Road improvement enhances smallholder productivity and reduces forest encroachment in Ghana ☆

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ARTICLE INFO

ABSTRACT

Agriculture employs about 70% of the active labour force, yet contributes only 30% to the Gross Domestic Product (GDP) of Sub-Saharan Africa. About 60% of African farmers cultivate mainly for household consumption on 2–2.5 ha of land and depend upon roads to access local and regional markets. Forest encroachment by smallholder farmers is a major cause of deforestation in Africa. We used regression analysis to determine the degree to which road improvement influenced farm size, forest encroachment and market participation in rural Ghana. We obtained data on household size and characteristics and farm plot size from 300 farmers in 10 communities. Farms accessible by improved roads had stable or slightly declining areas under cultivation. Improved roads led to better market integration, more use of farm inputs and higher yields. Farmers in areas with unpaved roads used fewer inputs, had less market penetration and were forced to encroach on forests for additional farmland to increase production. Our evidence suggests that linking rural people more efficiently to markets by improving roads will encourage commercial farming and reduce farm expansion into forests. Improved agriculture alone will not limit forest encroachment. Enforcement of forest protection regulations will also be needed to restrict encroachment.

1. Introduction

Agriculture is an important economic sector in Africa. About 70% of the active labour force in Sub-Saharan Africa (SSA) are farmers practicing subsistence farming mostly for household consumption (Food and Agriculture Organization (FAO, 2012). About 60% of farmers in SSA consume their own farm produce partially or entirely. Almost 75% of cereals and all root crops consumed in Africa are produced by both small- and large-scale farmers (Alliance for a Green Revolution in Africa (AGRA, 2013). Agriculture in Africa is constrained by poor infrastructure, especially poor quality and extent of roads, which increases the prices of inputs such as fertilizers and limits access to markets for farm produce. Poor road networks are obstacles to farmers' technology uptake, training, and education and these factors combine to limit innovation in farming (Badu et al., 2013). In Africa, roads are the main means through which farmers transport their produce to market (Angmor, 2012; Bafoil and Ruiwen, 2010). Farm size and the integration of farms into the cash economy are influenced directly by roads that connect farmers to markets (Amadi, 1988). However, the degree to which improved roads influence farm size and commercialization of agriculture varies from place to place, and few empirical studies have

been published (Amadi, 1988; Yamauchi, 2016). This research statistically tests the degree to which improved roads influence farm size, which has been identified as a proxy for deforestation (Gibbs et al., 2010; Laurance et al., 2014), and market participation in rural Ghana.

Global population is projected to exceed 9 billion by 2050 at which time Africa is expected to have 25.5% of the world's people (FAOSTAT, 2015). Some authors predict that global food demand will increase by 70–110% during this period as a result of population growth and changed diets (e.g. Laurance et al., 2014). Other authors have suggested that up to a billion hectares of land would need to be converted to agriculture by 2050 to meet this growing food demand (e.g. Edwards et al., 2014). Agricultural expansion is portrayed as a major threat to tropical forest conservation (Laurance et al., 2014). However, agricultural production could increase through the use of improved seeds and inputs, introduction of new farming techniques that are resistant to varied climatic conditions, and improved transport (Sayer and Cassman, 2013). Food needs could be met by producing more food on existing farmlands using modern agricultural techniques (Alliance for a Green Revolution in Africa (AGRA, 2013). Improved transport, especially roads, could make a major contribution to facilitating farm productivity enabling food needs to be met without increasing the need for
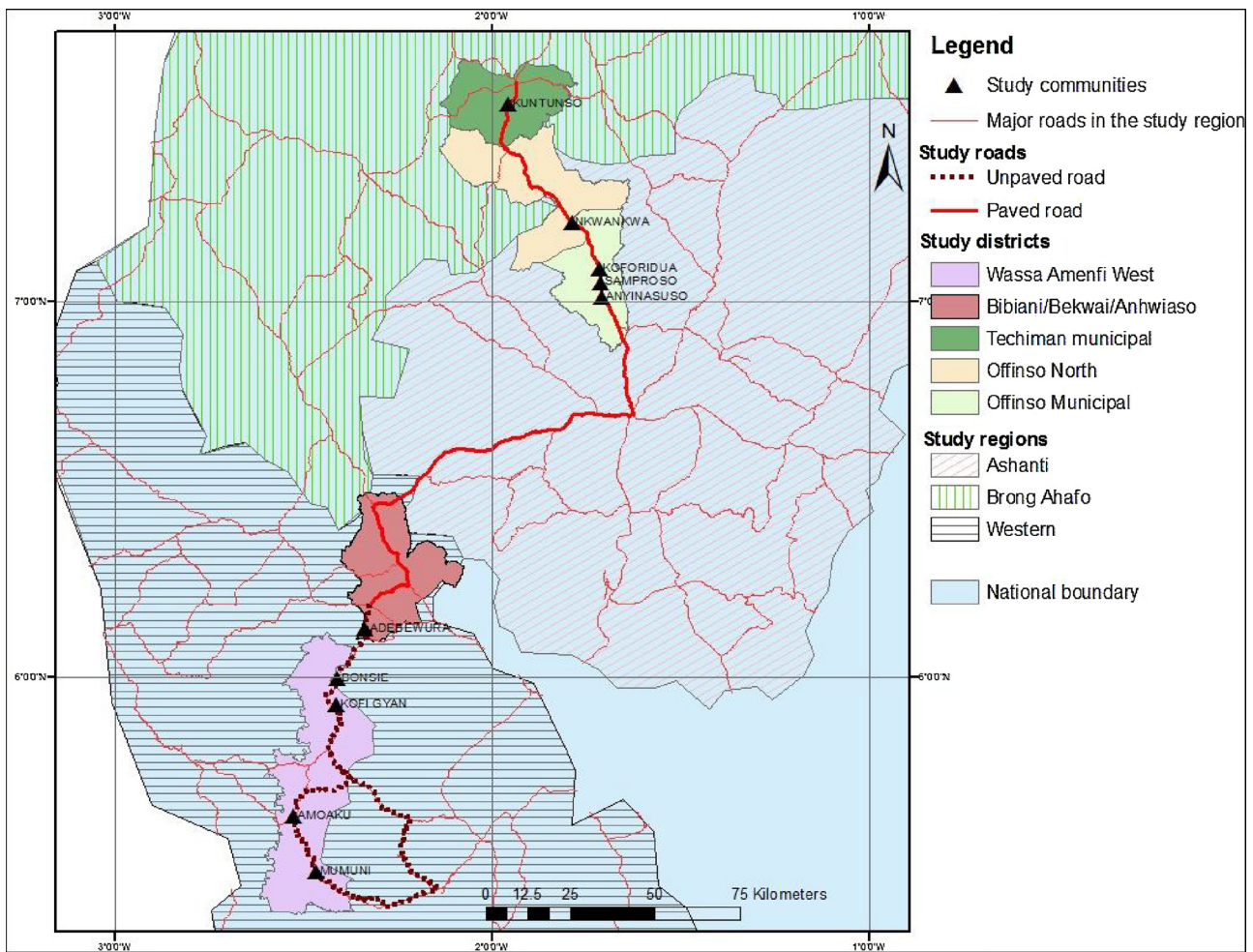

Fig. 1. Study regions, districts, and communities in Ghana.
Source: Resource Management Support Center, Forestry Commission of Ghana, 2015.

additional land (Amadi, 1988; Yamauchi, 2016). The degree to which improved roads influence farm size and market connectivity could be a major determinant of future demand for land. Farm size and productivity will determine the future of Africa's forests because most farmlands were initially forests; expanding agricultural land in forest frontiers would mean loss of the remaining forests and biodiversity (Gibbs et al., 2010).

Farm size dynamics are linked to the household life cycle (HLC); smallholder households with young age structures farm smaller plots of land (Perz et al., 2006). The HLC theory holds that farm sizes initially increase as family size increases and then decrease as land is sub-divided to meet the needs of grown children (Leonard et al., 2011). Many young farmers with small household sizes and less capital migrate to new farming areas to farm on initially small land parcels. These farmers expand their farms as their household sizes expand. Farm sizes begin to decline as household members grow and leave to start their own farms and families. The presence of a successor influences the current farmer's decision to maintain, reduce, or transfer farmland to other farmers. Farmers without a successor often retire on their farm, gradually dis-investing and reducing farm size (Van Vliet et al., 2015). Migration to cities and employment in manufacturing and services reduce the trend for farm subdivision.

The HLC theory does not address the question of how other factors such as access to improved roads and farm inputs influence farm size. Neither does it address the effects of farm expansion on forests. Limited access to inputs resulting from financial constraints and lack of non-farm income could lead to the persistence of subsistence farming (Van

Vliet et al., 2015). Rural areas with high transport costs resulting from, among other factors, unimproved roads, tend to have small farms and practice subsistence farming (Gockowski et al., 2014; Hazell et al., 2010). In some SSA countries, the area under cultivation expanded by 50% between 1990 and 2011 (Alliance for a Green Revolution in Africa (AGRA, 2013) due to the growing population of farmers. However, increasing demand for land is leading to declines in farm size and farmers have little option other than continuing subsistence cultivation.

Subsistence farmers suffer financial and agricultural input constraints, which prevent them from intensifying their production. Most subsistence farmers rely on forests as land banks and achieve increased productivity due to the fertility of the soil in freshly cleared areas (Owubah et al., 2000). Large household size often exacerbates this problem (Wiggins, 2009). Evidence however shows that access to improved roads increases market integration by enabling smallholder farmers to transport a larger proportion of their produce to markets (Hazell, 2013) the income from which can be used to intensify farming. Many studies have shown that road condition, distance to market, travel time to market, household size, labour availability, and farming experience, influence the transition to commercial agriculture (Ouma et al., 2010; Sebatta et al., 2014).

Previous research has related farmers' market participation to road distance and condition by arguing that farmers in the hinterlands with poor or no roads fail to commercialize their produce due to high transport costs especially during the wet seasons (Amadi, 1988; Ouma et al., 2010; Sebatta et al., 2014). Road quality is also known to influence agricultural intensification and when combined with the

enforcement of forest protection laws could reduce the threats to forests (Angmor, 2012; Christ and Ferrantino, 2011). However, a relationship between market participation and improved roads is yet to be statistically established in Ghana. This research examines the intensity of the effects of roads' condition on market participation and farm size variations in rural Ghana.

2. Materials and methods

We studied two areas in rural Ghana from February 2015 to August 2015. In the first area, communities had roads that were paved and in the second area, roads were unsealed. Aside from the road condition that distinguished the two areas, both areas had similar environmental, social, and economic characteristics. Both areas had fertile land and favourable climatic conditions for farming. The main economic activity was farming and the farmers produced for both market and household consumption. Both areas' farmers practiced rain-fed agriculture. The same crops were grown in both areas although cocoa was grown more in the area with unsealed roads, and the farmers practiced similar farming systems. The research covered five districts in three regions of Ghana (Fig. 1).

These districts were selected because they contain some of the major agricultural production corridors in Ghana. They produce various food and commodity crops both for household consumption and regional and national markets. Three of the five districts (Offinso North, Offinso Municipal, Techiman Municipal) were connected by a 206.7 km length of paved road while the other two were linked to each other by a 226.9 km of unsealed road (the Western region section of the study area, see Fig. 1). We sampled and surveyed 10 communities from the selected districts and compared five villages along the unimproved roads with five along the paved roads (see S1).

About 70% of the active labour force in both study areas were farmers (Ghana Statistical Service (GSS, 2013). A sample of 269 farm households was selected in order to allow statistical inferences at the 95% confidence level (Krejcie and Morgan, 1970) (see Appendix). Samples of 30 farmers (which is above the minimum sample for each community) from each of the 10 communities (i.e. 300 farmers) were selected to facilitate comparative analysis between the two types of communities. Thus, 150 (both male and female) respondents were interviewed in each study area (see S1). The respondents were selected in such a way that they cover the entire community.

The data obtained from the farmers included household demographics, farming operations, farm produce marketing, number of non-farm employments in which a farmer engages, travel time to markets and road distance to the nearest central market (see S2). Total farm size was calculated by adding the sizes of the individual plots each farmer was cultivating. Net farm income was obtained by deducting the overall expenses on farm (cost of: fertiliser, weedicides, pesticides, hired labour, and transport) from the gross farm income. Gross farm income was obtained by adding the prices of the total output sold which was cross-checked with the actual prices from the market. It was difficult getting accurate information on prices of produce sold by the farmers due to differences in market locations, daily variations in prices, and variations in where the farmer sold their produce. However, we managed to get approximate estimates through averaging the figures from different market locations the farmers patronised.

Road distances from each community center to the market, and from each farmer's house to the community center were recorded using a GPS device. These distance measurements were used to compute the distance from each farmer's house to the nearest market. Information on the time taken by each farmer to reach the market was provided by farmers and verified using the average of 14 different travel times recorded by the interviewers in each community. The travel time reported by each farmer was rounded to the nearest travel time recorded by the interviewers in each community such that each farmer had a unique mean travel time from house to market, regardless of whether the

farmer used the market. Each community used a single road to access the market so no confounding factors such as travelling on a different road were encountered to influence road quality measurements. Road quality was assessed as the average speed travelled by a car and the time required to access the nearest market (Yamauchi, 2016). Absolute distances from the farmers' house to the market were used to control for the fact that distant communities and close communities may differ in many ways other than road quality.

K-means cluster analysis was used to obtain the similarities and differences among the farmers and the variables that influenced the variations (Emtage et al., 2006). We used three distinct clusters and employed a maximum of 10 iterations and convergence criterion of zero to categorise the farmers based on the study variables. We used multiple regression analysis to test the effect of road quality on farm size and market participation net of all other household and non-household factors. Prior to running the regression tests, the data were checked for normality and homogeneity of variance and the data that required correction were log-transformed (Zar, 1999). The models were then checked for multiple collinearity problems using collinearity statistics (Variance Inflation Factor, and tolerance). Multiple collinearity was not a problem as the highest VIF was 1.8, less than the critical value of 10 and the lowest tolerance was 0.7 (Gujarati and Porter, 2009).

3. Results

Almost all the farmers had similar characteristics for the variables measured except for road quality, travel distance to market, years of farming, and proportion of farm produce sold per cropping season (see Table 1). Types 1 and 2 farmers in Table 1 for instance are similar in terms of road quality, distance to market and percentage sales while type 3 farmers vary in terms of the aforementioned variables. For the purpose of this research, types 1 and 2 farmers can be termed as those with access to improved roads who travel shorter distances to markets and sell majority of their farm produce. Type 3 farmers are farmers with access to unimproved roads who travel longer distances to markets but sell less proportion of their farm produce.

Three-quarters (75%) and 23% of the farmers along the improved and unimproved roads respectively are migrants from other parts of Ghana. Resident farmers at both improved and unimproved road areas own freehold land through inheritance. Migrants that farm along the improved roads do not own their farmlands. They cultivate on lands leased from local residents either through sharecropping or annual payment agreement. All the migrant farmers in the hinterlands own some farmlands but without official documentation confirming their ownership rights. The land ownership process in the hinterlands is that, first, the resident land owner gives their land to the migrant farmer on condition that the farmer will grow cocoa on the entire land. The Western region of Ghana is noted for its cocoa production, hence, the

Table 1
Economic and demographic characteristics of the farmers showing their dissimilarities.

Cluster variables	Means of variables		
	Type 1	Type 2	Type 3
Road quality (km/h)	70.09	68.98	35.01
Average distance to market (km)	9.05	8.55	16.56
Total farm size in 2014 (ha)	2.9	5.0	4
Years of farming	10	27	15
Percentage sales per cropping season	83.0	78.0	31.0
Labour hired per cropping season	4	6	4
Farmer educational level (grade completed)	6	6	4
Number of crops grown	3	3	3
Number of economic activities per farmer	3	4	2
Number of cases (n = 300)	88	62	150

Source: Cluster analysis results from survey data, June 2015.

Table 2
Regression results showing the extent to which roads and other factors correlate with farm size expansion.
Source: Regression results from survey data, June 2015.

Predictor variables	Standardised coefficients (Degree of influence on farm size)	P-values
Average distance to market (km)	0.077	.139
Household size	−0.037	.524
Household labour	0.071	.197
Labour hired per cropping season	0.214	.000***
Frequency of labour hired	0.089	.058
Years of farming	0.346	.000***
Non-farm employment per farmer	−0.036	.496
Number of plots farmed as at 2014	0.334	.000***
Percentage sold per cropping season	0.132	.012**
Road quality (km/h)	−0.151	.013**

Dependent variable: farm size (ha)
$F_{(10,279)} = 21.214$, $P < 0.05$, $R^2 = 0.432$, $N = 289$

*** Significant at $p < 0.005$.

** Significant at $p < 0.05$.

farmers always meet this condition. According to the farmers, they interplant the cocoa seedlings with food crops so that the food crops will provide shade to the young cocoa seedlings. The cocoa trees take approximately 5 years to mature. After the first and second harvest of the cocoa pods, the landowner divides the entire cocoa farm into two and gives half to the migrant farmer as his property.

3.1. Influence of improved roads on farm size

Various factors influenced farm size. From Table 2, five of the predictors had significant correlation with farm size ($F_{(10,279)} = 21.214$, $P < 0.05$, $R^2 = 0.432$, $N = 289$). Despite road quality being the fifth significant predictor, it was the only variable in the model that reduced the rate of farm expansion (see Table 2). Labour usage, years of farming, and number of plots possessed corresponded to the HLC theory; road quality however correlated negatively with farm size ($t = -2.449$, $p < 0.05$, $p = 0.01$).

A comparative analysis of the trend in farm expansion showed that since the beginning of farming, 35% of the improved road farmers had not expanded their farms whereas 66% of the hinterland farmers had expanded their holdings (Fig. 2).

Prior to the year 2000, the mean size of a hinterland farm was 3.7 ha

Table 3
The rate at which farm sizes have declined in areas with and without improved roads before and after the year 2000.
Source: Authors' field survey, June 2015.

Changes in farmlands		N	Min.	Max.	Sum	Mean
Overall farmlands (ha)	Total	300	0.4	20.6	1168.3	3.89
	Improved road	150	0.4	20.6	570.6 (48.8%)	3.80
	Unimproved road	150	0.8	10.1	597.6 (51.2%)	3.98
Farmlands before 2000 (ha)	Total	115	0.4	20.6	472.5	4.11
	Improved road	56	1.2	20.6	256.2 (54.2%)	4.58
	Unimproved road	59	0.4	9.7	216.3 (45.8%)	3.67
Farmlands (2000–2014) (ha)	Total	242	0.4	17.4	695.8	2.88
	Improved road	116	0.4	17.4	314.4 (45.2%)	2.71
	Unimproved road	126	0.8	10.1	381.3 (54.8%)	3.03

while that of an improved road farm was 4.6 ha. By 2014, the mean farm size had declined by 18.9% and 45% for hinterland and improved road farmers respectively. Although this confirms that mean farm sizes are declining in Africa (Masters et al., 2013), farm sizes of improved road farmers were declining more rapidly than those of hinterland farmers (Table 3).

Although other factors might account for farm size dynamics (as presented in Table 2), road quality is a significant factor that reduces the rate of farm expansion, all other things being equal.

3.2. Influence of improved roads on commercial farming

Road quality strongly correlated with increasing farmer's market participation ($t = 6.869$, $p < 0.005$, $p = 0.000$). Net farm income some of which is used to purchase farm inputs was the second highest influential factor to commercial farming.

Some farmers grow only cocoa- a cash crop which must be processed industrially before it can be consumed. When we exclude these farmers, only one hinterland farmer sold almost all the farm produce he harvested from the major crops he grew while 37% of the improved road farmers sold all their farm produce. While 26% of food crop farmers in the hinterland consumed all their farm produce, only 2% of the improved road farmers did so. When we combined all the farmers (Fig. 3), more farmers along improved roads than farmers in the hinterland commercialised their farm produce. The principle cash crop
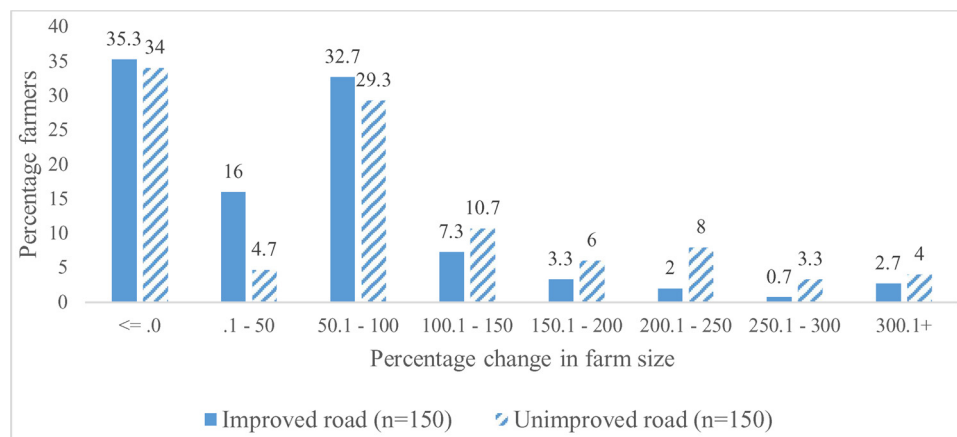

Fig. 2. The extent to which farmers with and without improved roads have expanded their farms since the start of farming.
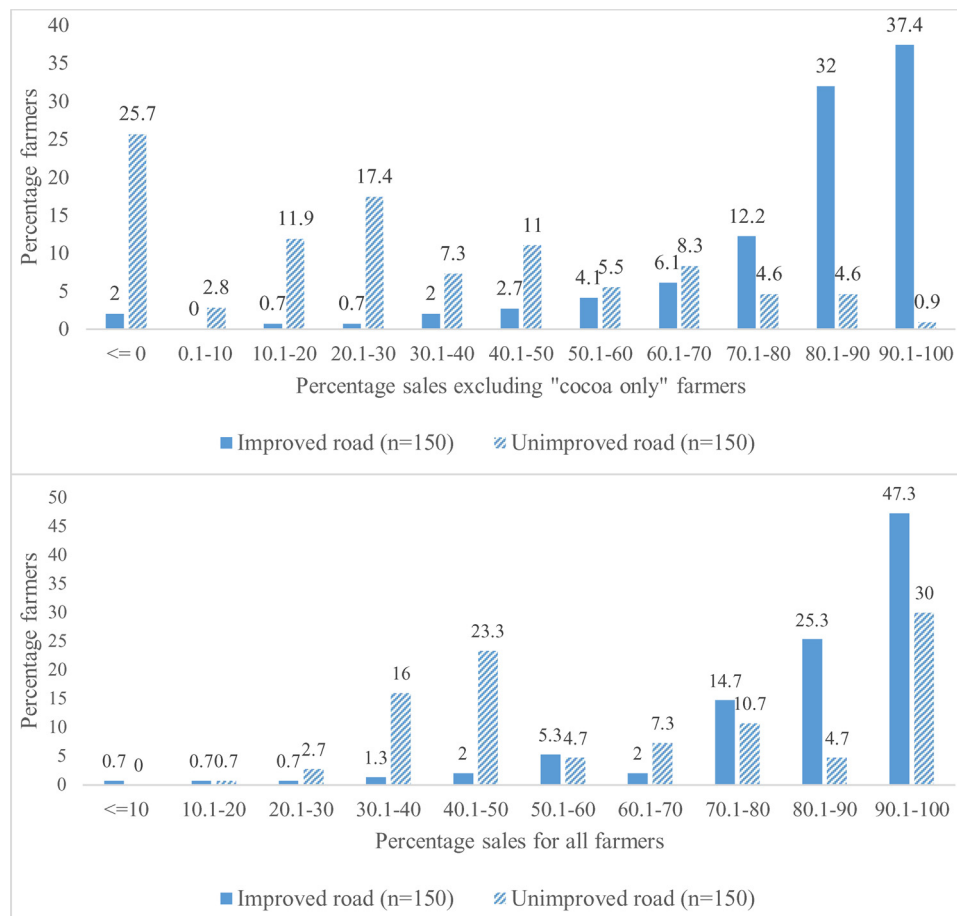Source: Authors' field survey, June 2015.

Fig. 3. Percentages of crops sold in relation to road quality.
Source: Authors' field survey, June 2015.

grown by hinterland farmers was cocoa; everything else was grown for consumption.

Improved roads provide easier access to markets for famers. These markets are located alongside the main road and vehicles pass frequently, often stopping to buy agricultural produce before they continue their journey. Improved road farmers therefore have access to both daily and weekly markets. This encourages the farmers to sell most of their produce regardless of farm size and engage in other non-farm economic activities along the road. While 78% of improved road farmers engaged in two to four economic activities, 65% of the farmers in the hinterland relied solely on farming and 35% had only one additional non-farm economic activity. Non-farm income contributed 45% to the income portfolio of the improved road farmers as compared to 10% of the hinterland farmer. The hinterland farmers only have access to weekly markets, with a mean distance of 29 km away from their communities. Vehicles move at approximately 34 km/h due to the nature of the road (Fig. 4). Once a farmer misses the last vehicle, they must wait until the next market day, a situation that does not favor sale of perishable farm produce.

4. Discussion

Improved roads have the capacity to decrease the rate of farm expansion since farmers do not have to depend solely on natural soil fertility to increase agricultural production. Improved road farmers have access to fertilizers and pesticides since they are able to earn more income from the daily sales of their farm produce. Improved roads increase the probability that farmers will market their produce irrespective of farm size.

4.1. Effects of roads on farm size

Evidence from other parts of Africa shows that farms in accessible areas are relatively larger and more integrated into markets (Amadi, 1988; Masters et al., 2013; White and Roy, 2015). Road improvement has shown to lead to larger farms that are more productive. This contrasts with the situation described in this study where farms are larger in the hinterlands than in the improved road zones and the rate at which farms expand is higher in the hinterland than the accessible areas. The explanation for this unexpected finding is that farmers in Ghana are migrating to improved road areas with good market access (Kuemmerle et al., 2013). This research has shown that there are more migrant farmers along improved roads than unimproved roads. These migrants do not own land but cultivate land leased from local residents.

As more farmers move into the accessible areas as compared to relatively inaccessible areas, competition for land intensifies and leased plots become smaller since only finite areas of land are available (Table 3). In the hinterlands however, farmers sharecrop land owned by local inhabitants and intercrop cocoa with food crops. The standard arrangement allows them to retain ownership of half of the land when the cocoa trees reach maturity. Hinterland farmers grow food crops mainly for consumption and when the cocoa canopy closes, they are obliged to seek new land to cultivate food crops. This practice of sharecropping is driving the expansion of farms into forests and contributes to deforestation in Ghana (Damnyag et al., 2011). It is the off-reserve areas that suffer from farm expansion since their protection is not as strict as protected forest reserves.

Security of land tenure is weaker in the hinterlands than in the improved road areas. In Ghana, there are three main land tenure

Fig. 4. 206.7 km length of improved road (the 2 photos at the bottom) connecting Offinso North, Offinso Municipal and Techiman Municipal and 226.9 km stretch of unimproved road (the 2 photos on the top) connecting Wassa Amenfi West and Bibiani/Bekwai/Anhwiaso districts.
Source: Authors' field survey, June 2015.

systems: public, stool, and freehold lands. The lands in both improved road and hinterland areas are mainly freehold and individual families have title. Some land is administered under the "stool" system where it is allocated by traditional leaders. Resident farmers in both areas own freehold land through inheritance. Before freehold land is transferred to a new owner, the land has to be registered in the new owner's name (Obeng-Odoom, 2012). All the migrant farmers in the hinterlands own farmlands but none of them had official documentation confirming their ownership rights; this makes it difficult to prove ownership, especially when the owner dies. Farmers who need more land for food crops due to the cocoa canopy shading-out subsistence crops are obliged to encroach adjoining off-reserve forest. Forest protection laws, especially off-reserves, are difficult to enforce in hinterland areas in Ghana (Damnyag et al., 2011). Conversely, none of the migrant farmers in the improved road areas have title to their farmland. These farmers are land insecure; they either sharecrop or hire the land annually for farming. This explains why they grow only annual marketable food crops. The farming practices and the land tenure complexities appears to determine the rate and extent at which forests are converted to farms in Ghana.

The improved road farmers rarely relied solely on agriculture for their livelihoods, unlike the farmers in the hinterland. Reliance on subsistence crops exerts more pressure on adjoining forest for fertile land (Gibbs et al., 2010; Owubah et al., 2000). The presence of the improved roads enabled the farmers to participate in other businesses. The livelihoods of the improved road farmers are more secure as they have alternative economic activities during the non-farming season. Improving roads in agricultural areas therefore promote livelihood diversification, enhance food security, and serve as a pathway out of poverty (Foley et al., 2011). Improving roads could minimize threats to forests and biodiversity in the medium to long term provided the enforcement of forest protection laws is strengthened. The tendency for farms to decrease in size in improved road areas can be a short-term phenomenon. As the farmers in these areas gradually accumulate capital, they will be able to purchase land from neighboring farmers and a scenario for increased farm size will materialize (Masters et al., 2013).

4.2. Influence of roads on commercialization of farming

Commercial farming is mostly linked to large farms as farmers produce beyond their households' consumption level (Sebatta et al., 2014); however, there are other more significant factors influencing the shift to commercial farming than farm size. Improved roads, access to farm inputs and farm profitability all drive market integration (see Table 4). Improved roads provide a ready market for farm produce irrespective of farm size. Although, the improved road farmers have relatively small farms (see Table 3), they sell 84% of their farm produce compared to only 31% for the larger-scale hinterland farmers. This suggests that improved roads could significantly increase smallholder farmers' income (t = 3.892, p < 0.005, p = 0.000). Hinterland farmers rarely market any produce other than cocoa due to high transport costs resulting in little or no profit (Ouma et al., 2010). For instance from the survey, it was discovered that transporting 50 kg bag of maize over the same road distance would cost a hinterland farmer

Table 4
: Regression results showing the extent to which roads and other factors influence farmers to engage in commercial farming.
Source: Regression results from survey data, June 2015.

Predictor variables	Standardised coefficients (Degree of influence on market retail)	P-values
Average distance to market (km)	− 0.063	.283
Household size	− 0.099	.105
Household labour	− 0.080	.201
Net farm income for 2014	0.399	.000***
Total farm size in 2014	0.269	.000***
Number of plots farmed as at 2014	− 0.158	.007
Non-farm employment (No.)	0.015	.798
Farm inputs used (amount)	0.297	.004***
Road quality (km/h)	0.433	.000***
Dependent variable: Farmers' market participation		
$F_{(9281)}$ = 11.120, P < 0.005, R^2 = 0.263, N = 290		

*** Significant at p < 0.005.

three times as much as transporting the same produce on an improved road. High transport costs and post-harvest losses from untimely marketing of perishable food crops constrain hinterland farmers to subsistence cultivation (Barrett, 2008) and cocoa production. Agriculture in the hinterlands could be transformed through improved roads and contrary to some published claims (e.g. Laurance, 2013) could reduce agricultural encroachment into forest areas, when it is combined with regulations to restrict access to those forest areas.

Access to markets is important both for the sale of farm produce and for the purchase of farm inputs. Agricultural transformation in this part of Ghana appears to be strongly linked to improvement of roads. Improved road farmers are able to commercialise their farm produce and farm inputs allow them to produce more. No improved road farmer travels more than 10 km to access farm inputs while hinterland farmers have to travel up to 50 km. Second, the improved road farmers combine farm and non-farm income to buy inputs. With the exception of larger cocoa farmers, no hinterland farmer applies inputs to food crops because they could not afford to do so. Their subsistence cultivation does not provide any income to purchase farm inputs. The only means of increasing production is to expand farms into forests (Gibbs et al., 2010; Owubah et al., 2000). Improving existing roads could generate non-farm employment opportunities leading to diversification of income sources, some of which could be used to intensify farming thereby sparing forest and biodiversity (Perz et al., 2012).

5. Conclusion

Farm expansion does not necessarily increase production, and large farms do not necessarily provide higher yields. This study suggests that agricultural intensification increases production irrespective of farm size. The surplus produce can then be marketed using the improved road system. Improved roads will allow hinterland farmers to transform from subsistence to commercial farming and attract more investors thereby creating more non-farm jobs. Consequently, farmers would no longer need to depend solely on farm produce for their livelihoods but would be able to derive income from non-farm employment. Agricultural extension officers would also be able to visit farmers via improved roads. Farmers' access to improved roads and knowledge about modern farm technology would enhance the transition from subsistence to commercial farming, hence leading to agricultural transformation.

New road construction especially at forest frontiers poses a threat to tropical nature but improving existing roads provides wide range of benefits to farmers and communities. This study suggests that linking existing rural populations in Ghana more efficiently to markets by improving the existing roads will reduce the need for forest conversion that farmers rely on for fertile land, thereby reducing the rate of deforestation. This will be made more likely through building consensus on conservation goals and promoting collaborative governance for rural landscapes. Ultimately, forest conservation will only succeed when farmers' livelihoods are improved (Sayer and Cassman, 2013; Sayer and Collins, 2012; Sayer et al., 2015). We recognise that other factors such as land tenure arrangements, farming systems dynamics, and utilisation of modern farm technology will also influence farm size and commercialization. Road improvement is a necessary but not sufficient factor in reducing pressure for forest encroachment. Ultimately, the stabilisation of forest areas will depend upon progress on a broad range of governance and economic attributes. Secure land tenure, effective forest management institutions and improved farm productivity will all be needed to achieve broad-based forest protection goals and farmers' livelihood development.

Declaration of interest

None.

Appendix A

Sample size calculation
$s = [z^2*N*P (1-P) / [e^2*(N-1) + z^2*P (1-P)]$, where:
s = sampled farmers;
N = total farmers in the study area
z = standard score at specific significant level;
P = probability of selecting a farmer
e = error margin
$s = [1.96^2*1612*0.7 (1-0.7) / [0.05^2*(1612-1) + 1.96^2*0.7 (1-0.7)] = 269.0101 = 269$ farmers.

Appendix B. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.envsci.2018.04.001.

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