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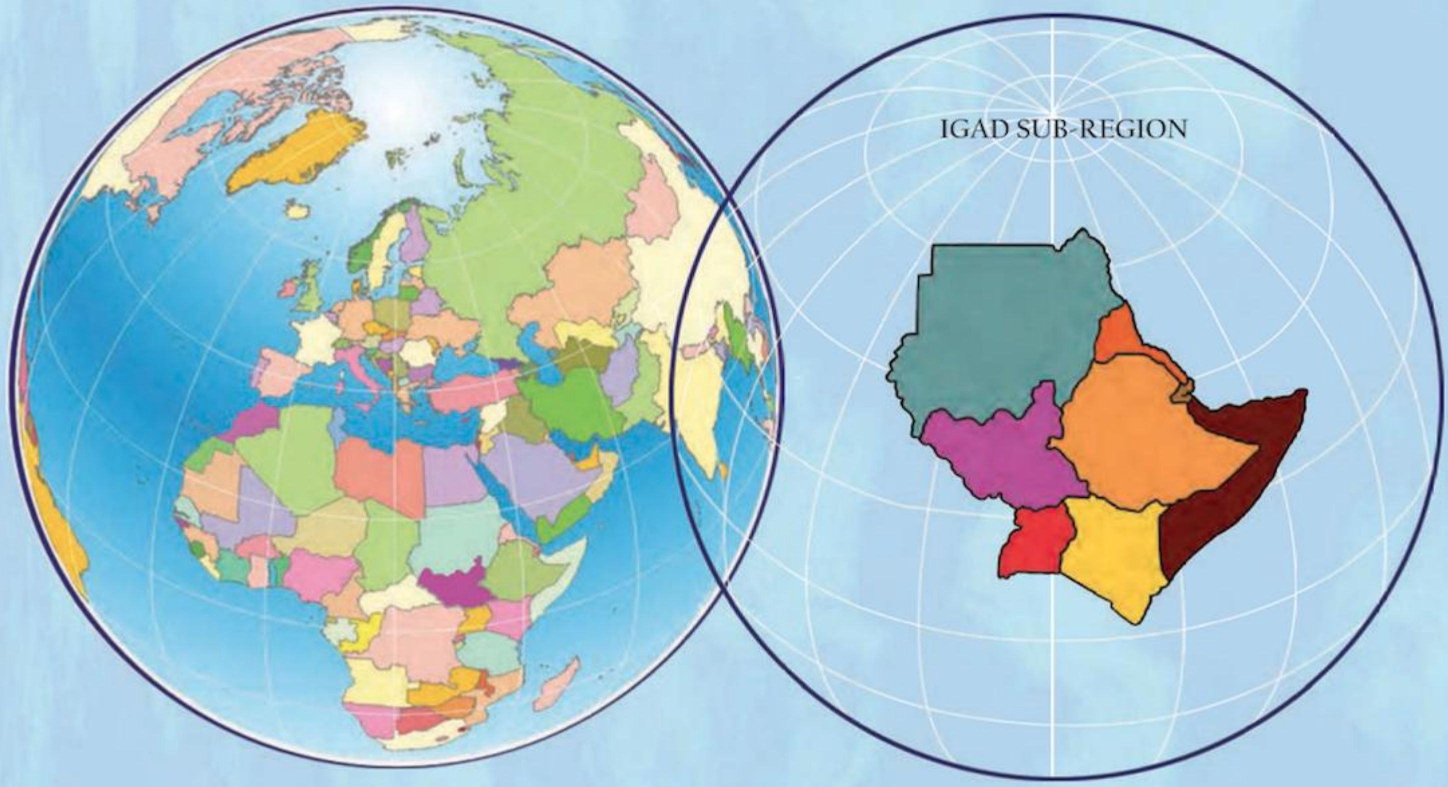

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HESPI is a non-profit, non-political research institute that conducts economic, social and policy oriented research to promote high quality policy analysis and advisory service to assist African government, the private sector and other stakeholders with a special focus on the IGAD sub-region. HESPI conducts commissioned studies and interacts with principal institutions and entities to address the challenges the region faces. HESPI's focus also covers institutional capacity building and instilling values for better management of social and broad based sustainable economic growth aimed at prosperous future for the region.

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Abstract

Rural roads are very important for economic development, especially in rural areas. Empirical studies confirmed that rural roads provide safe and efficient human mobility, enhance access to markets for inputs such as fertilizers and improved seeds, enable framers to sell their produce to nearby markets through a reduction in transport fare and time, and allow farmers to achieve additional non-farm employment opportunities, leading to a rise in income and reduce poverty.

Most empirical evidences on impact of roads on socio economic conditions are analyzed using quazi-experimental methods and on wealth differentiated approaches. However, roads can influence rural communities differently depending on their distance from the road. Attempts to delineate the road influence on the basis of distance from road, understand threshold type trends and map the influence zone on socio economic outcomes are scanty at best. Road influence zone, which is defined as the area in which significant ecological, environmental and socio economic effects extend outward from a road, has been used to analyze influence of roads on ecological and environmental effects of road but not on socio economic conditions.

In the first study of its kind, we measured the extent and type of relationship underlying the road-influence zone of rural roads on socio economic outcomes. Both positive and negative socio economic effects of roads are used for analysis. Accordingly, for the positive socio economic outcomes, four indicators namely trip per capita, use of fertilizers, motorized transport and commercial activities; and for negative effects of roads, three indicators road dust, flooding and erosion, have been used in the analysis.

We selected two rural roads constructed under the URRAP program, and two regional highways. 529 households from four tabias have been surveyed and we used piecewise and linear regressions to determine delineation of road influence zones. Except for number of trips per capita and erosion, threshold effects have been observed for the rest of the socio economic outcomes analyzed. The road influence zone occurs at different distance from the road for the different socio economic outcomes. It ranges from 200 to 240 meters on both sides of the road in the case of road dust to about 2.6 km in the case of motorized transport. The results of our study suggest that socio economic impacts of roads differ not only on socio economic and wealth differences of households but also on distance of households from road.

Key words: socio economic, road influence zone, piecewise regression, Ethiopia.

1. Introduction

In most African countries, road transport network and road density measured as per person and per square kilometer of land area is very low compared to the global average. Yet road transport sector is the dominant means of transport in the continent carrying around 80 to 90 percent of passenger and freight traffic; and most rural communities are accessible only through roads (Gwilliam, 2011). Recently countries in the continent are making huge progress in allocating funds and building road infrastructure, but still rural road accessibility remains to be one of the challenges to eradicate extreme poverty and achieve the sustainable development goals (SDGs).

Poor rural accessibility and poverty are extremely linked; when people are isolated, they are unable to harness the economic and social opportunities within a wider geographic region. Poor accessibility also makes diffusion of new technologies difficult, contributes to high transaction and production costs, and limits access to health, education and other social infrastructure (Hajj and Pendakur, 2000). It also hinders household mobility to access inputs and supply their produce to the market. Such poor physical accessibility often compounds the effects of poverty and deprivation (Porter, 2007). And a recent study by Alkire *et al* (2014) also shows that 85 percent of the poor (measured using Multidimensional Poverty Index) in 105 countries reside in rural areas where the pattern of higher incidence and intensity of poverty in rural areas than in urban ones is consistent across the different regions in the developing world. Thus, those in acute poverty are mostly concentrated in rural areas. Hence improvements in transport infrastructure particularly of rural roads are critical to support sustainable economic growth and reduce poverty.

Cognizant of the importance of roads, the government of Ethiopia has embarked on massive investment on road construction by formulating the Comprehensive Road Sector Development Program (RSDP) in 1997. Since then, the RSDP has been implemented in four separate phases, and as part of the fourth RSDP, a Universal Rural Roads Access Program (URRAP) envisaged to connect rural kebeles by standard rural roads has been set out and implemented.

Previous empirical works conducted in various countries show that rural roads infrastructure development reduced poverty and improved the quality of life, especially for the poor and narrowed down the income gap between citizens (Calderon and Serven, 2010; 2014; ADB, 2012). Infrastructure can also have a strong impact on the incidence and depth of poverty by supporting inclusive growth, i.e., economic growth that can facilitate a meaningful and sustainable poverty reduction (World Bank, 2009). But better rural roads are not sufficient but necessary conditions to benefit the poor. The ability of the poor to make significant economic use of a road depends on their asset base and the entitlements to resources and opportunities that they can command. The poor benefit mainly through the indirect impacts of road improvements, of better access to state services and improved provision of services to the village, and of opportunities in alternative livelihood income streams where the preconditions for their development are right. The poor can also benefit broadly from improvements to the rural economy through increased opportunities for agricultural wage labor, but, again, these impacts are contingent on favorable preconditions being in place (Hettige, 2006).

Besides socio economic conditions of the poor, distance of location of households from road also affects their ability to harness the direct and indirect benefits of roads. In the case of the study sites especially those connected by feeder roads, one road connects the tabia center with the main road. Since settlement of rural households is highly spread, some households may travel hours on foot to reach the feeder roads. Households located close to a road may thus be affected differently from households located far from a road.

The road influence zone which can be defined as the area over which significant ecological, environmental, socio-economic effects extend outward from a road (Forman and Deblinger, 2000) is widely used to assess ecological and environmental effects of roads. However, this has not been used to analyze the socio economic influence of roads. This study intends to use the methodology to quantify the influence zone of rural roads in two woredas in northern Ethiopia by taking feeder and non-feeder roads as case points. The study primarily focuses on the mobility and other socio economic impacts of roads including some road side effects. It is the first attempt to quantify the influence zone of roads on socio economic outcomes.

The rest of the paper is divided into five sections. Sections two and three review relevant literature and road network in Ethiopia respectively followed by section four which describes the data source and methodology. Results and discussion are presented in section five and finally section six concludes.

2. Empirical Evidence

Infrastructure investments especially in rural road development enhances access to markets for inputs such as fertilizers and improved seeds and enables the farmers to sell their produce to nearby markets through a reduction in transport fare and time (Raballand *et al*, 2010). On the other hand, the lack of road network can lead to increased transaction cost in rural areas which results in limited market access for farmers (Key, de Janvry, and Sadoulet, 2000). In developing countries like Africa, transport cost constitutes more than half of the marketing costs (Fafchamps, Minten, and Eleni, 2005). Hence such roads are vital in improving agricultural productivity and raising living standards in poor rural areas (Gannon and Liu, 1997).

Rural roads also allow farmers to achieve additional non-farm employment opportunities, leading to a rise in income and reduce rural poverty (Ali and Pernia, 2003). Rural roads improve mobility which in turn facilitates access (Donnges, 1998). In China, Fan and Chan-Kang (2005) found that rural roads have benefit–cost ratios for national GDP that are about four times greater than the benefit–cost ratios for high-quality roads. As far as agricultural GDP is concerned, high-quality roads do not have a statistically significant impact while low-quality roads are not only significant but also generate 1.57 yuan of agricultural GDP for every yuan invested. Investment in low-quality roads also generates high returns in rural non-farm GDP. It also lift more urban as well as rural poor out of abject poverty than do high quality roads. Using state level data from India in 1970-93, Fan and Thorat (2000) found that government spending on rural roads have larger poverty reducing impacts per rupee spent than any other government investment and generate higher productivity growth. Similarly using household level data from Nepal, Jacoby (2000) showed that providing extensive roads access to markets would lead to substantial benefits on average especially to poor households.

In three Africa countries-Burkina Faso, Uganda and Zambia, using village level data, Barwell (1996) showed that proximity to an active local urban center and to a main road, complemented by good rural road access, has a positive influence on the level of household income; and good road access broadens the economic opportunities available to rural people. In most African countries women and children shoulder most household transport burden and make significant contribution to the agricultural efforts of the household, including frequent trips to the field for cultivation activities. It significantly reduce the transport burden of women and children (Barwell, 1996).

Using Generalized Methods of Moments and controlling for household fixed effects, Dercon *et al*, (2008) found that access to all-weather roads reduces poverty by 6.9 percentage points and increases consumption growth by 16.3 percent in Ethiopia. Road infrastructure and the spread of extension services has contributed to growth and poverty reduction in rural Ethiopia (Dercon *et al*, 2007). Improvement in road infrastructure resulting from large scale public investment programme like RSDP[1] also contributed positively to the size and structure of the manufacturing sector in Ethiopia (Admasu *et al*; 2012).

Bryceson, Bradbury and Bradbury (2008) found that in extremely remote areas, road improvements may catalyze the expansion of social-service provision, as evidenced in Ethiopia. However, given the poor's relative lack of motor vehicles and ability to pay for public transport, they are, by no means, a sufficient condition for enhancing the mobility of the rural poor.

Most of the above empirical evidences and others on impact of roads on socio economic conditions are analysed using quasi-experimental methods and on wealth differentiated approaches. Attempts to delineate the road influence on the basis of distance from road, understand threshold type trends and map the influence zone on socio economic outcomes are scanty at best. Road influence zone analysis has been used to analyze influence of roads on ecological and environmental effects of road but not on socio economic conditions. This study is the first attempt to quantify and map out the influence zone of roads on socio economic outcomes.

[1] Road Sector Development Programme (RSDP) is a large scale infrastructure development programme implemented by the Government of Ethiopia since 1997.

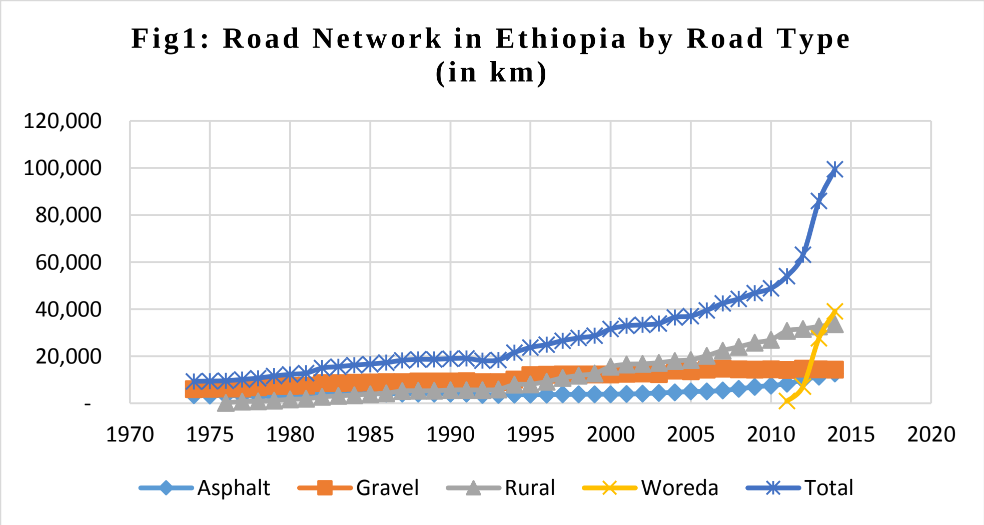
3. Overview of Road Network in Ethiopia

For a long time, roads infrastructure had been the major bottleneck in Ethiopia on doing business especially in rural areas due mainly to the mountainous topography in many parts of the country. Fig. 1 shows the road network development by road type in Ethiopia between 1974 and 2014. During the imperial regime, road coverage mainly concentrated in urban areas. In the early 1950s, total road network both the asphalt and gravel roads in Ethiopia was 6400 km. In 1974 the total road network increased to 9,260 km of which only 36 percent was asphalted and the remaining was gravel roads. By 1991, the total road network rose to 19,017 km.

Cognizant of the challenges the sector pose for the economy as a whole, recently the Government of Ethiopia (GoE) has shown greater commitment for road sector development by formulating the comprehensive Road Sector Development Programme (RSDP) in 1997 to address the constraints the road sector faced for long. Since then the RSDP has been implemented in four separate phases as follows:

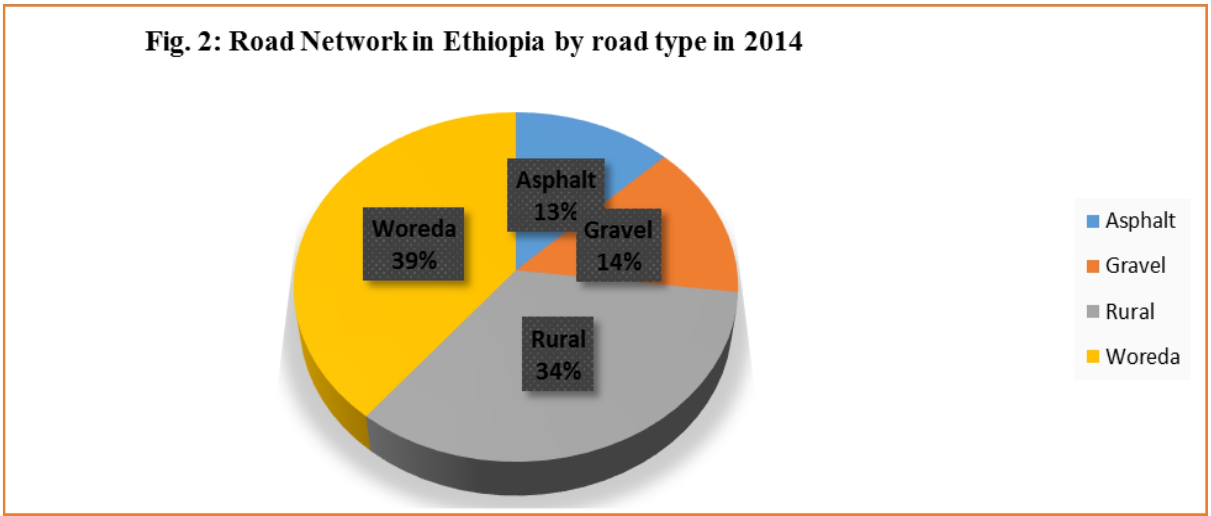
- RSDP I - Period from July 1997 to June 2002 (5 year plan)
- RSDP II - Period July 2002 to June 2007 (5 year plan)
- RSDP III - Period July 2007 to June 2010 (3 year plan)
- RSDP IV - Period July 2010 to June 2015 (5 year plan). RSDP IV was aligned with the Growth and Transformation Plan I (GTP). As part of the RSDP-IV, the GoE embarked on the Universal Rural Road Access Program (URRAP) that sets out to connect all kebele (also called *tabia*s in rural Tigray) by roads of a standard that provides all-weather, year round access, meets the needs of the rural communities, are affordable and maintainable. It is mainly designed to improve rural mobility by reducing isolation for rural populations and to provide year round access to their markets, social and other services (ERA, 2013)

During the period of the RSDP until 2014, the government constructed around 72,972 km new additional roads of all type (asphalt, gravel, rural and community level roads). In 1997, the total road network was 26,550 km and reached at 99,522 km in 2014. During the last phase of RSDP (in 2010-2014), the total road network grew on average by a staggering 17 percent annually.



Source: Ethiopian Roads Authority

In 2014, the total stock of road network reached nearly 100,000 km of which majority are either rural or woreda level roads constituting around 73 percent; while asphalt roads constituted only 13 percent. Since 2011, there has been huge woreda and rural road construction indicating government emphasis on rural road.



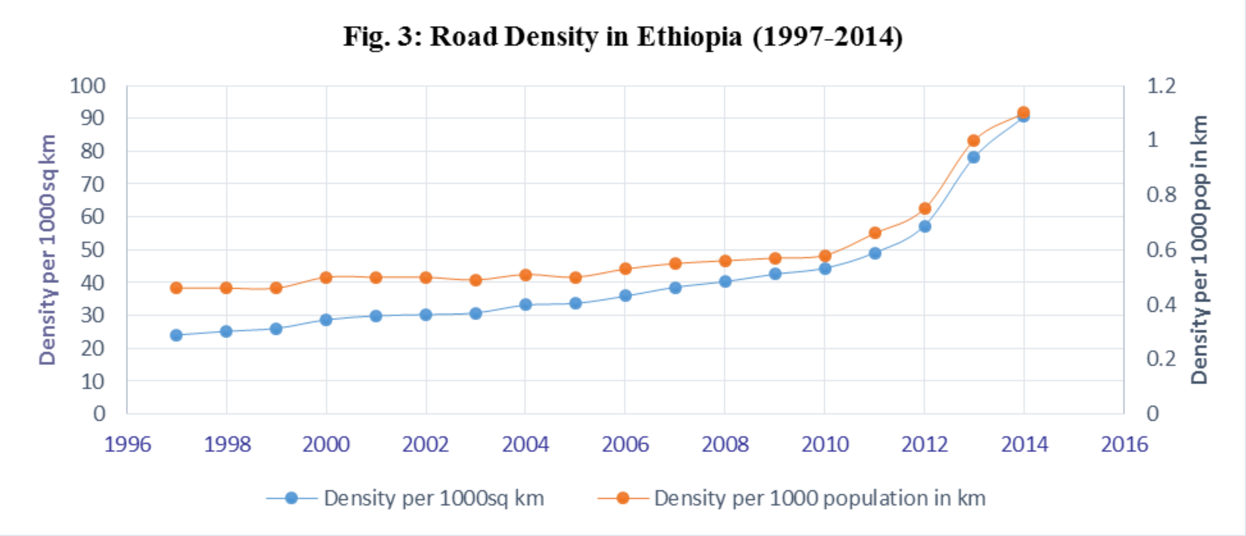
Source: Ethiopian Roads Authority

Road Density[2]

Even if there has been improvement in road network especially after the 1994, road density remains very low compared to other developing countries. For long, road network

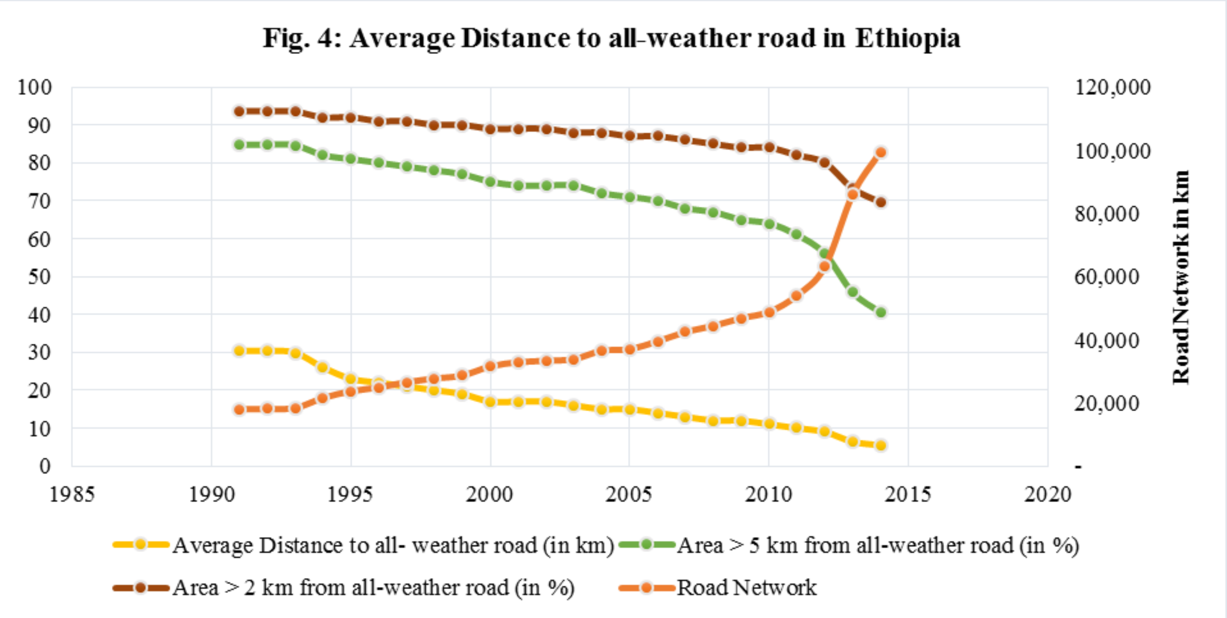
[2] Road density is the ratio of the length of the country's total road network to the country's land area. The road network includes all roads in the country: motorways, highways, main or national roads, secondary or regional roads, and other urban and rural roads

improvement was very slow in the country. But since 2011 there has been massive government infrastructure investment mainly on community (or Woreda) level roads which are administered by the respective regional rural roads authority. In 1997 when the RSDP started road density measured as density per 1000sq km was 24.1, while measured by density per 1000 population in km was 0.46. But since 2010 it improved considerably reaching nearly 90 km per 1000sq km in 2014.



Source: Ethiopian Roads Authority (ERA)

At the downfall of the Derg regime, the average distance to all weather road in Ethiopia was 30 km which decline drastically to 5.5 km in 2014 (see figure 4). In 1991, nearly 93 percent of the areas in Ethiopia were farther than 2 km of all-weather roads and 85 percent farther than 5 km. But since especially 2010, there has been dramatic improvement mainly of woreda and rural roads contributing to declining average distance to all weather roads throughout the country.



Source: Ethiopian Roads Authority (ERA)

4. Data source and methodology

The predominance of isolated rural settlements in Ethiopia with poor spatial integration and unreliable or non-existent access to markets stifles economic activity and further adds to the rural poverty burden. According to the Ethiopian Road Authority (ERA), approximately 64 percent of the land area in Ethiopia lies more than 5 km from an all-weather road, some 48 million people in the rural areas of Ethiopia live further than 2 km away from the nearest all weather road. On average, households are often more than 10 km away from a dry-weather road and 18 km away from public transport services (ERA, 2013). Cognizant of this fact, the Ethiopian government has embarked on massive infrastructure investment in an attempt to try to close the gap. Since 95% of the movement of people, and goods is carried out by road transport, the Ethiopian government has placed increased emphasis on improvement of the quality and size of road infrastructure in the country.

Following Ethiopian Road Authority's (ERA) road network classification (ERA 2013 cited in Rammelt et al. 2015), road networks in Ethiopia are classified into:

- Federal highways that connect regional states (primary network)
- Regional highways that connect woreda headquarters (secondary network)
- Rural roads within woredas (tertiary network) that includes feeder roads and community roads

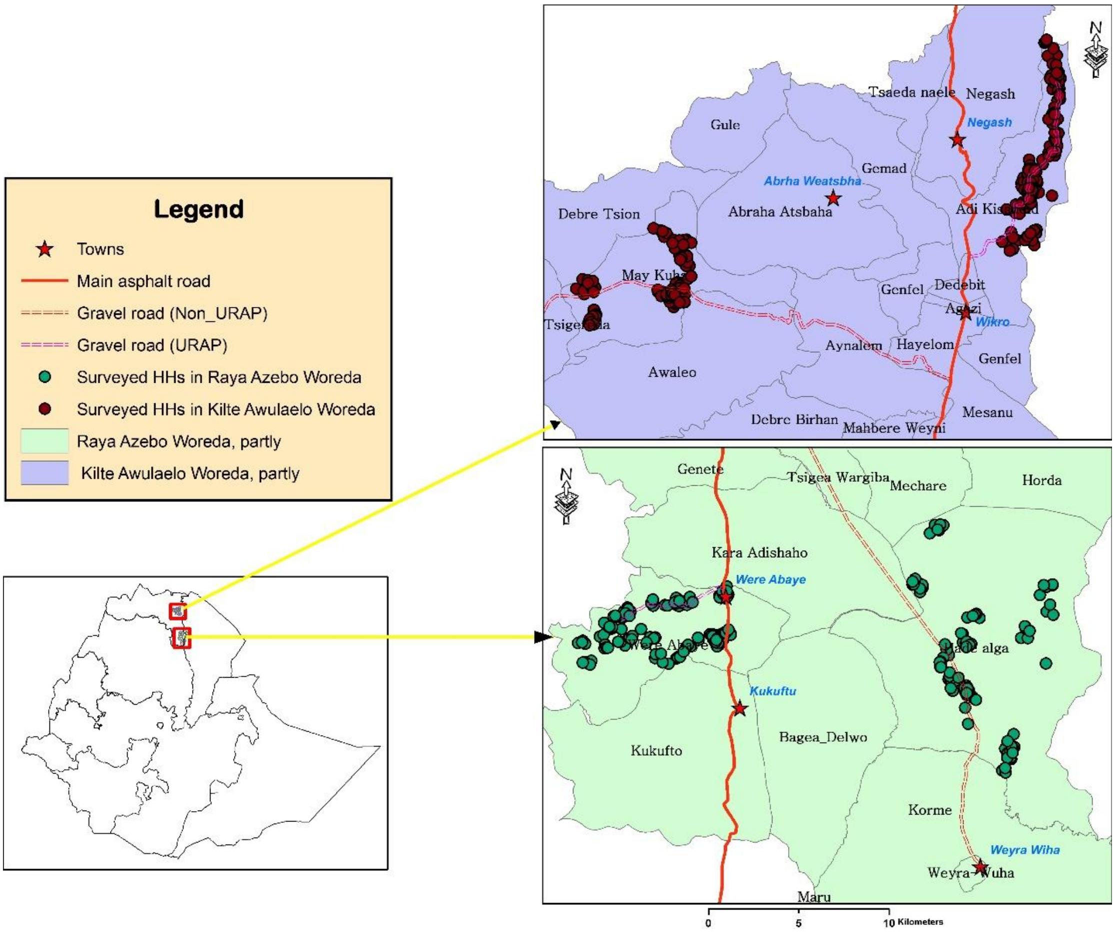
The emphasis of this study is on regional highways and rural roads. Two feeder roads constructed under the Universal Rural Roads Access Program (URRAP) and two regional highways were selected for the study.

4.1. Sample and data collection

The study areas for this study are located in two woredas[3] – Raya Azebo and Kilte Awlaelo – in Tigray regional state in northern Ethiopia. Two types of roads were selected for analysis – feeder roads and regional highways. The study is conducted in four selected *tabia*s[4] namely Hade Alga and Werebaye both from woreda Ray Azebo, and Lailay Adiksanded and Mai Quiha from woreda Kilte Awlaelo. Figure 5 below shows the location of the study sites.

[3] Woreda is the second administrative unit above *tabia*
[4] *Tabia* is the smallest unit of local government in rural communities in present day Tigray

Fig. 5: Location of study sites



A total of 529 Sample households were selected from the four study *tabias*. Sample households were distributed proportionately to each *tabia* and in each *tabia*, sample households were further proportionately distributed to each sub-village locally called *kushet*[5]. Once sample households were proportionately distributed to each *kushet*, simple random sampling was used to select sample households from each *kushet*. List of households was obtained from each *kushet* and sample households were selected at regular interval with a random start. The table below shows the distribution of sample households by *tabia*.

Table 1: Distribution of sample households

Tabia	Sample size	Percentage
Adi Ksanded	151	28.54
Mai Quiha	118	22.31
Hade Alga	124	23.44
Werebaye	136	25.71
Total	529	100.00

[5] A *tabia* consists of three to four kushets

A multi-purpose questionnaire was used to gather information on household demographics, mobility, household activities and income; and impact of roads on selected welfare indicators. The survey questionnaire was administered to the 529 sample households selected from the four *tabia*s.

Ten experienced enumerators that served in similar surveys before were hired for data collection. The enumerators were given intensive training for two days and pilot testing was made. During the survey field work, close and regular supervision was made. Filled out questionnaires were checked on the spot and those with significant inconsistencies were made to be filled again.

After fieldwork, data processing was done. All forms were manually checked to ensure that they had been completed fully and coding was made. Once coding was completed, data encoders were hired to accomplish data entry. Data is entered and processed using STATA software.

4.2. Methodology

Both descriptive and statistical analysis were used to summarize the influence of roads on the socio economic conditions of rural households. Tables and figures were used for the descriptive analysis.

For the statistical analysis of the road influence zone on selected welfare indicators and selected road side effects, we built a generalized linear regression and, when appropriate, a generalized, linear piecewise regression model for each selected welfare indicators and road side effects. Because the distribution of the response varied among the welfare and road side effects, we used a Gaussian, Poisson, Binomial or Negative Binomial link function as appropriate. We used the *glm* function for the regressions.

A piecewise linear regression with one breakpoint (Muggeo 2003, Toms and Lesperrence 2003, cited in Eigenbrod et al. 2009) is expressed as:

$$Y = a + b_1X_1 + \cdots + b_jX_j + dD \; where \; D \leq breakpoint \; T$$

$$Y = a + b_1X_1 + \cdots + b_jX_j + dD + (d_e)(D - T) where \; D > T$$

Where Y is the response, a is the intercept; $b_1, \ldots, b_j$ are the regression coefficients for all X_j local predictors; d= the slope of distance to the road (D) in the piecewise regression model to the left of the breakpoint (T);, e = “difference in slope parameter” so that d+e is the slope of the line segment to the right of the breakpoint.

5. Results and discussion

5.1. Descriptive result

In this section, we present the descriptive result for mobility and other selected welfare indicators including road side effects.

5.1.1. Rural Mobility and distance from road

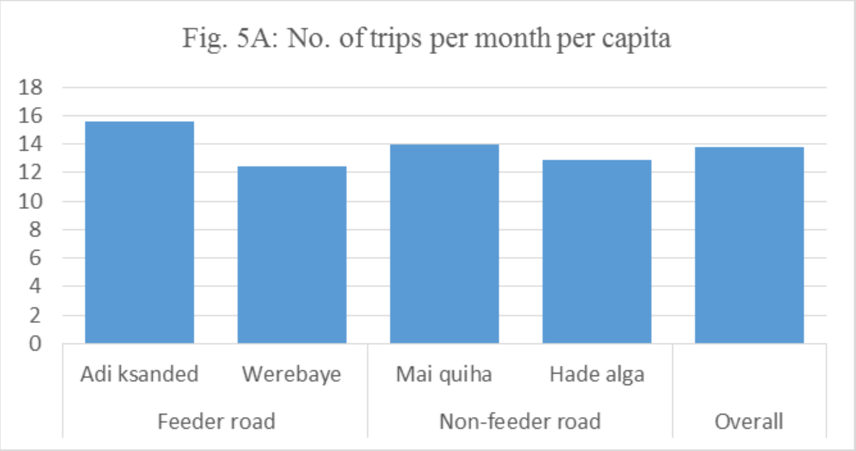
a. Travel Patterns

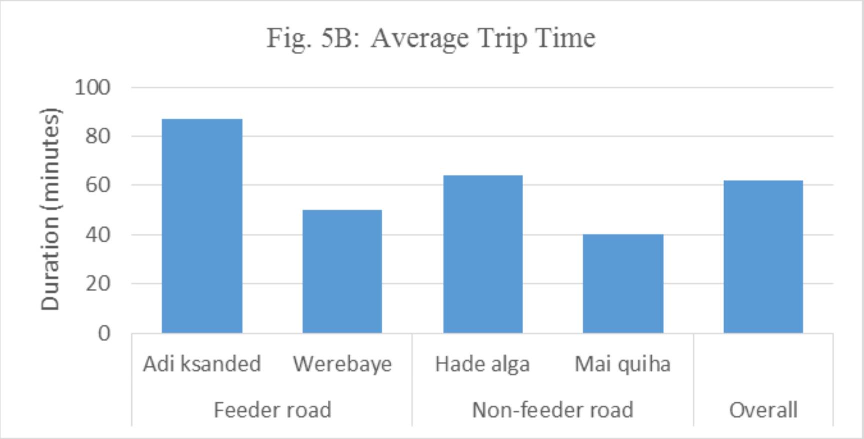
In the survey, respondents were asked to recall the number of trips household members made in a typical month for purposeful destinations with the exception of domestic trips for firewood and water. It should be noted that this method of generalized trip recall obscures the multipurpose nature of many rural trips. Figures 5A through 5C below indicate the average number of trips per capita per month by *tabia*.

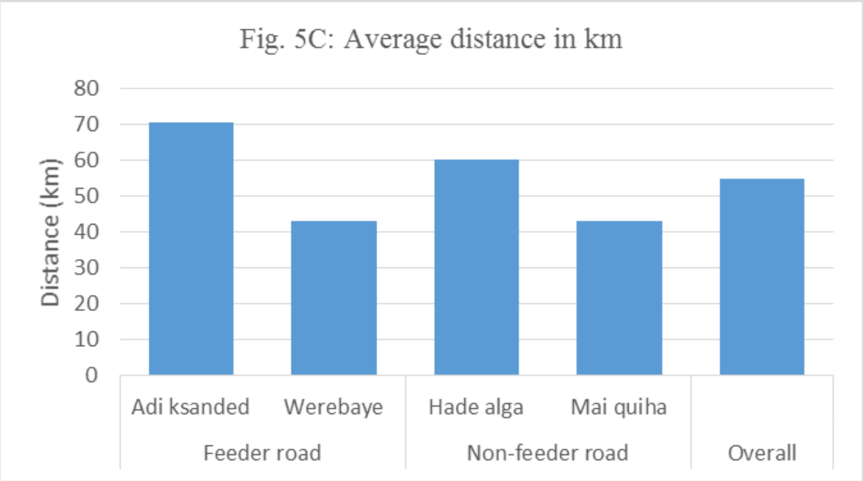
The average number of trips per month per person is close to 14 trips. However, there are slight differences between *tabia*s – the highest number of trips is shown at *Adi Ksanded* and the lowest number of trips in *Werebaye*. It seems that people in the highland are more mobile than people in the lowland. However, there is no clear indication of difference in mobility between *tabia*s with access to URRAP road compared to *tabia*s with access to non-URRAP roads.

Similarly, the average trip time is around 60 minutes with clear difference between *tabia*s. The largest average trip time is close to 90 minutes in *tabia Adi Ksanded* and the lowest being in *Mai Quiha* which is only 40 minutes, i.e., less than half of that of *Adi Ksanded*. This could be due to the fact that households in *Mai Quiha* are located far from big towns such as the *woreda* town of Wukro and unlike households from *Adi Ksanded* which are close to the woreda town, they do not often travel to the towns. When they do, usually during the marketing days (which is ones in a week), they travel by bus which significantly reduces travel time.

But in terms of trip distance, it seems that people from the low land (with relatively small number of trips per capita) make fewer trips but much longer journeys than people in the highland. The average trip distance is the highest for *Hade Alga* which is close to 5Km per trip and it is the lowest for *Mai Quiha*, which is around 3Km per trip.





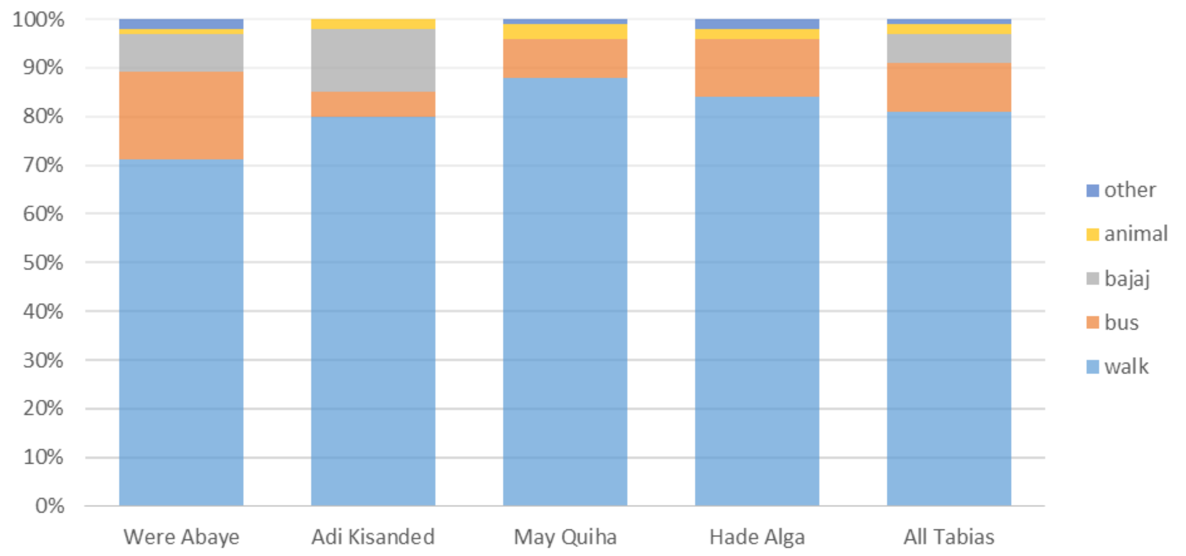


b. Modal Options

The form and content of rural mobility and transport depend on both public and private investment to provide transport modal choice. Public money may help to subsidize rural bus and /or trucking services. Alternatively these may be entirely dependent on private capital investment of local entrepreneurs in which case the population density and purchasing power of the area will have had to reach a certain level for such bus services to appear. Sometimes, in the Ethiopian context, the transport authorities in consultation with private transporters, assign privately operated buses to new transport lines usually ones in a week following a marketing day in the area or nearby towns. But prior to the availability and use of motorized automobile transport, there are a number of modes that rural people can invest in to ease their transport and travel burdens. The most common are pack animals, animal drawn-carts, bicycles, motorcycles and three wheeler Bajaj.

All the four *tabia*s in the study reveal an overwhelmingly rural 'walking world' regardless of whether the village is connected through URRAP or non-URRAP road. Walking constitutes well over 80% of all trips in all the four villages with some minor differences among villages. Following walking, the next mode of transportation used in the villages is bus. In two of the four villages, bajaj is also an important mode of transportation.

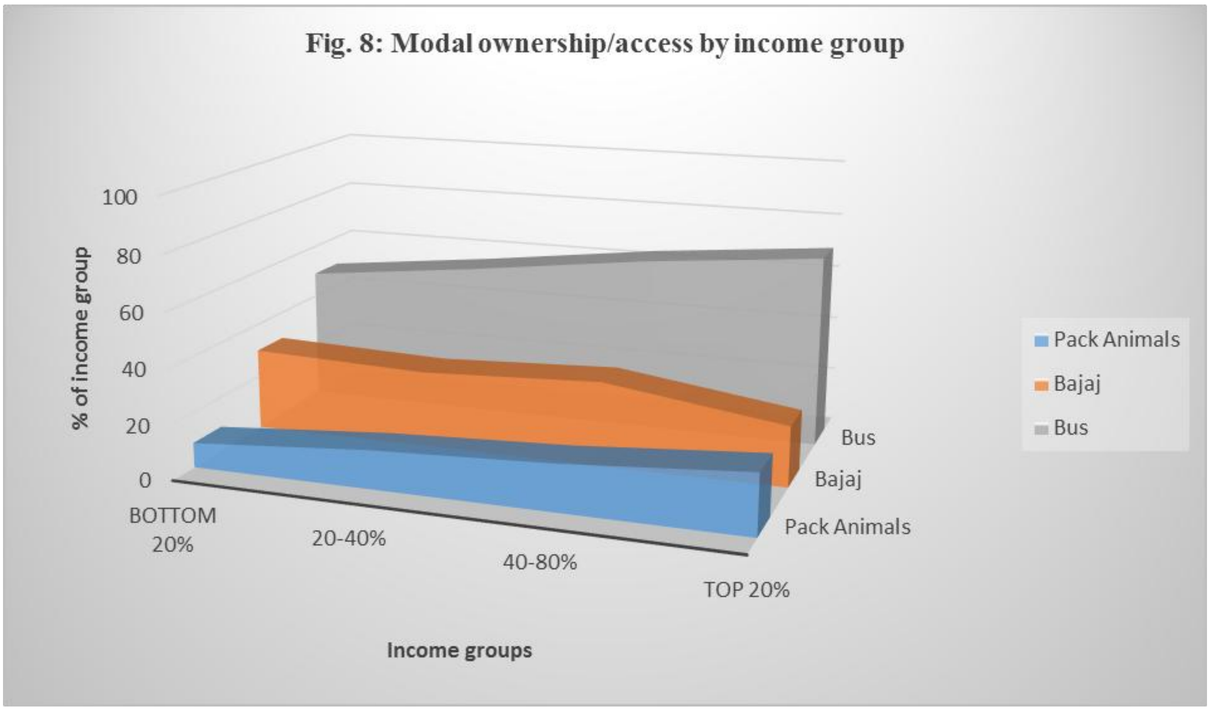
Figure 6: Trip by mode of transport (%)



The villages where bajaj is used for transportation are the ones that have irrigation agriculture and connected through URRAP road. Modes of transportation such as bus and cars are too big to serve the specific *tabia*s from the main road. The three wheel driver locally known as bajaj are filling the gap. For feeder roads that connect villages with the main road, bajaj started to serve as an affordable means of transportation to transport people and goods from villages to the main road. This is clearly seen in Werebaye, where there are well over a dozen of bajajs providing transportation service to people and goods.

Fig. 7: Bajaj transporting people from the *tabia* center of Werebaye to main road

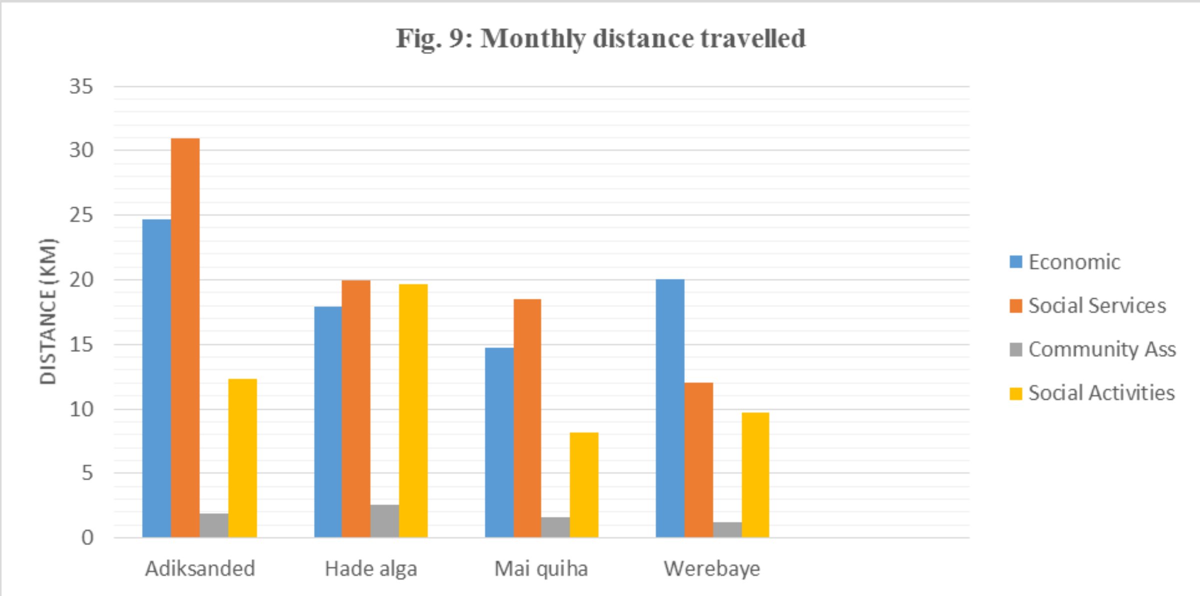
Affordability is one of the important issues considered when use of different modes of transportation is concerned. The higher the income of households the better their ability to afford costs of transportation by different modes of transportation. The figure below shows modal ownership and/or access by different income groups to show if people at different income groups use different modes of transportation. Access here is defined by availability and affordability of a transport modal.



Bus ownership/access and pack animal ownership seem to be positively correlated with income but not as strong as might be thought. On the other hand, access to bajaj seems to be not correlated with income. This could be due to the fact that bajajs are used for short transportation (from village to main road) and the price could be affordable to most. For example, one way bajaj transportation in Werebaye costs ETB 10.

c. Trip Purpose

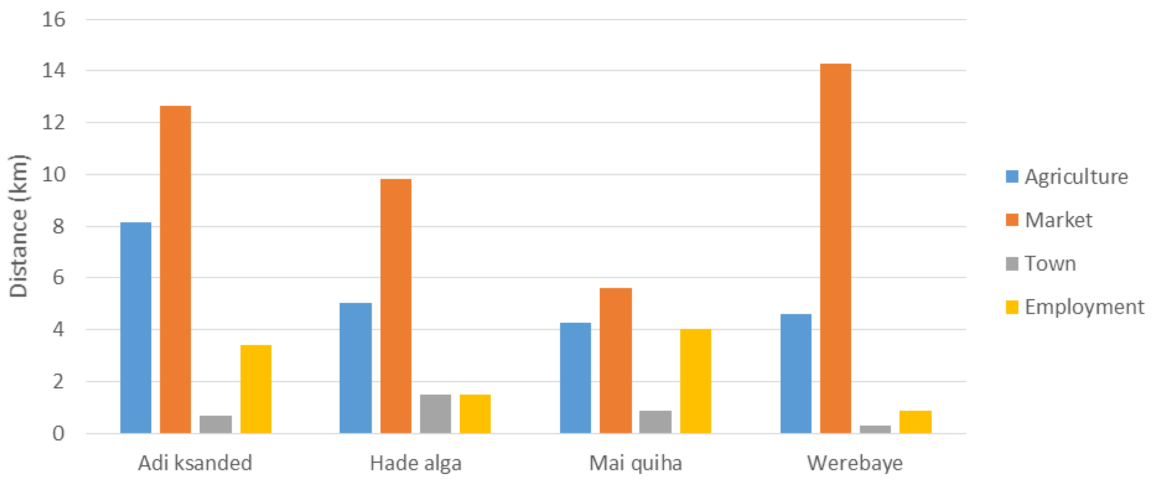
Trips are defined as travel both inside and outside the village by any means for the following purposes: economic activities, social services, social activities and community association. In all the villages travel for social services dominate with the exception of Werebaye where travel for economic activities are well prevalent. Economic activities tend to be the second most important purpose of travel followed by social activities and community association, the latter being very small in all four villages. Economic travel is relatively high in the areas where irrigation is widely practiced – Adiksanded and Werebaye.



The next four figures (Figures 10A through 10D) examine the components of the four major purposes of travel. Figure 10A provides a breakdown of economic travel. Market travel is the major form of economic travel revealed in all four villages. However, market travel displays significant variation from village to village. The average distance per capita for market travel in Werebaye is more than 14 km which is three times that of the market distance travel in MaiQuiha. Next to Worebaye, market travel time is high in Adi Ksanded. One possible explanation for such a difference in market travel is due to the fact that there are relatively functional markets at tabia level in both Mai Quiha and Hade Alga, whereas such markets are absent in tabias Werebaye and Adi Ksanded. Another possible reason could be differences in the communities' engagement in irrigation agriculture. The market distance travel is higher in villages with irrigation agriculture. Irrigation is relatively widely practiced in Werebaye and Adiksanded villages and in some parts of HadeAlga village. Agricultural output produced through irrigation is mainly for the market. Thus, households who practice irrigation agriculture often travel to the market to sale their produce otherwise. Moreover, they travel to far off places in search of better market for their produce. In Worebaye, for example, the dominant crop grown through irrigation is *quat*, a mildly narcotic leaf. Producers or local traders travel as far as Alamata (the zonal town) and in some cases Mekelle (the capital city of the regional state) to sale their *quat*.

Agricultural travel which consists of trips to farm fields, for input collection, transport of the harvest and travel to grinding mills, is the second major travel for economic activities. The agricultural travel distance ranges from an average of 4 km in MaiQuiha to an average of 8 km in Adi Ksanded.

Fig. 10A: Monthly distance traveled for economic activities per capita



Travel for employment is reflected in all four *tabia*s but it is relatively highly noticeable in the *tabia*s in the highland – Mai Quiha and Adi Ksanded. It is relatively low in the low land villages. The extent of town visits are low in all the four villages.

Figure 10B below reveals the constituent categories of social service travel showing that in all the four villages, education overwhelmingly dominates travel for social services. This consists mostly of school children who walk daily to school. School buses are not available and hence roads do not facilitate this travel.

Travel for education reflects national educational policy and local occupational expectations. Over the past one and half decade, the Ethiopian government has placed great emphasis on primary school education and is endeavoring to provide a primary school in the rural areas.

Rural travel surveys over the last two decades have repeatedly found that the high value of rural roads in local people's eyes is most often associated with the enhanced accessibility of medical centers that they provide (Bryceson et al. 2006). Moreover, local people in rural Ethiopia appreciate the importance of rural roads to have access to ambulance service for emergency purpose. Given this pervasive attitude, it is interesting to see that a small proportion of people's overall travel is actually devoted to health services as opposed to education. Nonetheless healthcare travel poses the issue of ease of travel more than any other. A sick person who is unable to walk long distances or walk at all must be transported by motor vehicle or carried long distances on a stretcher by people walking. In emergencies the latter mode of transport is a very severe sometimes life-threatening constraint that remote communities face and which would lead them to prioritize road access to health facilities.

Ambulance service at Lailay Adi Ksanded

Amakelech Kebede lives on the hilly side of *tabia (kebele) Lailay Adi Ksanded* in a *kushet* (sub-village) called *Bahra*. On the 16th of June 2015, she was seriously injured after falling from the hilly area close to her residence house. The local people called the Woreda office for ambulance service and an ambulance was sent immediately. The woman was taken to Wukro (the woreda town) hospital. The local people appreciated the importance of the rural road to have access to medical centers especially at times of emergency.

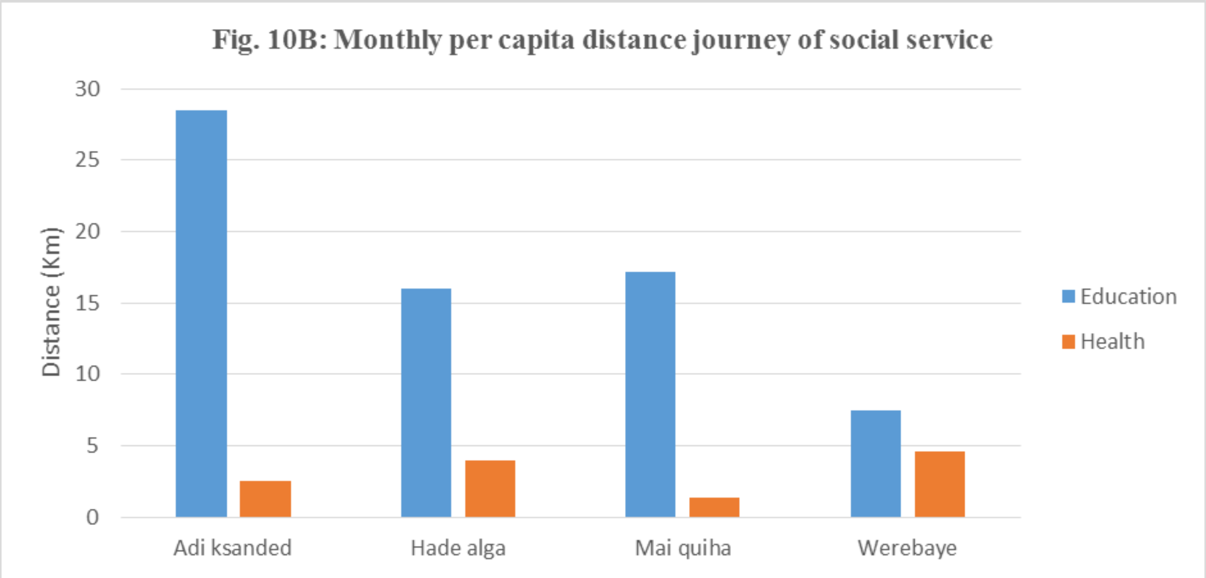


Figure 10C shows the distances travelled for purposes of community association or what is otherwise referred to as 'social capital' in recent development literature. Travels to village committee, religious group, burial society and farmers & women's groups account for most of the travel for community association.

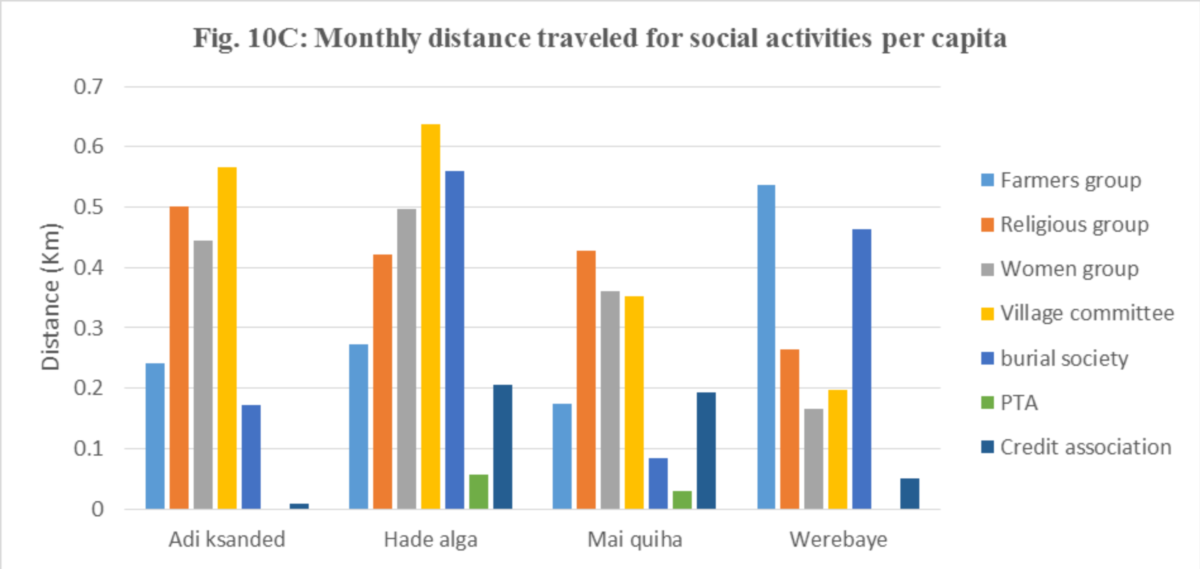
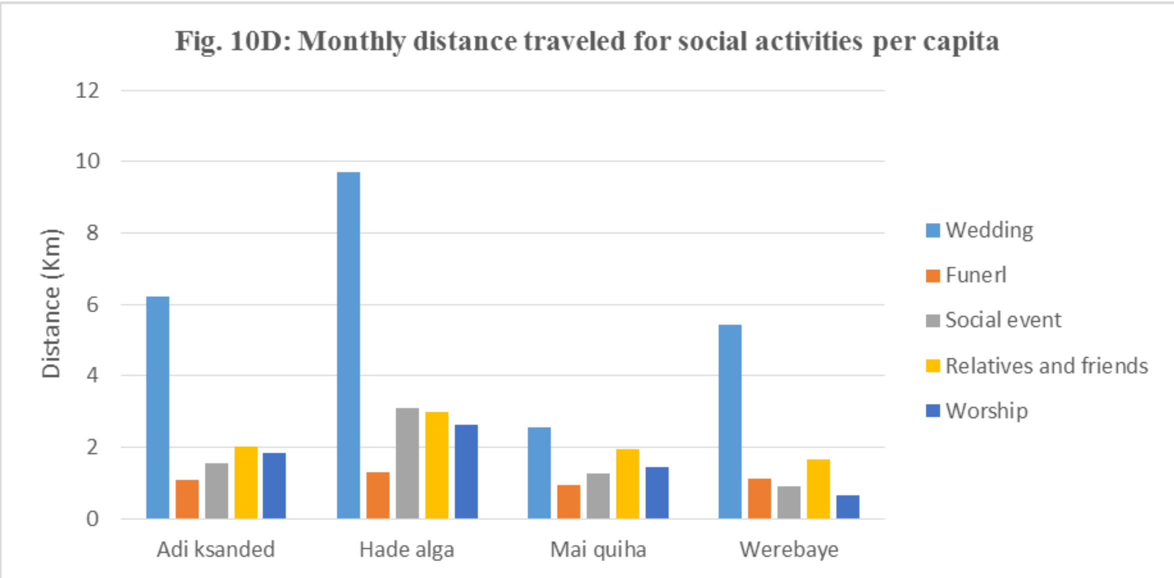


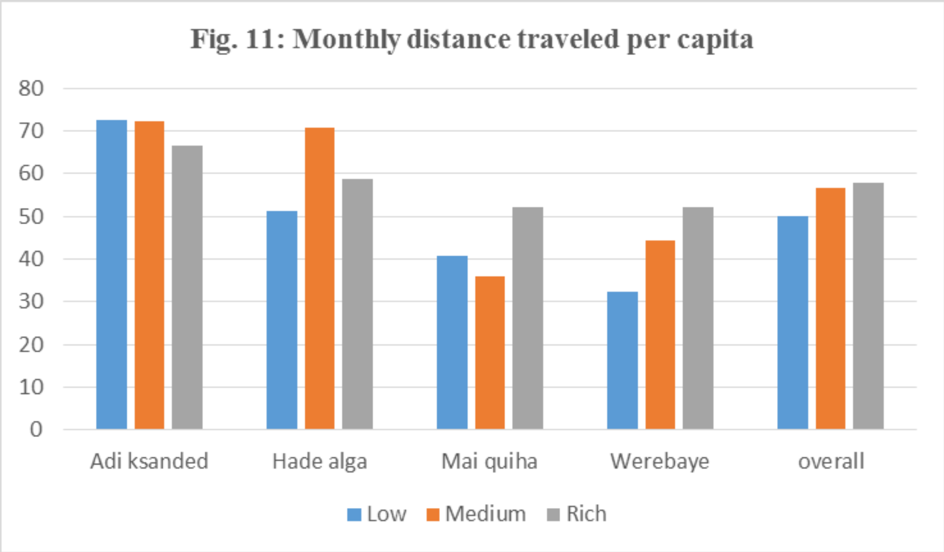
Figure 10D shows the distances travelled for purposes of social visits. Wedding accounts for a substantial portion of the travel. All the other social visit travels are more or less uniform across all *tabia*s.

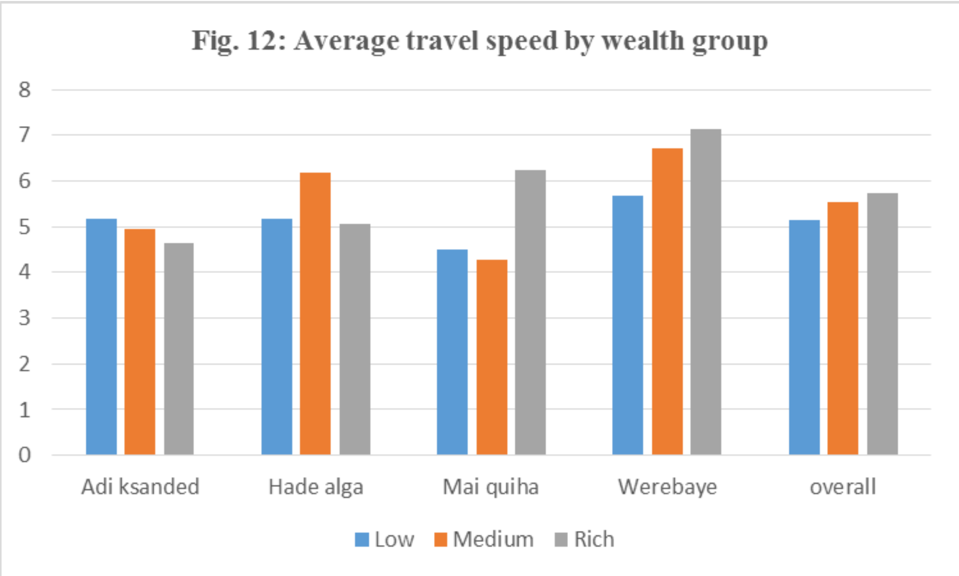


d. Wealth Differentiated Travel Patterns

Household wealth differentiation within the village would be expected to relate to variation in travel patterns. Households are categorized into high, medium and low wealth groupings on the basis of the per capita income data.

Average monthly distance travelled per capita (Figure 11) and average travel speeds (Figure 12) are used as summary mobility measures.





The pattern of wealth differentiated mobility measures (distance travelled and speed) is not so clear. The evidence suggests that while the high income group generally travel further distance and at a higher speed per hour and this is especially the case in Mai quiha and Werebaye.

e. Distance from road

The economic and social benefits of a road to individual households depends on how far or close a household is located from the road. In this section, we discuss how the influence of rural roads (both feeder and non-feeder roads) varies with distance of households from the road.

Distance from road and travel patterns

The table below shows travel patterns by distance from road, the latter being categorized into three – close, medium and long. The categorization is made so as to have comparable number of households in each category. The first category includes households located up to 0.3 km

(300 meters) from road. The medium category lies in the range of 0.31 to 1.5 km, while that of the long distance covers households located 1.51 km and above from the road.

The table indicates that the number of trips household members make correlate with the distance they have from the road. The closer are households to the road, the higher is the number of trips they make. Households located closer to the road made on average 79 trips per month while households in the medium and long distance ranges made 77 and 73 trips per month respectively. This means households located closer to the road (up to 300 meters) made on average five more trips per month than households located more than 1.5 km from the road. On a per capita basis, a person located close to the road made 2 more trips per month than a person located more than 1.5 km from the road.

Table 2: Travel patterns by distance from road

	Distance from road (near_to_road_tert)		
Travel Pattern	Close	Medium	Long
Average no. of trips per month	78.78409	77.29545	73.08807
Average no. of trips per month per capita	14.92329	13.47924	12.81719
Distance per capita (km)	58.9759	50.51899	54.90745
Travel speed	5.370235	5.158789	5.909568
Walking per capita	10.42614	10.81818	10.47727
Walking	73.42614	72.19429	69.14489
Animal transport per capita	0.2670455	0.2102273	0.3579545
Animal transport	0.7670455	0.4488636	0.7897727
Motorized transport per capita	2.653409	2.267045	1.755682
Motorized transport	9.534091	7.784091	6.164773

In a similar way the distance covered per capita in km corresponds with distance from the road. Households located close to the road not only travel frequently but also travel relatively longer distance per capita than households located far from the road. Households located up to 300 meters on both sides of the road travel on average 59 km per month compared to 51 km for households located 1.51 km or more on both sides of the road. This could be due to the fact that households located close to the road have a better access to motorized transportation and hence travel relatively long distance.

As far as travel by mode of transportation is concerned, there are no significant or consistent differences across all modes of transportation between households located at different distance from the road except for the use of motorized transport. As rural communities with less access to modern modes of transportation, we observe that the frequent mode of transportation is walking. Regardless of how far or close households are located to rural roads, the frequency of trips made by walk is comparable. On the other hand, transportation by pack animals, although very low, seems to be relatively frequently used by households at the far end from the main road than households close to the road. Finally, motorized transportation which is the second frequently used by the sample households after walk, shows clear association with distance from road. Households located close to the road use motorized transport for an average of 10 trips per month whereas households located 1.5 km or more from the road travel on average 6 trips per month, i.e., households close to the road travel on average four more trips per month, i.e., a 67% increase, by motorized transport than households located 1.5 km or more away from the road.

5.1.2. Agricultural Extension, agricultural inputs and distance from road

Access to agricultural extension agents is often viewed as an important determinant of the adoption of improved technologies. In the survey, respondents were asked about their access to agricultural extension, utilization of modern inputs – fertilizers and selected seeds. Table 3 below shows summary of the questions.

Table 3: Agricultural extension and use of modern inputs

	Unit	No. of observation	Mean	S.D.
Agricultural extension				
Access to agricultural extension and/or vocational training	Yes=1	528	0.848485	
Visits by agricultural or health extension workers	Yes=1	528	0.973485	
Modern input				
Fertilizer	Kg	528	88.52557	70.19273
Selected seed	Kg	528	6.724432	17.29412
fertilizer per *timad*	Kg	528	33.77664	35.8488

Following large investments by the Ethiopian government towards improving agricultural extension in the country, the results show that access to agricultural extension is high. However, the summary here only shows whether farmers can get access to agricultural extension. The extent and when such access is given is not included here. On the other hand, the use of modern inputs in the survey area is low. The average use of fertilizers per timad (a quarter of a hectare) is 34 kg and that of selected seed is 7 kg per household. However, there is significant variation among households as revealed by the high value of the standard deviation.

Does access to road influence use of modern inputs in farming? The table below shows application of modern inputs by distance from road, the latter being categorized into three as close, medium and long.

Table 4: Fertilizer and selected seed application by distance from road

Input application	Distance from road		
	Close (0 – 0.3 km)	Medium (0.31 – 1.5 km)	Long (>1.5 km)
Average fertilizer use per household	109.23	97.94	58.40
Average fertilizer use per timad	47.86	36.22	18.07
Average selected seed use	7.61	8.53	4.04

The table indicates that the rate of fertilizer application by rural households relates to distance from road. Households close to the road apply on average more than two and half times per timad than households located more than 1.5 km from the road.

Households were further asked what would have happened to their purchase of fertilizers and improved seeds if the road was not constructed. Table 5 below summarizes the response.

Table 5: Purchase of fertilizers and seeds without a road

Purchase of fertilizers without a road	Freq.	Percent
Cannot purchase inputs	124	24.85
Purchase smaller amount	159	31.86
Purchase same amount but higher transportation cost	155	31.06
Price would be higher	8	1.6
purchase and transporting inputs remain unchanged	53	10.62

Results indicate that a quarter of the respondents said that they would not have purchased inputs if roads were not constructed. Similarly, a third of the respondents (32%) said they would have responded by purchasing smaller amount of inputs. Close to a third of the respondents (31%) said they would continue to purchase the same amount of inputs they are purchasing now but transportation cost would be higher. Only 11% of the respondents believe that both the purchase and transportation cost of inputs would remain unchanged.

5.1.3. Non-farm activities and distance from road

The survey asked questions on different sources of income of households and types of commercial activities the households were engaged. Table 6 indicates contributions of different sources of income.

Table 6: Household income source

	No. of observations	% of households with income source	Mean HH income	Standard deviation	Share of total income
Agricultural income	518	98	12501	19906	76
wage income	241	46	2067	3365	12
Business income	66	13	885	3879	5
Transfer income	101	19	757	2696	5
livestock income	272	52	336	727	2

As agricultural communities, it is understandable that most of the income source (more than three fourth) comes from agriculture followed by wage income contributing 12% of the total income. Income from own business and transfer income (both aid and remittance) contribute about 5% each. Livestock income which contributes only 2% of the income source includes sale of livestock products. Sale of live animals and livestock products used for own-consumption are not included.

Survey respondents were further asked how income from the different sources has changed after construction of the rural roads. Results are summarized below. A reasonably good percentage of respondents have said that income from the different categories has risen after construction of the rural roads. The percentage varies among income types, the highest percentage being observed in Agriculture with 48% of the respondents who earned income from agriculture said income from the sector has increased after construction of rural roads, followed by wage earning respondents where 41% have indicated their wage income has increased. The least being in business income where only 29% have responded a rise in business income after construction of rural roads (table 7). The relatively low percentage response of business income earners could be partly due to the fact that most business activities operated only after construction of rural roads.

Table 7: Changes in income after construction of road

Income type	No. of observations	% of households who responded changes in income		
		Increased	Decreased	Unchanged
Agricultural income	517	48	3	49
Livestock income	271	37	2	61
Wage income	239	41	2	57
Business income	63	29		71
Transfer income	100	30	1	69

The figures in the above table indicate only possible association. The reason(s) for changes in income could be due to other factors other than road construction. To indicate how much of changes in income could be attributed to the rural road construction, respondents were asked how much of the change in income they attribute to road construction. The three point scale response of households is summarized below on table 8. Most respondents believe that only part of the change in income is attributable to the construction of the road. However, a good percentage of the respondents (ranging from 17% to 33%) also believe that the change in income is fully attributable to the construction of the road. Except in the case of transfer income, where close to 22% of the respondents believe road construction has no influence on income change, in all the remaining cases, only a small fraction not more than 4% believe road construction contributes nothing to income change.

Table 8: Attribution of changes in income to road construction

Income type	No. of observations	changes in income attributed to road construction (% of HHs)		
		All of the change	part of the change	None of the change
Agricultural income	260	30	66	4
Livestock income	140	33	63	4
Wage income	102	32	65	3
Transfer income	32	25	53	22
Business income	24	17	83	-

Commercial activities and distance from road

Although communities in the study sites are rural which mainly depend on agriculture for their living, with the expansion of infrastructure and rural towns, it is expected that non-farm activities especially small business activities play a role in diversifying income sources and supporting the lives of rural households. In the survey, rural households were asked whether they engage in commercial activities and type of commercial activities they undertake. Among survey respondents, only 48 households (9%) were engaged in commercial activities. Table 9 below summarizes the type of commercial activities.

The most common type of commercial activity in the rural areas is to engage in trading of live animals, grain and other agricultural products such as *quat*. Close to 36% of the commercial activities is constituted by trading of livestock and other agricultural products, followed by small shops which constitute close to a third of the business activities. The third dominant form of business activity is selling local drinks locally called *Suwa, Me'es etc.* The remaining commercial activities – selling food, tea & coffee; and hair dressing constitute only 8% and 4% of the business activities respectively.

Table 9: Types of commercial activities

Type of commercial activity	Frequency	Percentage
Small shops	16	33
Barber/Women's hair dresser	2	4
Selling local drinks	9	19
Selling food, tea, coffee	4	8
Trader (grain, livestock, *quat* etc)	17	36

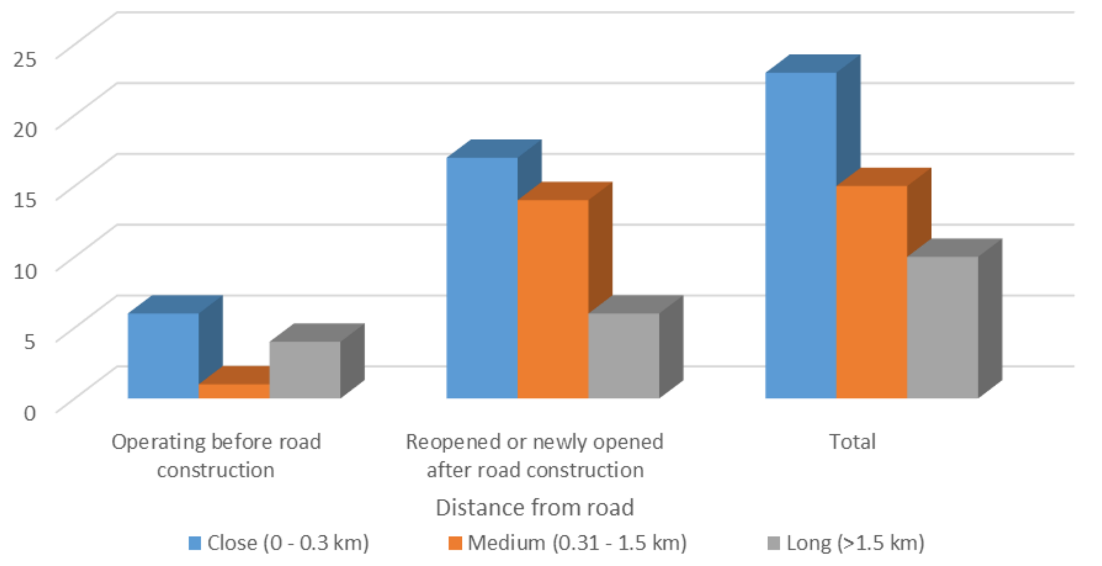
To relate the commercial activities to construction of rural roads, survey respondents were asked whether they started to engage in the business activities after/before construction of the rural roads. As indicated on table 10 below, most of the commercial activities were opened only after construction of the road (65%). If we add to this those that were operating before construction of the road but were closed for some time and reopened after the construction of the road, 77% of the business activities were opened or reopened due to the construction of the rural roads.

Table 10: Operation of commercial activities

	Frequency	Percent
Operating before construction of road	11	23
Reopened after construction of road	6	12
Opened after construction of road	31	65

Figure 13 below shows distribution of commercial activities by distance from road. Most of the newly opened and reopened businesses are concentrated in areas close to the rural road. As indicated in the figure, the number of newly opened and reopened businesses in the areas closer to road is almost three times that of the newly opened and reopened businesses in the areas far from the road.

Fig. 13: Distribution of commercial activities by distance from road



5.1.4. Distance from road and changes in marketing of agricultural products

Rural roads are believed to facilitate access to market. With construction of rural roads and possible expansion of rural transportation system, rural communities can increasingly interact in close and far off markets. In this survey, questions on sales of agricultural products and how marketing of agricultural products has been changed due to road construction have been asked. Table 11 below summarizes the result.

As the communities in the study sites are predominantly rural highly dependent on rainfall agriculture, most households sell cereals. The number of households engaged in vegetables and fruits market is quite small, not more than 8% of the rural communities.

Table 11: Participation of households in sales of products

Product type	No. of observation	Households engaged	
		Frequency	Percent
Cereals	528	389	74
Vegetables	528	43	8
Fruits	528	42	8
Other Products	528	128	24

To relate to construction of roads, survey respondents were asked how their sales of the agricultural products have changed after construction of the road and to what extent the changes are attributable to the road. Table 12 below indicates that most respondents engaged in sales of agricultural products believe that sales of their products has increased after construction of the road. Most of the changes are reflected in agricultural products primarily produced for the market such as vegetables, fruits and other permanent tree products such as *quat, eucalyptus etc,* where more than 80 percent of the respondents said that their sales of these products has increased after the construction of the road. However, the increase in sales may or may not be attributed to the construction of roads. The last two columns indicate how respondents attribute the changes to the roads. About a quarter to a third of the respondents believe that all the changes are attributed fully to the construction of roads. Without the road, such changes would not have been possible. Most, however, believe the changes are partly attributed to road and partly to other factors. In general, it can be observed that construction of the rural roads has enhanced marketing of agricultural products.

Table 12: Changes in sales of agricultural products

Product type	Change of sales			Change of sales attributed to road	
	Increase	Decrease	No change	All of the change	Part of the change
Cereals	69	3	28	24	74
Vegetables	81		19	34	66
Fruits	81		19	35	65
Other products	87	2	11	34	64

5.1.5. Negative Effects of roads (Road Side Effects):

Besides mobility and positive impacts on welfare of households, roads can have unwanted consequences. As rural communities highly dependent on agriculture, farming land can be used for construction of roads and hence households can permanently lose their main income source. At the same time, roads can also affect the livelihood of rural households through flooding, water logging, increased erosion, dust clouds etc. These can have negative impact on income of households and hence reduce their welfare.

In the survey, households were asked if they have lost land for road construction. About 14% of the respondents said that they have permanently lost farm land for road construction. The size of land lost ranges from a minimum of 2 m2 to a maximum of 2500 m2 averaging at 335 M2. Given the high dependence of the local communities on agriculture for their livelihood and the fact that land holding in the region is generally small (the average land size is one-half of a hectare, i.e., 5000m2), land lost to road construction causes significant income lose to these households. The table below summarizes response of households on how land lost to road construction has affected their agricultural production. Results indicate that about 48% of the respondents who lost their land to road construction said that their agricultural production has fallen remarkably and 36% said their agricultural production has declined slightly due to the land lost for road construction. Only close to 16% of the respondents said that the loss of land does not affect their agricultural production. For this group, the effect is negligible probably because of the small (negligible) size of land that they lost. The average land lost for this group is 185 M^2 which is much lower than the average land lost for the other two groups.

Table 13: Effect of lost land on household agricultural production

Effect on agricultural production	Average land lost(M^2)	Frequency	Percent
Does not affect agricultural production	185	10	16
Reduces household agricultural production slightly	290	22	36
Reduces household agricultural production remarkably	427	30	48

Furthermore, the effect of the rural roads on household welfare and health through changes in flood, dust, erosion, sediment deposition and water logging is analyzed. The table below summarizes the percentage of households who reported that roads have increased the occurrence of flooding, water logging, erosion, sediment deposition, dust and weeds. The three most common consequences cited by respondents in the order of number of respondents are dust, flooding and erosion. Close to 44% of the respondents said that the occurrence of dust has increased after construction of the road. The second most occurrence reported by 34% of the respondents is flooding followed by erosion where 29% said it has increased after construction of road. The least common consequences of roads cited by respondents are sediment deposition, water logging and occurrence of weeds.

Figure 14: Dust lifted up by heavy truck and even by bajaj in Tigray region

However, all households who reported changes in any of the consequences may not be directly affected by the problem. The last column of table 14 indicates the frequency and percentage of households directly affected through reduction of production of crops and/or income as a result of the various effects of construction of roads. Close to 11% of the sample households faced a decline in crop production and/or income due to dust lifted up by trucks from roads. There are a number of evidences that dust can have both physical and chemical impact on crops. Dust on plants can smother the leaves, block stomata and obstruct photosynthetic activities (Rahul and Jain, 2014). Moreover, dust particles can interfere with the mechanisms of stomatal pores. The dust accumulation on leaf surfaces causes conditions similar to water stress, such as a reduction of stomata conductance, photosynthesis and transpiration and increased leaf temperature (Zia-Khan et al., 2015). A study conducted on cotton plants showed 28% reduction in yield due to dust deposition (Zia-Khan et al., 2015).Following dust, flooding and erosion are the other two factors that negatively affected crop production and/or income of nearly 8% and 7% of the sampled households respectively.

Table 14: Effects of roads on flooding, erosion, water logging, sediment deposition and dust

Effect of road	**No. of observations**	**Frequency**	**Percent**	**Proportion of households whose crop production/income is affected**	
				Frequency	percent
Increased flooding along road	525	179	34	41	8
Water logging along road	525	61	12	9	2
Erosion along road	525	153	29	34	7
Sediment deposition along road	525	95	18	21	4
Dust clouds along road	525	229	44	56	11
Occurrence of weeds along road	525	47	10	8	2

Respondents were further asked the magnitude of reduction in crop production and/or income of households that were directly affected by any of the aforementioned consequences of road construction. Results shown on the table below indicate that the loss in production reached up to 50% of crop production. However, for most households the loss in production ranges from 10 to 30% of crop production.

Table 15: Road side effects on crop production/income

Type of effect	No. of households directly affected	Amount of decrease in crop production/income		
		Less than 10%	Between 10 – 30%	Between 30 – 50%
Increased flooding along road	41	10 (24%)	24 (59%)	7(17%)
Water logging along the road	9	1 (11%)	6 (67%)	2 (22%)
Erosion along the road	34	15 (44%)	15 (44%)	4 (12%)
Sediment deposition along the road	21	8 (33%)	12 (57%)	2 (10%)
Dust along the road	49	14 (29%)	27 (55%)	8 (16%)
Occurrence of weed along the road	8		5 (63%)	3 (37%)

5.2. Statistical Results

The statistical analysis is made for seven outcome variables – number of trips per capita households made, access to motorized transport, use of fertilizer, commercial activities, road dust, flooding, and erosion - using linear regression and piecewise regression models in order to identify if threshold type relationship between outcome variables and distance to road can be established.

To quantify the magnitude of the effect of the road on the different welfare indicators and effects of road, we compared the Akaike's Information Criterion (AIC) values for the simple linear models, the piecewise regression model, and of an additional simple log linear model, which was identical to the first, except that we log-transformed distance to road.

A stepwise regression model was used to determine the other variables to include on the regression models. We included all household characteristics, income variables and some asset variables along with distance to road. The variables that were retained through the stepwise selection (see table 16 below) were used in the piecewise and linear regression models.

Table 16: Variables included in both the linear and piecewise regressions models

Response	Variables
Trip per capita	Sex of hh head, no. of children, marital status and hh size
Motorized transportation	Sex of hh head, no of children, marital status, hh size and income per capita
Use of fertilizer	Sex of hh head, age of hh head, land holding and hh size
Commercial activities	Sex of hh head, age of hh head and education of hh head
Road side effect – dust cloud	Age of hh head, level of education of hh head and income per capita
Road side effect – flooding	Income per captita and no. of adults
Road side effect – erosion	Income per capita and no. of children

Regression results are shown on table 17 below. We tested the significance of the slope of the relationship between distance to road and the response in the linear models. For the piecewise regression models, we tested the significance of the slope of the relationship between distance to the road before the breakpoint, and the significance of the “difference in slope parameter.” We compared overall model fit of the linear and piecewise regression models for each response using the Akaike Information Criteria (AIC) value.

We found a statistically significant difference in slope parameter and that the piecewise regressions models gave at least as good a fit to the data as the linear models for all the response variables except for number of trips per capita households made and effect of erosion on households.

The breakpoint occurred approximately at 2 to 3 km from the road for access to motorized transport which includes transportation by bus, car, bajaj etc., 1 to 2.6 km from the road for use of fertilizers, 1.5 to 1.53 km for commercial activities, 0.2 to 0.24 km for effects of road dust effect, and 0.67 to 0.74 km for flooding effect (table 17). For all the five response variables – access to motorized transportation, use of fertilizer, commercial activities, road dust, and flooding – there was also a statistically significant relationship with distance to the road up to the threshold distance (table 17). For trip per capita and effects of erosion, there was no significant change in slope in the piecewise regression models and the linear regression model gave a better fit than the piecewise regression model.

Table 17: Relationship between outcome variables and distance to road as measured by linear, log-linear and piecewise regressions

	Simple linear model		Log linear model		Piecewise regression model			
Response	AICs	Slope: Distance to road	AIC	slope: log(distance to road)	AIC	Breakpoint (km)	slope before breakpoint	difference in slop parameter
Trip per capita	6.4239	-0.0006357 ±0.0002***	6.4244	-0.5248077 ±0.1746***	6.4213	1.162871 ±0.589226**	-1.63418 ±1.1299	1.667077 ±1.184257
Motorize trans.	3.926561	-0.0002057 ±0.0000475***	3.932637	-0.1537283 ±0.0392254***	4.132065	2.582799 ±0.5999455***	-0.6803487 ±0.1315623***	0.8057044 ±0.2423928***
Fertilizer	10.84331	-0.0002489 ±0.0000343***	10.86748	-0.1762703 ±0.0320652***	11.12777	1.827203 ±0.7809998**	-25.4246 ±5.830958***	12.49647 ±7.562724*
Commerce	0.5814599	-0.0001687 ±0.0001486	0.578345	-0.1728623 ±0.0975074*	0.575394	1.509743 ±0.022683***	-0.7504323 ±0.5296078	1.178707 ±0.5754481**
Road Dust	0.5653387	-0.0022705 ±0.0004803***	0.562908	-0.7454171 ±0.1040662***	0.554017	0.2380927 ±0.0429969***	-8.35692 ±3.104761***	7.097131 ±3.138872**
Flooding	0.5145403	-0.6977623 ±0.2355912***	0.499878	-0.4607678 ±0.1020981***	0.520029	0.6984002 ±0.0270316***	-2.127998 ±1.112379*	2.091812 1.155207*
Erosion	0.4568031	-0.491879 ±0.2239143**	0.450038	-0.3546718 ±0.1099543***	0.462087	1.745005 ±1.041801*	-0.8228435 ±0.4713619*	0.7570253 ±0.647741

* significant at 10%; **significant at 5%; ***significant at 1%

Table 18 shows the best fitting models for the statistical analysis. Three of the seven outcome variables were fitted using simple linear regression, two using log linear regression and the remaining two using piecewise regression.

Table 18: Best fitting model

Type of effect	Best fitting regression model
No. of trips per capita	Simple linear
Frequency of use of motorized transport	Simple linear
Use of fertilizer	Simple linear
Engaged in commercial activities	Piecewise
Effect of road on dust clouds	Piecewise
Effect of road on flooding	Log linear
Effect of road on erosion	Log linear

Discussion:

Our results show that road influence zones delineated by thresholds exist for access to motorized transportation, use of fertilizers, commercial activities, road dust and flooding, and that the influences extend from up to 0.24 km in the case of road dust to about up to 2.6 km in the case of access to motorized transport from the road (table 19). The other two responses, number of trips per capita households make and erosion showed a significant linear negative response to distance from road, but not threshold type relationship.

Table 19: Threshold distance for road influence zone

Response	Breakpoint (km)
No. of trips per capita	NA
Motorized transport	2.58 ± 0.6
Fertilizer	1.83 ± 0.78
Commercial activities	1.51 ± 0.02
Dust cloud	0.24 ± 0.04
Flooding	0.7 ± 0.03
Erosion	NA

Our findings indicate that comparing linear and piecewise regressions is a useful method to quantify the shape of the distance response of the welfare and effects of road. However, for the statistically significant piecewise regression models, we found more than one estimate of the location of the breakpoint. This is likely a result of there being a zone in which threshold effects exist, rather than a sharp break.

There is no threshold effect observed for number of trips per capita households make. This is mainly due to the fact that most trips in the rural areas of Ethiopia including in the study sites are made on foot. Walking is the dominant mode of transportation used. For walking roads are not required and that is why threshold effect could not be observed in number of trips per capita households make.

For the responses in which threshold type relationship is observed, the threshold effects occurred at different distances from the road. Considering the number of times (frequency) household members use motorized transport such as cars, buses, bajaj etc in a typical month as a proxy for access to motorized transport, we observe that a threshold for access to motorized transport exists at a distance of about 2.6 km from both sides of the road. Although different other factors such as the topography of the land, the terrain etc can affect people's ability to access motorized transportation, the idea of the above threshold is that in the study areas, people up to 2.6 km on both sides of the road travel to the place where they can get motorized transport.

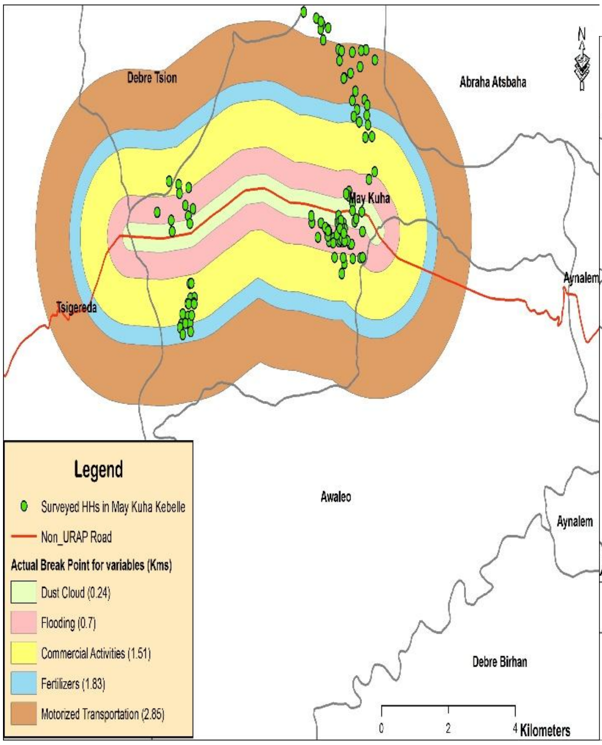
Similar to access to motorized transportation, threshold type relationships are observed in application of fertilizers and commercial activities. For application (use) of fertilizers, the threshold occurs at a distance of about 1.83 km from both sides of the road. Among other factors, access to road has an influence on use of fertilizers. However, the influence is well perceived in a radius of 1.83 km from the road.

Similarly, commercial activities in the rural areas, although very limited, are influenced by road. The influence of rural roads on commercial activities is well perceived in the range of 1.5 km from both sides of a road. After all, most of the commercial activities in the study cites were opened only after the construction of the road.

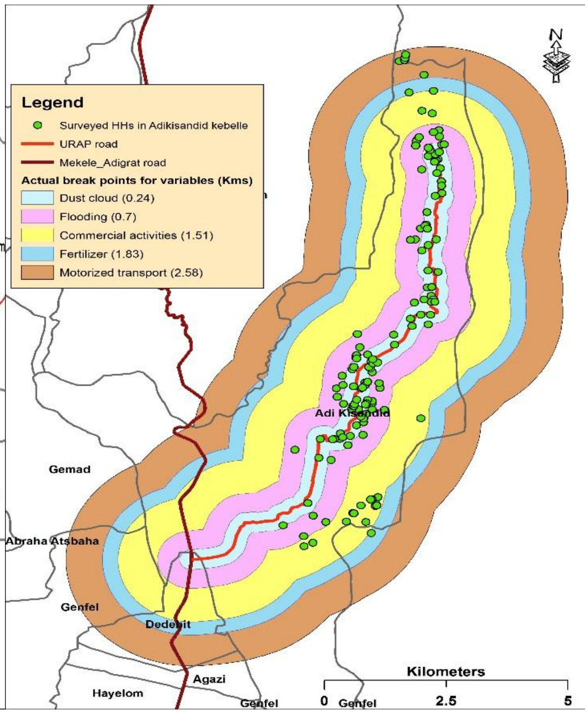
Finally, roads can also have negative consequences. The two typical consequences reported in this case are road dust and flooding. Threshold type relationship has been observed between distance to road and the road side effects. The effect of dust that is lifted up when cars especially heavy trucks use the rural roads is typically felt in a radius of 240 meters from both sides of the road. In a similar way, floods coming out of the roads especially from the road culverts influence households or areas in the range of 0.7 km on both sides of the road.

Figure 15 below shows the influence map for the selected indicators for each of the four study sites. Depending on the distance of the settlement of households from the road, the road influence zone is different for the different study sites. In case of the lowlands (Hade Alga and Werebaye), the settlement is so disperse that there are a good number of households who lie outside the influence zone of the different indictors including motorized transport. On the other hand, in the highland tabias mainly on tabia Adi Kisanded where most households reside along both sides of the road, the influence of the road on the community is large even in the case of road dust where the influence dimension is the smallest of all, which is 200 meters from both sides of the road.

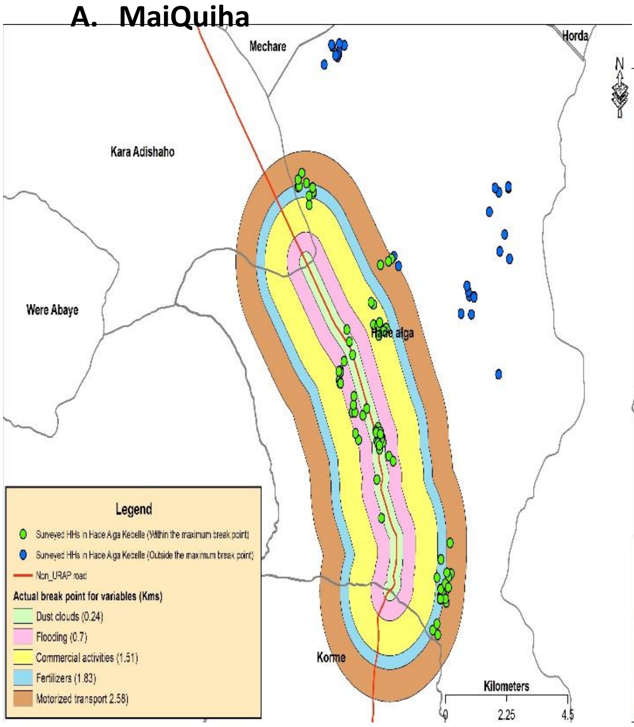
Figure 15: Map of Road Influence Zone



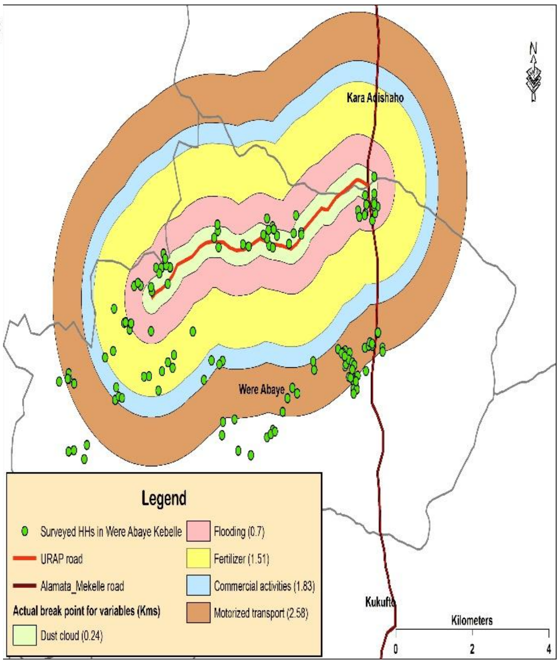
A. MaiQuiha



B. Adi Ksanded



C. Hade Alga



D. Werebaye

6. Conclusion

This study investigates the influence zone of rural roads on socio economic development in rural Tigray. To do so, the study used four rural roads – two rural roads and the other two regional highways – and a sample of 529 rural households in all the four study sites. Both descriptive and statistical analysis were used.

The descriptive analysis was made on rural mobility and selected welfare indicators namely non-farm activities, agricultural extension and marketing of agricultural products. Results indicate that rural roads contribute to the socio economic development of rural livelihoods.

Households in the study areas traveled on average 14 trips per month per person. However, most of these mobility are made by "walking". What is abundantly clear in all the study sites is that when roads enhance mobility they do so in association with wheeled or motorized transport easing people's movement and making them faster and capable of achieving longer distance. This can have influence on the social economic development when the time saved and distances bridged provide either greater economic opportunities or better access to social services or useful social contacts. Although limited in terms of the number of users, next to walking the dominant mode of transport observed in the study sites is motorized transport. Motorized transport especially the use of buses is correlated with wealth indicating the fact that road improvement alone may not enhance the mobility of the rural poor. The poor require better access to wheeled or motorized transport to utilize a road. Recently a new development in this regard is the use of the three wheeled motor locally called *bajaj*. It is increasingly becoming an important mode of transportation from villages to the main road. Unlike the other motorized transport like buses, it is not significantly correlated to wealth.

Besides wealth, location of households also play an important role to benefit from roads. Classifying distance of location of households from road into three – close, medium and far – results indicate that households located close to the road are more mobile both in terms of number of trips and average distance traveled than households located far from the road. Households located close to road traveled on average five more trips per month than households located far from road. There is also significant difference in use of motorized transport. While households located closer to road travel on average 10 trips per month by motorized transport the figure for households located far from road is 6 trips per month.

Differences on the socio economic influence of roads on households located at different distance from road leads to the question of whether there exists a threshold pattern so that one can delineate the road influence zone. In this regard, threshold analysis is made for selected welfare indicators and road side effects. Our statistical analysis result indicate that for most of the selected outcome variables, threshold pattern is observed. In this way, threshold pattern is observed in the influence of roads on use of motorized transport, use of fertilizers, commercial activities that the rural households engage and on two effects of roads – dust and flooding. However, threshold patterns are not observed on number of trips households make. The fact that the study sites are overwhelmingly a walking world, and as walking does not require roads, threshold effects are not observed on mobility as proxied by number of trips rural communities make.

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