farm income alone was sufficient to keep 62% of the full-time farmers out of poverty (Table 7). Full-time farmers in Kitui were poorer, with only 40% above the poverty line based on total income and 33% based on farm income. Crop income alone would have kept 45% in Embu and 24% in Kitui out of poverty, indicating the importance of mixed crop-livestock systems (Thornton and Herrero, 2015). Recall that full-time farmers in both districts had the highest adoption rates for new technology. The results thus indicate that intensification has potential to reduce poverty for full-time farmer households.

### 4.3 Agro-ecology and market access

Although Kitui and Embu are both rainfed farming systems, the contrast between them is striking. Full-time farmers in Embu were noticeably more commercialised than in Kitui, with a higher share of income from crop sales (45% compared to 23%) (Table 1). This can be correlated with the more widespread production of horticultural and cash crops, together with higher use of chemical fertiliser (Table 3). Clearly, farmers in Embu benefit from higher and more reliable rainfall, which provides two full growing seasons. Combined with fertile soils, better market access and greater access to state extension services, this has enabled full-time farmers in Embu to earn almost twice the returns to land than their counterparts in Kitui. High-value cash crops, horticulture and dairy farming are characteristic of households above the poverty line (Radeny et al., 2012). Similarly, dynamic agricultural regions like Embu exemplify a virtuous cycle, with technology adoption leading to agricultural surpluses and opportunities for trade that stimulate the non-farm economy (Haggblade et al., 2010).

By contrast, the benefits from intensification in low-potential zones like Kitui appear more restricted, with rural households forced out of farming into low-return non-farm activities or farm labour. Although households in Kitui cultivated more land and had more available labour than in Embu, this was insufficient to compensate for inferior rainfall and market access. Households in semi-arid systems are more reluctant to adopt new technology because of the higher risk of crop failure (Ogada et al., 2010). In addition, smallholders in remote disadvantaged areas of Kenya are faced with higher input costs, lower output prices, fewer buyers and weak access to extension (Chamberlin and Jayne, 2013). Together with lower agricultural potential, these factors reduce the incentives for the adoption of new technology and help explain the lower adoption index in Kitui. Favourable soils and rainfall can tilt the scales sufficiently to make full-time farming a profitable occupation associated with a higher standard of living. The contrasting tale of these two regions thus suggests that it is unwise to generalise about ‘rainfed agriculture’.

## 5 Conclusions

The ability of smallholder agriculture in SSA to deliver widespread poverty reduction is the subject of debate. In particular, the relative merits of agricultural intensification or livelihood diversification as pathways from poverty require critical scrutiny. On farms of just 1 ha, how realistic is the hope that intensification can generate incomes above the poverty line?

A comparative study of high-and low-potential agricultural zones in eastern Kenya showed that full-time farming was a minority occupation; the majority of households were part-time farmers who received most of their income from farm labour or non-farm activities. Although full-time farmers had adopted a greater number of new technologies, part-timers had also adopted. Intensification was therefore compatible with livelihood diversity. Consequently, ‘intensify’ or ‘diversify’ is not a binary choice, as these two livelihood strategies are best seen as complementary. Among part-timers, agriculture may primarily be a source of household food security, rather than cash income. Given the risk of relying on markets for staple food supply and the scarcity of alternative employment opportunities, agriculture remains essential for rural households, irrespective of their dominant livelihood strategy. However, the returns to intensification were much lower for part-timers, particularly farm-worker households.

Although households that had diversified into non-farm activities had higher average incomes, a high share of full-time farmers in the high-potential zone had incomes above the poverty line. This was facilitated by two growing seasons, high value cash crops and horticulture, dairy farming and good market access. Thus, intensification may be a viable pathway from poverty for rainfed agriculture in high-potential environments. For full-time farmers in a low-potential environment, however, agricultural technologies offer reduced benefits, making intensification a riskier strategy than diversification into non-farm activities. Once again, intensification will have limited benefits for the poorest farm-worker households with fewer assets.

The contrasting benefits from intensification between high- and low-potential agricultural zones suggest the need to avoid generalisations about rainfed agriculture and to evaluate intensification across a spectrum of rainfed farming systems. The semi-arid and sub-humid zones compared here are at opposite ends of this spectrum. Further research is required to determine how much the benefits from adoption vary across these systems. The heterogeneity of farming systems and variations in market access suggests that these benefits vary widely, but that under favourable conditions new technology has the potential to offer full-time farmers a pathway from poverty.

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# Appendix

TABLE 8 DESCRIPTIVE STATISTICS FOR VARIABLES USED IN THE REGRESSION MODELS

| Variables | (1)<br>N | (2)<br>Mean | (3)<br>St. Dev. |
|---|---|---|---|
| Adoption Index (No.) | 680 | 8.350 | 2.064 |
| Chemical fertilizer use (kg/ha) | 680 | 108.0 | 206.6 |
| Certified maize seed (% maize area) | 680 | 77.39 | 37.13 |
| Maize yield (kg/ha) | 680 | 1,905 | 1,938 |
| Land return (USD / ha) | 680 | 2,771 | 3,941 |
| Labour return (USD / day) | 680 | 18.93 | 47.04 |
| Male head (yes=1, no=0) | 680 | 0.824 | 0.382 |
| Age household head (years) | 680 | 50.16 | 15.16 |
| Education head (years) | 680 | 7.644 | 4.029 |
| Married head (yes=1, no=0) | 680 | 0.778 | 0.416 |
| Household size (No.) | 680 | 4.760 | 2.109 |
| Dependents (%) | 680 | 37.89 | 25.82 |
| Access to electricity (yes=1, no=0) | 680 | 0.300 | 0.459 |
| Distance to nearest all-weather road (km) | 680 | 0.620 | 1.166 |
| Current asset value (USD) | 680 | 1,826 | 3,454 |
| Land owned (ha) | 680 | 0.927 | 1.088 |
| Tropical livestock units owned (No.) | 680 | 1.721 | 2.286 |
| Has credit (yes=1, no=0) | 680 | 0.229 | 0.421 |
| Has savings (yes=1, no=0) | 680 | 0.690 | 0.463 |
| Grows horticultural crops (yes=1, no=0) | 680 | 0.569 | 0.496 |
| Grows agroforestry crops (yes=1, no=0) | 680 | 0.876 | 0.329 |
| Grows cash crops (yes=1, no=0) | 680 | 0.412 | 0.493 |
| Source: Government extension (yes=1, no=0) | 680 | 0.301 | 0.459 |
| Source: FIPS-Africa (yes=1, no=0) | 680 | 0.207 | 0.406 |
| Source: Farmer group (yes=1, no=0) | 680 | 0.200 | 0.400 |
| Source: Mass media (yes=1, no=0) | 680 | 0.559 | 0.497 |
| Cluster: Full-time farmer (yes=1, no=0) | 680 | 0.265 | 0.442 |
| Cluster: Farm worker (yes=1, no=0) | 680 | 0.104 | 0.306 |
| Cluster: Mixed (yes=1, no=0) | 680 | 0.319 | 0.466 |
| Cluster: Non-farm (yes=1, no=0) | 680 | 0.312 | 0.464 |
| Herfindahl Index: Income diversification | 680 | 0.481 | 0.185 |
| District (1=Embu, 0=Kitui) | 680 | 0.507 | 0.500 |