Access to the North-South Roads and Farm Profits in Rural Nepal

Slesh A. Shrestha*
University of Michigan

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Abstract

Transportation infrastructure in rural areas is an important development strategy in low-income countries. However, accurate estimates of the economic benefits from such investments are limited. Comparing regions with various degrees of infrastructure gives a biased estimate of its effect on economic development because development in and of itself also increases demand for infrastructure. I overcome this endogeneity by constructing an instrument for road networks based on a unique geographic feature that partly determines the placement of rural roads in Nepal. The cheaper cost of constructing a north-south road relative to an east-west road to connect the district headquarters led to greater access for villages in north-south hinterlands relative to those in east-west hinterlands. I use this to develop an instrumental variable strategy and find that the value of farmland appreciates by 0.25 percent when the travel time to the nearest road decreases by 1 percent.

*Department of Economics, University of Michigan, Ann Arbor, MI 48104. Email slesh@umich.edu.
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1 Introduction

Rural transportation is an important development strategy in low-income countries. It enhances economic gains for agrarian households by providing easier access to both input and output markets. Moreover, such gains are likely to have a substantial impact on poverty reduction because the poor are concentrated in the rural agricultural sector, where transportation infrastructure is most scarce.[1]

The World Bank in 2005 invested more than $8 billion US dollars on infrastructure in developing countries, which accounts for 35 percent of their total lending (World Bank, 2006). But measuring economic benefits of these large investments is difficult because of reverse causality. Although past economic growths are often always accompanied by rapid expansion of infrastructure, such strong correlations do not imply that investments on infrastructure will promote growth. On one hand, comparing regions with various degrees of infrastructure could overestimate its effect on economic development because development in and of itself also increases demand for infrastructure. On the other hand, given Burgess and Jedwab (2010) find that political appointees considerably influence road allcoation across region, if political power and economic wealth are negatively correlated, this will bias the estimate of the effect of infrastructure towards zero. I overcome the endogeneity bias by utilizing a unique geographic feature that exogenously determines the placement of road in rural Nepal and estimate the impact on its agricultural economy.

Nepal is one of the poorest countries in the world with a dominant agriculture sector and a sparse road network due to an extremely rugged terrain. Based on 2001 Nepal census data, 44 percent of its population including 3.3 million poor live in the hills, out

[1]50 percent of the poor in Nepal live in rural areas and are involved in agricultural production. Rural areas are often characterized by rugged terrain, sparse population, and isolation, thereby making effective transportation infrastructure for market integration even more crucial.

of which 75 percent of them rely on agriculture for their livelihoods. The rough terrain poses a serious challenge for road construction, which is reflected by one of the lowest road densities in the world.[2] Nevertheless, in the last four decades the government constructed 15,308 kilometers of roads by relying significantly on international donors, expanding from a meager length of 376 km in 1951.[3]

The main purpose of these roads is to connect district headquarters, which are historical fort towns that currently serve as administrative centers. The government's 20-Year Road Plan in 2001 adopted five main objectives, the top of which was "strengthening political and administrative linkages." Shrestha (2001) points out that the economic consideration is always secondary to the administrative consideration in constructing rural roads. More importantly, because all mountains in the region span north-south, it is cheaper to construct a north-south road, which follows one of such mountain ranges, relative to constructing an east-west road that has to cross multiple mountains via bridges.[4] This unique geographic feature has resulted in a road network that includes a single east-west highway that stretches the entire country and multiple north-south roads, which connect to this highway at various locations. Each north-south road connects several district headquarters that are situated directly north of its junction with the east-west highway.

I use this geographic north-south corridors to construct an instrumental variable to

[2] In 2007, the road density in Nepal was 121 km/100 km^2 or 0.8 km per 1,000 people. Only 43 percent of the rural population have access to all-season road and the average distance to the nearest transportation stop in rural area is 30 kilometers. 60 percent have access to roads within two-hours walking distance, while 23 percent are beyond a four-hour walk.

[3] According to the World Bank, Nepal's road network annually increased by 6.7% between 1995 and 2004 with the largest expansion occurring in roads classified as "district or rural roads", which grew annually by 11% during this period. Based on the "Twenty Year Road Plan" published by the Ministry of Physical Planning and Work, Department of Roads, the public road expenditure accounted for 12 percent of the total national budget in 2001.

[4] In 2001, the cost of constructing two-lane bridge in the hill region was estimated to be half a million rupees per meter. In the same year, the construction of bridges comprised of more than 30 percent of the total government funding on road development, and 15 percent of the total road investments based on the estimates from the Ministry of Finance. This illustrates that the construction of bridges constitutes a significant cost burden on any road project's total budget.

deal with the endogeneity issue of where the road is constructed. In particular, I divide the country into 10 equal north-south blocks and connect all the district headquarters within each block with its nearest district headquarter by using a straight line.[5] Dividing the country into such north-south blocks ensures that the district headquaters are connected along the north-south direction rather than east-west direction, as suggested by the geographic feature of mountains. I also connect the district headquarter that is closest to the east-west highway within each block to that highway via a shortest distance, which results in 10 north-south lines connecting all the district headquarters in the hills to the east-west highway. Although 10 north-south blocks are based on the actual political and administrative division of Nepal,[6] I repeat the algorithm using 12 north-south blocks and show that the results are robust to my choice of the algorithm parameter. Lastly, I show that the distance to these straight lines is a strong predictor of household's proximity to road. Moreover, the construction of the straight lines are based on two factors, administrative integration and geographic feature that favors north-south linkages, both of which are likely to be independent of the socio-economic characteristics of households in the hinterlands.

My empirical method improves the identification strategies used by previous studies. While Banerjee et al. (2009) and Atack et al. (2009) construct a straight line connecting important historical cities to predict modern railway network, their instruments coincide with historical trade corridors and therefore could be correlated with unobserved characteristics that are associated with living close to a historical route. In contrast, I confine the linkage to a north-south direction making it less likely to be correlated with historical trade routes, which stretch in both an east-west and a north-south directions

[5]As seen in figures 3 and 4, the following algorithm leads to some district headquarters being connected to multiple other district headquarters because the nearest district headquarter pairs are not symmetric i. e. the district headquarter that is nearest to another district headquarter does not always imply that the later district headquater is also the nearest district headquarter of the former.

[6]Nepal is divided into 5 political and administrative regions, as shown in figure 6. The five pairs of these adjoining north-south blocks coicide well with these 5 administrative regions.

according to Stiller (1976).[7] Jacoby and Minten (2008) include transportation costs directly into a nonparametric model, while arguing that the differences in transportation costs are due to geographic terrain. The costs are significantly higher at the top of the mountain relative to the bottom. However, elevation could be correlated with land productivity as well as household's unobserved characteristics, especially if poor households are more likely to settle at higher elevations due to cheaper access to those lands. Apart from the physical feature of the terrain, my empirical strategy also relies on an administrative integration policy to explain the variation in access to road, and therefore, allows for appropriate controls of terrain quality such as elevation and land gradient.

Using cross-sectional household data from 2011 Nepal Living Standard Survey and geo-spatial data from MENRIS, I estimate a 2SLS model to calculate the effect of roads on household profit from agriculture as measured by the farm value. If farms behave like assets,[8] the improvement in farm's future profits due to lower transportation cost should be reflected in its value. This approach is used by Arnott and Stiglitz (1981) and Jacoby (2000) to circumvent the daunting task of calculating actual farm profits. Household surveys in low-income countries lack accurate information on farm profits, partly because many input purchases and sales of output are conducted informally through non-monetary transfers.

My results suggest that decreasing a household's travel time to the nearest road by one percent increases its farm value by 0.25 percent. The 2SLS estimates are statistically significant at the 5 percent level and are robust to the algorithm parameters used to construct the line. While earlier infrastructure studies like Michaels (2008) and

[7]Based on Stiller (1976) and Shrestha (2001), communications between district headquarters were historically carried out through foot trails that stretched east-west as well as north-south by connecting the district headquarters via a shortest distance, and they constituted the central nerve of the hill economy prior to the construction of roads.

[8]The standard asset-pricing model states that the present value of a plot is equal to the discounted sum of its future profits. This hypothesis is tested on rented farm plots later in the paper.

Donaldson (2010) focus on price convergence from the view point of trade framework, I estimate household-specific economic gains from infrastructure investments. Because most of the world's poor inhabit rural areas and agriculture accounts for a significant fraction of a rural economy, the results directly contribute towards the government's goal to reduce poverty. Mansuri et al. (2012a) and Mansuri et al. (2012b) find that farm productivity and commercialization are two important determinants of escaping poverty in rural Pakistan and Uganda, both of which are likely to be directly affected by access to transportation (Fafchamps and Hill, 2005; Gollin and Rogerson, 2010). These results are consistent with my findings and together they highlight the benefits of rural transportation investments on agriculture, poverty alleviation, and food security.

The rest of the paper is structured as follows: Section 2 describes the geographic feature that influences road network in Nepal. Section 3 presents a theoretical model that illustrates the benefits of road projects on farm profits. Section 4 explains the identification used for causal estimation and Section 5 describes the data used for this strategy. Section 5 presents the empirical results and Section 7 concludes.

2 Background

Nepal is a landlocked country with isolated, localized economies referred to by Shrestha and Jain (1977) as "pocket economies". This fragmentation is a direct manifestation of its extremely rugged terrain, which has seriously undermined the development of adequate communication and transportation infrastructure (Shrestha, 2004). 77 percent of its land surface is covered by mountains and hills, with an exception of the Terrai plain in the south. The elevation in the hill region changes sharply from only 80 meters above sea level to more than 8800 meters within a stretch of just 100 kilometers, making road construction very difficult. As a result, road density is only 14 km/100 km^2 or 0.8 km per 1,000 people, which is one of the lowest in the world (Meyer, 2008). Figure 1 illustrates the rough landscape that covers almost the entire country.

Despite such rugged terrain, almost half of the population live in the hills where poverty incidence of 35 percent is the highest among all the regions (NLSS, 2004). According to Upadhyaya (2010), majority of these poor own small, fragmented landholdings and rely on subsistence farming for their livelihoods.[9] Moreover, most of the hill lands are steeply sloped, highly vulnerable to soil erosion, and impervious to irrigation, leading to an extremely low farm productivity (UNDP, 2002). These factors, together with a poor access to input and output markets due to sparse road network, severely restrict the economic gains from farming and worsen the food security problem in the region.[10] Therefore, the government has emphasized the construction of roads in the hill region as an important means to fight poverty.[11]

One of such infrastructure projects is the construction of the East West Highway (EWH), which began in the late 1950s but was only completed in the early 2000s. EWH spans the entire country along its southern border with India in the Terrai plain, with the total length of 1024 kilometers. It is the longest and the most important highway in Nepal. According to Shrestha (2004), it is the backbone of Nepal's road network and plays a significant role in fostering social, economic, and political integration, by connecting all the major regional economies.

Although expanding the road network is an important government strategy for poverty reduction, its chief purpose is geared towards administrative integration by stressing the linkage between district headquarters. These are historical fort towns, which are scattered throughout the hill tops, and were converted into administrative

[9] 46 percent of the land owning households in the hills own less than 0.5 hectare of agricultural land.

[10] Based on the estimates by the International Fund for Agricultural Development (IFAD), more than 48 percent of children under 5 years of age are malnourished in the rural areas of Nepal.

[11] The Government of Nepal's Interim Three Year Plan (2007-2010) strongly emphasizes the role of roads in reducing poverty in rural areas, by improving rural access and prompting higher agricultural output as well as non-farm income in remote hill areas of the country.

centers under the current political system. According to Shrestha (2001), the economic consideration have and still remains secondary to the administrative consideration in determining the construction of rural highways. The national transportation policy of the government states that "high priority shall be given to completing north-south roads connecting all 75 district headquarters to the main highway."

2.1 North-South Road

North-South (NS) roads are the most cost effective way of connecting district headquarters due to a geographic feature of the region, especially after the completion of EWH. All mountain ranges in the hill region span north-south followed by deep and narrow valleys or rivers on either sides. Consequently, a rural road is constructed by following one of such mountains from north to south until the road joins EWH in the Terrai plain. In contrast to constructing roads that stretch east-west, NS roads cross fewer mountain ranges and therefore require fewer number of bridges, which significantly reduces costs. Based on figures from the Finance Ministry, bridge construction accounts for more than 30 percent of the government's funding on road projects and 15 percent of its total road expenditure, which suggests that building a bridge constitutes a significant cost burden on a project's budget. Therefore, district headquarters are connected to the national road network via NS roads that all feed into EWH. The Twenty Year Road Plan published by the Ministry of Physical Planning, emphasizes the construction of NS roads and highlights the government's reliance on NS roads to achieve its goal of administrative integration.

Transportation and communications between district headquarters were historically carried out through numerous foot trails that stretch east-west as well as north-south, connecting the district headquarters via a shortest distance (Stiller, 1976). Figure 2 shows all the foot trails that span across the country. According to Shrestha (2001), the network of walking paths across the hills consisted of rope bridges, ferries, and other means of crossing between mountain ranges and prior to EWH, they constituted the central nerve of the hill economy. This implies that the recently constructed NS roads are likely to be uncorrelated with these foot trails that formed the trade link between district headquarters in the past. More importantly, the construction of NS roads in order to connect the district headquarters to EWH led to an exogenous increase in access to road for villages in north-south hinterlands relative to those in east-west hinterlands.

3 Theory

Farmers cultivate a single crop using two factors of production, x kg per hectare of chemical fertilizer and l hours per hectare of labor. Using a fixed technology, their crop yield y (kg per hectare) is given by the neoclassical production function $y = f(x, l)$. All farmers trade agricultural output and fertilizer in a competitive market centers located at the juncture of a rural road and the main highway.[12] The transportation of goods between farms and their nearest market center involves two components– head-loading goods between the farm and the road using human porters and trucking goods along the road, the former constituting the majority share of the total transportation cost.[13]

From a given farm, it takes h hours to reach the nearest road junction and the portage cost of goods is t Rupees/ (kg hours). If k and p be the prices of fertilizers and

[12] As explained in the earlier section, the road network in Nepal comprises of EWH, which runs through the entire country, with various NS roads feeding into this main highway from the north at various locations along its length.

[13] This feature is likely to closely match the reality on the ground for most rural farmers in the hills, where almost six million people or 23% of the population still live more than four hours' walk away from the closest road. The markets at intermediate points between the farms and the road are an inessential complication because goods still need to be head-loaded from the road junction, the cost of which will be reflected on their prices at these intermediate market centers.

outputs in the market center, respectively, then the effective purchase price of fertilizer is $\widetilde{k} = k + th$ Rupees/kg and the effective selling price of output is $\widetilde{p} = p - th$ Rupees/kg.[14] Let w be the wage rate of agricultural work. The per hectare land rent, r, can be defined as the maximal profit that can be earned from a hectare of land,

$$r\,(w,\,\widetilde{k},\widetilde{p}\,) \equiv max_{l,x}\,(\widetilde{p}y - wl - \widetilde{k}x\,) \tag{1}$$

Moreover, using the envelope theorem, the relationship between land rent and travel time to the nearest road is given by:

$$\frac{d\,r(w,\widetilde{k},\widetilde{p})}{d\,h} = -t(y+x) < 0 \tag{2}$$

The above equation implies that an improved access to roads for farmers increases their agricultural profit and therefore, raises the per hectare rent (r) of their plots. The negative rent gradient is equal to the total portage cost per hour per hectare.

4 Empirical Strategy

While the theoretical analysis above is framed in terms of land rents that capture the economic profits from cultivation, I use plot values in the empirical analysis instead.[15] According to the standard asset-pricing model, the present value of a plot is equal to the discounted sum of its future profits, given by

$$log\,(V) = log\,[\,r(w,\,\widetilde{k},\widetilde{p})\,] - log\,(b) \tag{3}$$

[14]The price of goods, k and p, are assumed not to vary across the market centers along the main highway (EWH). However, this assumption is relaxed in the empirical analysis with the inclusion of district (regional) fixed effects.

[15]Nepal Living Standard Survey 2011, a nationally representative survey, collects detailed information on each plot owned by the household, its soil and irrigation characteristics, and its market value measured by the survey question, "If you wanted to buy/sell a plot exactly like this, how much would it cost/fetch you? "

where V is the present market value and b is the constant discount rate. Although the above equation provides a valuable link between observable land values and mostly unobservable land rents, the relationship may not be valid in Nepal because of land and credit markets distortions. If land is the sole form of collateral for loans, its price could capture its collateral value on top of the discounted future revenue stream from its rent (Chalamwong and Feder, 1988). Therefore, proving the validity of the asset pricing model requires estimating the following regression

$$log\,(V) \quad = \nu_0 \,+\, \nu_1\, log(r) \,+\, \varepsilon \tag{4}$$

and testing whether the coefficient estimate $v_1 = 1$. If this condition holds, then estimating the log-rent function of a plot is equivalent to estimating its log-value function, up to a constant.

4.1 Instrumental Variable

The empirical strategy to overcome selection bias is based on the unique geographic feature of Nepal. As described in the section above, all mountain ranges stretch north-south that results in a cheaper construction of roads that also run in the same direction. I use this feature to predict the placement of rural roads and implement an instrumental variable strategy to estimate the economic gains from better road accessibility for agrarian households living in the hills.

I take district headquarters that lie north of EWH and connect them using a simple algorithm. First, I divide the country into 10 north-south blocks based on equal longitudinal spacing. The five pairs of these adjoining blocks coincide well with the 5 development regions of Nepal,[16] with each block embodying 6 district headquarters on

[16]Nepal is divided into 5 development regions: Eastern, Central, Western, Mid-Western, and Far-Western regions, starting from east to west. Figure 6 maps these 5 development regions.

average. Within each block, I draw a straight line from each district headquarter to the nearest other district headquarter. Some district headquarters could be connected to multiple district headquarters because the nearest-headquarter pairs are not always symmetric.[17] Furthermore, restricting the connections to a north-south block ensures that the district headquarters are connected in a north-south direction rather than an east-west direction, which is an important feature of the intrumental variable strategy. Lastly, I connect the district headquarter within each block that is closest to EWH with EWH via a shortest straight line. The following algorithm results in 10 separete north-south linakges connecting the district headquarters to EWH. Figure 3 illustrates the 10 geographic blocks, the straight lines connecting the district headquarters, and EWH; whereas, figure 4 shows the five development regions. While 10 north-south blocks are based on the actual administrative division of Nepal, figure 5 shows the outcome of a similar exercise, but using 12 geographic blocks instead of 10 for alternate north-south linkages.

The straight line serves a proxy for NS road in the hill region. Whether the line drawn this way coincides well with actual road network can be tested, by estimating the correlation between the distance to the line and distance to road using the following regression framework:

$$log\,(T_{id}) \quad = \; \alpha \; + \eta_d \; + \beta \; log\,(D_{id}) \; + \varepsilon \tag{5}$$

where T_{id} is the distance to the nearest road for rural household i living in district d, D_{id} is the distance to the nearest line, and η_d is district fixed effects. More importantly, D_{id} is influenced by two factors– administrative need to connect district headquarters

[17] Suppose there are three district headquarters A, B, and C. If A is the nearest district headquarter to B and vice versa, whereas the nearest district headquarter to C is also A, then district headquarter A will be connected to both district headquarters B and C by using the above algorithm.

and the geographic feature that favors north-south linkages. Both of them are likely to be independent of the socio-economic conditions of communities in the hinterlands, providing a plausibly exogenous variation in access to infrastructure for households in these regions.

The use of $log(D_{id})$ variable as an instrument to estimate the effect of road on farm profits requires satisfying the exclusion restriction. One potential concern in this strategy is that D_{id} could be picking household's proximity to the district headquarter itself, which in turn, directly affects farm profits and market land values. To address this, I control for the distance to the nearest district headquarter as well as the distance to EWH. Banerjee et al. (2009) point out that the distance to the straight line joining two cities in China violates the exclusion restriction because it also coincides with the historical trade routes between those cities. In contrast, the historical routes connecting any two cities in Nepal are equally likely to stretch east-west as well as north-south,[18] while the line is restricted to a north-south direction. Nevertheless I control for the distance to the nearest foot trails, which constitute the main channel through which all trades were carried out between two cities before the construction of highways as pointed out by Stiller (1976). Finally, D_{id} could also be correlated with the physical attributes of the agricultural land that directly affect its productivity and profits, I control for geographical characteristics such as distance to river, elevation, and land gradient as well as productivity variables such as suitability for rice plantation (the main staple crop of the region) and irrigation. Therefore, the 2SLS model to estimate of the effect of road on farm profits is given by

$$\begin{aligned} log\,(T_{id}) \;=\; & \alpha' + \eta_{1d} \;+ \beta'\; log\,(D_{id}) \;+ \gamma'\; log\,(Q_{id}) \;+ \delta'\; log\,(R_{id}) + \theta' log\,(M_{id}) + \\ & \zeta'\; log\,(F_{id}) \;+ \xi'\; E_{pid} \;+ \vartheta'\; G_{pid} \;+ \psi'\; log\,(A_{pid}) \;+ \Phi'\; \bar{X}_{pid} \;+ \varepsilon' \end{aligned} \tag{6}$$

[18] See figure 2 for the mapping of historical trade routes across the country.

$$\begin{aligned} log\,(V_{pid}) \;=\; & \alpha \;+\eta_{1d} \;+\beta \; log\,(T_{id}) \;+\gamma \; log\,(Q_{id}) \;+\delta \; log\,(R_{id}) \;+\theta \; log\,(M_{id}) \;+ \\ & \zeta \; log\,(F_{id}) \;+\xi \; E_{pid} \;+\vartheta \; G_{pid} \;+\psi \; log\,(A_{pid}) \;+\Phi \; \bar{X}_{pid} \;+\varepsilon \end{aligned} \tag{7}$$

where V_{pid} is a market value of plot p owned by household i living in district d; η_{id} is a district dummy for each d; Q_{id} is the distance to the nearest district headquarter for household i in district d; R_{id} is the distance to the nearest river; M_{id} is the shortest distance to EWH; F_{id} is the distance to the nearest walking trails; E_{pid} is an elevation in meters; G_{pid} is a land gradient; A_{pid} is a total area of plot p owned by household i in hectares; $\bar{X}_{pid}$ is a vector of plot level characteristics.

The excluded instrument from the land value equation i.e. equation (7) is the log distance to the line. The effect of road is identified by variation in the household's access to road due to its proximity to the north-south line connecting two district headquarters. As discussed above, since the land value equation also includes distance variables and plot characteristics, the instrument is likely to be uncorrelated with the error term ε. Under these conditions, the estimation of β in equation (7) using 2SLS, is interpreted as the causal effect of improved access to road on agricultural profits.

5 Data

The data for this study come from two major sources. The household information on agriculture and access to infrastructure is obtained from the 2011 Nepal Living Standards Survey (NLSS). It is a nationwide survey collected by the Central Bureau of Statistics with a stratified random sample of 5988 households, out of which 2058 households reside in the rural hill region with farmland. The Survey includes detailed agriculture module with information on all individual plots owned or leased by the household, along with its area, quality, market value, irrigation, and the net rent received by the household if the plot was leased out. Additionally, it collects information on household's access to various facilities, including the nearest paved road, in terms of travel time. Travel time measures are more useful than actual distance calculated using satellite telemetry because of mountainous terrain.

A unique feature of the 2011 NLSS is that it provides GIS information on the location of its households. I use this GIS data to merge the Mountain Environment and Natural Resources' Information System (MENRIS) data for the NLSS sample households. The MENRIS geospatial data is collected by the International Centre for Integrated Mountain Development, ICIMOD, and has information on elevation, foot trails, and river paths for the Hindu Kush Himalaya region including Nepal. I use this to construct all the distance variables including the instrumental variable, and terrain characteristics such as land gradient.

Table 1 provides summary statistics for rural households residing in the hills that own a farmland along with their plot characteristics. An average landholdings of a household is only 0.62 ha, with an average plot size of 0.19 ha. 30 percent of the plots are categorized as being suitable for rice cultivation; whereas, almost 70 percent of all plots do not have access to irrigation in any agriculture season.

6 Results

The relationship between rent and market value of a plot, as described by the asset-pricing model, can be established by estimating equation (4). Table 2 presents the estimate of coefficient η_1 in equation (4), by using 321 plots that were either rented out in both agricultural seasons or in the wet season. These plots were rented mainly through sharecropping and account for about 5 % of the total plots owned. Their net rents are calculated by summing the rents across both seasons and including the value of in-kind payments, while the costs of inputs provided by the tenants are deducted. The mean rent to value ratio ($\frac{r}{V}$) is 0.055, which can be interpreted as an estimate of the discount rate b.[19]

The OLS estimate of η_1 in column 1 assumes that the log rent is uncorrelated with the error term. Although the estimate is less that one, attenuation bias because of random measurement error in rents could bias the estimate towards zero, as pointed out by Jacoby (2000). Therefore, the specifications in columns 2 and 3 instrument rents with plot area and column 3 additionally includes district fixed effects. The estimates, 1.12 and 1.08 respectively, are accurate and not statistically different from unity even at the 10 % level, and therefore the validity of the asset pricing model cannot be rejected.

Table 3 estimates of the impact of transportation infrastructure on the economic gains from agriculture using a log-linear specification described by equation (7). Because farmland behaves like an asset as proven by the results from table 2, higher farm profits because of lower transportation costs should be capitalized in farmland values. Therefore, the total economic benefits of having better road accessibility for agrarian households can be calculated by estimating β, the coefficient of the log travel time to road in equation (7), where the dependent variable is the log value of farmlands. Only controlling for the size of farmland, the OLS estimate of β in column 1 is statistically significant at the 1 percent level and its value of -0.19 implies that that an increase in the travel time to the nearest road by 10 percent decreases the value of the farmland by 1.9 percent. However, profitable plots may encourage larger road investments or rural roads may be more abundant in relatively more productive regions. The inclusion of plot characteristics in columns 2 and 3, and district fixed effects in column 3, ameliorates the endogeneity problem as long as the location of roads are determined by observed plot charateristics or by unobserved characteristics of the district and not by unobserved

[19] Jacoby (2000) also finds the rent to value ratio among rented lands in Nepal using 1996 NLSS to be 0.055.

characteristics of the specific plots within the district. While the estimate in coulmn 3 implies a strong positive effect of road on farm value, nevertheless, unobserved socio-economic and political factors may influence road allocation within the district, which could bias the above OLS estimates in either direction and necessitate the use of an instrumental variable strategy to overcome the potential endogeneity bias.

Table 4 estimates the correlation between the travel time to the nearest road and the distance to the nearest line by using equation (5). The sample is restricted to 2058 households living in the rural hills, for which this strategy is most relevant. Panel A presents estimates that use the line constructed based on the algorithm which divides the region into 10 blocks; whereas, the estimates using the line constructed with 12 blocks are shown in Panel B. All the estimates are positive and significant at the 1 percent level, even after controlling for district fixed effects in column 2 and additionally for the distance to the nearest district HQ and the distance to EWH in column 3.

This strong correlation suggests the possibility of using this variable as an instrument in a 2SLS model described by equations (6) and (7), to estimate the effect of better access to road on land value. The threat to the validity of such a model arises from the potential correlation of the instrumental variable with (1) proximity to district headquarter, (2) closeness to the historical trade corridors, and (3) physical characteristics of the plot. However, NLSS and MENRIS datasets have a wide set of household and plot level information that can be used to construct these variables, which are then included in equations (6) and (7). The measures of plot characteristics include the distance to river, land gradient, elevation, a dummy indicating whether the plot is suitable for rice cultivation, dummies indicating year round or seasonal irrigation, and dummies indicating types of irrigation. The distance to foot trails picks up unobserved characteristics that are correlated with the proximity to historical trading routes; whereas the distance to the nearest district headquarter and the distance to EWH variables control for the proximity to district headquarter and EWH respectively.

Tables 5 and 6 estimate the reduced form effect of the distance to the line constructed by using 10 and 12 blocks algorithms, respectively. The specification in column 1 in both tables only includes controls for district fixed effects, farm size, and the proximity to the nearest district headquater and EWH. According to table 5 column 1, an increase in the distance to the line by 10 percent decreases the value of land by 0.34 percent. As discussed above, the distance to the line could be correlated with proximity to the historical trade corridors and physical characteristics of the land, both of which directly affect farmland value. To address this, I control for the shortest distance to the walking trails in columns 2 and 3 and observed plot characteristics in column 3. While many of these control variables have strong explanatory power and sensible signs, the coefficient estimates of the distance to the line do not change considerably in magnitude from previous estimates in column 1 and are statistically significant at the 1 percent level. The results show that plots suitable for rice and plots with year round as well as seasonal irrigation are more valuable. Likewise, an increase in land gradient negatively affects the value of the land; whereas, plots that are closer to the district headquarter or to the foot trails have greater value. The coefficient estimates on the distance to the line in table 5 column 2 and 3 equal -0.039 and -0.042 respectively, both of which are within a standard error of the estimate of -0.034 from column 1. Therefore, it seems unlikely that the instrumental variable– distance to the line– is correlated with unobserved characteristics associated with historical proximity to trade routes and with additional land quality variables that are not captured in the present data set, thereby bolstering the validity of the given instrument.

Tables 7 and 8 column 3 present IV estimates of road accessibility by using distance to the line as an instrument for the household's travel time to the nearest road. The estimates of the coefficient β from the 2SLS model are -0.234 and -0.263 for the two algorithms and they are statistically significant at the 5 percent level. The results suggest that an increase in the travel time to the nearest road by one percent decreases the farmland value by about 0.25 percent. Table 9 shows the results for the first stage of the 2SLS model by estimating coefficient β' in equation (6), which suggest that an increase in the distance to the line by one percent raises the household's travel time to the nearest road by 0.17 percent. The F-statistics on the excluded variable from both algorithms in the first stage are large, 24.58 and 20.53, which indicate that the IV estimates are unlikely to be biased due to weak instrument. Moreover, the IV estimates are robust to different parameters of the algorithm used to construct the instrument, suggesting that an improvement in rural road infrastructure has a positive impact on households' economic gains from their agricultural activities.

7 Conclusion

Transportation infrastructure plays a crucial role in rural development. It improves agricultural productivity by reducing transaction costs (Jacoby, 2000) and promotes efficient labor allocation by stimulating commercialization of agriculture (Gollin and Rogerson, 2010). Since many poor reside in remote locations, it provides a direct means of reaching them, thereby facilitating effective delivery of poverty programs and basic services in health, nutrition, and education. However, evaluating transportation projects poses a considerable challenge because roads are not randomly placed nor it is feasible to randomize by design.

I identify a unique geographic feature of mountains in rural Nepal that allows for a plausibly exogenous variation in the placement of rural roads. The empirical strategy is based on the fact that two important determinants of road construction, administrative need to connect district headquarters and the geographic feature that favors north-south linkages, are likely to be independent of the socio-economic characteristics of households living in the hinterlands. Using the distance to the north-south line that connect two district headquarters as an instrument for road accessibility, I find that reduction in travel time to the nearest road increases farm profits, implying a significant economic gains to rural agricultural households.

Although it establishes a causal link between economic benefits and infrastructure investments, the distributional consequences of such projects are unclear. While remote households have most to gain from improved access, the agricultural profits from farmland are confined to landowners who are usually not among the very poor. Moreover, the mechanisms through which farm profits rise are also not identified. The most likely candidates include a greater use of modern inputs such as chemical fertilizers and improved seeds, an easier dissemination of new farm technologies, and an improved access to urban centers with large demand for agricultural output. These important channels could be identified by employing a similar empirical strategy in the future. Moreover, the benefits from road construction are not only limited to farm profits. Gollin and Rogerson (2010) find increase in non-agricultural employment and greater urbanization due to better road network. By promoting factor mobility and improving access to schools, road construction could also raise expected returns to education, prompting households to invest more in human capital. The empirical strategy could easily be extended to evaluate the effect of road on a wider set of economic outcomes of interest including household's education, health, nutrition, and migration decisions, which are important determinants of its welfare and its community's long term economic development.

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Table 1: Descriptive Statistics

	Mean	Std. Dev
Panel A: HH CHARACTERISTICS		
Number of Households	2058	-
Land Area *(Ha)*	0.62	0.62
Number of Plots	3.30	2.19
Household Size	4.76	2.10
Travel Time to Paved Road *(Hrs)*	7.42	13.48
Panel B: PLOT CHARACTERISTICS		
Number of Plots	6785	-
Plot Size *(Ha.)*	0.19	0.25
Plot Value *(Million Rs. per Ha.)*	3.04	17.47
% Suitable for Rice	30.79	46.17
% with Year Round Irrigation	14.62	35.33
% with Seasonal Irrigation	16.34	36.98
% with Tubewell	0.87	9.29
% with Canal	25.78	43.74
% with Pond	0.25	4.99
% with Mixed	0.29	5.42
Elevation *(Meters)*	1215.45	457.63
Land Gradient *(Degrees)*	24.29	11.35
Panel C: DISTANCE VARIABLES *(in Km)*		
Distance to the Line (10 Blocks)	11.51	9.41
Distance to the Line (12 Blocks)	11.88	9.06
Distance to District Headquarters	15.95	8.82
Distance to EWH	51.75	21.18
Distance to River	0.84	0.59
Distance to Foot Trails	1.25	1.26

Notes: The household and plot samples are restricted to rural hill region. The household and plot level data in Panels A and B (except elevation and land gradient) is obtained from 2011 Nepal Living Standard Survey. The rest of the data including distance variables are calculated using MENRIS data.

Table 2: Relationship Between Plot Values and Rents

	(1) OLS	(2) IV$^{\tau}$	(3) IV$^{\tau}$
Log Rent (v_1)	0.69**	1.12**	1.08**
	(0.0560)	(0.1122)	(0.1152)
Ho: $v_1 = 1$ *(p-value)*	0.000	0.255	0.439
District Fixed Effect	No	No	Yes
Number of Plots	327	327	327

Notes: This table reports the coefficient of the log of rent from equation (5), where the dependent variable is the log of plot market value. If the asset-pricing model is valid and market value of the plot is equal to the discounted future rent stream, then this coefficient v_1 = 1. The table also presents the p-value of this test.

τ Log of plot area is the excluded instrument.

* indicates significance at the 5 percent level

** indicates significance at the 1 percent level

Table 5: Effect of Road on Land Value (OLS)

	(1)	(2)	(3)
Log Travel Time to Road	-0.190***	-0.173***	-0.146***
	(0.0058)	(0.0056)	(0.0060)
Log Plot Area	0.708***	0.677***	0.670***
	(0.0156)	(0.0150)	(0.0137)
Irrigation:			
Year-Round		0.582***	0.663***
		(0.0978)	(0.0859)
Seasonal		0.088	0.293***
		(0.0876)	(0.0767)
Mode of Irrigation:			
Tubewell		0.824*	0.240
		(0.1788)	(0.1568)
Canal		-0.037	-0.006
		(0.0837)	(0.0730)
Pond		0.452	0.145
		(0.3054)	(0.2640)
Mixed		0.540*	0.401
		(0.2827)	(0.2448)
Plot Quality:			
Suitable for Rice		0.458***	0.211***
		(0.0520)	(0.0462)
District Fixed Effect	No	No	Yes
R Squared	0.301	0.361	0.530
Number of Plots	6750	6750	6750

*significance at the 10 percent level ** significance at the 5 percent level *** significance at the 1 percent level

Table 3: Relation Between Travel Time to Road and Distance to the Line

	(1)	(2)	(3)
Panel A: 10 Blocks			
Log Distance to the Line	0.623***	0.603***	0.205***
	(0.0576)	(0.0554)	(0.0682)
Log Distance to District Headquarter			1.174***
			(0.117)
Log Distance to EWH			0.724***
			(0.184)
R Squared	0.055	0.431	0.463
Panel B: 12 Blocks			
Log Distance to the Line	0.592***	0.640***	0.237***
	(0.0601)	(0.0574)	(0.0719)
Log Distance to District Headquarter			1.145***
			(0.1190)
Log Distance to EWH			0.754***
			(0.1840)
R Squared	0.046	0.433	0.463
District Fixed Effect	No	Yes	Yes
Number of HHs	2025	2025	2025

Notes:
* indicates significance at the 5 percent level
** indicates significance at the 1 percent level

Table 5: Effect of Road on Land Value Using 10 Blocks (Reduced Form)

	(1)	(2)	(3)
Log Distance to the Line	-0.034*	-0.039**	-0.042**
	(0.0196)	(0.0196)	(0.0187)
Log Plot Area	0.696***	0.696***	0.676***
	(0.0147)	(0.0147)	(0.0141)
Irrigation:			
Year-Round			0.622***
			(0.0874)
Seasonal			0.258***
			(0.0783)
Mode of Irrigation:			
Tubewell			0.287*
			(0.159)
Canal			0.066
			(0.0744)
Pond			0.239
			(0.270)
Mixed			0.552**
			(0.269)
Plot Quality:			
Suitable for Rice			0.200***
			(0.0474)
Land Gradient			-0.169***
			(0.0168)
Log Distance to River			0.007
			(0.0138)
Log Distance to District Headquarter	-0.338***	-0.335***	-0.255***
	(0.0335)	(0.0335)	(0.0327)
Log Distance to Foot Trails		-0.044***	-0.041***
		(0.0116)	(0.0111)
Log Distance to EWH	0.203***	0.191***	0.298***
	(0.0559)	(0.0559)	(0.0601)
Elevation			-0.000***
			(0.0000)
District Fixed Effect	Yes	Yes	Yes
R Squared	0.457	0.458	0.511
Number of Plots	6745	6745	6745

*significance at the 10 percent level ** significance at the 5 percent level *** significance at the 1 percent level

Table 5: Effect of Road on Land Value Using 12 Blocks (Reduced Form)

	(1)	(2)	(3)
Log Distance to the Line	-0.0502**	-0.0489**	-0.0449**
	(0.0204)	(0.0204)	(0.0195)
Log Plot Area	0.698***	0.697***	0.677***
	(0.0147)	(0.0147)	(0.0141)
Irrigation:			
Year-Round			0.624***
			(0.0873)
Seasonal			0.263***
			(0.0783)
Mode of Irrigation:			
Tubewell			0.281*
			(0.159)
Canal			0.065
			(0.0744)
Pond			0.244
			(0.2700)
Mixed			0.558**
			(0.2690)
Plot Quality:			
Suitable for Rice			0.197***
			(0.0474)
Land Gradient			-0.167***
			(0.0168)
Log Distance to River			0.008
			(0.0138)
Log Distance to District Headquarter	-0.322***	-0.325***	-0.251***
	(0.0340)	(0.0340)	(0.0333)
Log Distance to Foot Trails		-0.042***	-0.039***
		(0.0116)	(0.0111)
Log Distance to EWH	0.194***	0.183***	0.295***
	(0.0561)	(0.0561)	(0.0601)
Elevation			-0.000***
			(0.0000)
District Fixed Effect	Yes	Yes	Yes
R Squared	0.457	0.458	0.511
Number of Plots	6745	6745	6745

*significance at the 10 percent level ** significance at the 5 percent level *** significance at the 1 percent level

Table 5: Effect of Road on Land Value (Using 10 Blocks)

	(1) OLS	(2) Reduced Form	(3) IV^{τ}
Log Travel Time to Road	-0.130***	-	-0.234**
	(0.00627)		(0.1050)
Log Distance to the Line	-	-0.042**	-
		(0.0187)	
Log Plot Area	0.686***	0.676***	0.692***
	(0.0137)	(0.0141)	(0.0152)
Irrigation:			
Year-Round	0.684***	0.622***	0.724***
	(0.0852)	(0.0874)	(0.0959)
Seasonal	0.305***	0.258***	0.334***
	(0.0761)	(0.0783)	(0.0827)
Mode of Irrigation:			
Tubewell	0.212	0.287*	0.169
	(0.1560)	(0.1590)	(0.1640)
Canal	-0.012	0.066	-0.064
	(0.0725)	(0.0744)	(0.0903)
Pond	0.086	0.239	-0.028
	(0.2620)	(0.2700)	(0.2900)
Mixed	0.459*	0.552**	0.380
	(0.2610)	(0.2690)	(0.2770)
Plot Quality:			
Suitable for Rice	0.176***	0.200***	0.159***
	(0.0461)	(0.0474)	(0.0498)
Land Gradient	-0.126***	-0.169***	-0.093**
	(0.0164)	(0.0168)	(0.0374)
Log Distance to River	0.019	0.007	0.028*
	(0.0134)	(0.0138)	(0.0165)
Log Distance to District Headquarter	-0.178***	-0.255***	-0.084
	(0.0264)	(0.0327)	(0.0991)
Log Distance to Foot Trails	-0.032***	-0.041***	-0.024*
	(0.0108)	(0.0111)	(0.0135)
Log Distance to EWH	0.361***	0.298***	0.395***
	(0.0590)	(0.0601)	(0.0689)
Elevation	-0.000	-0.000***	-0.005
	(0.0001)	(0.00004)	(0.0001)
F-Statistics on Instrument			24.58
Probability>F			0.000
District Fixed Effect	Yes	Yes	Yes
R Squared	0.540	0.511	0.522
Number of Plots	6710	6745	6710

τ **Log Distance to the Line** is the excluded instrument.

*significance at the 10 percent level ** significance at the 5 percent level *** significance at the 1 percent level

Table 6: Effect of Road on Land Value (Using 12 Blocks)

	(1) OLS	(2) Reduced Form	(3) IV$^{\tau}$
Log Travel Time to Road	-0.130***	-	-0.263**
	(0.00627)		(0.1160)
Log Distance to the Line	-	-0.045**	-
		(0.0195)	
Log Plot Area	0.686***	0.677***	0.694***
	(0.0137)	(0.0141)	(0.0156)
Irrigation:			
Year-Round	0.684***	0.624***	0.736***
	(0.0852)	(0.0873)	(0.0989)
Seasonal	0.305***	0.263***	0.342***
	(0.0761)	(0.0783)	(0.0848)
Mode of Irrigation:			
Tubewell	0.212	0.281*	0.157
	(0.1560)	(0.1590)	(0.1670)
Canal	-0.012	0.0649	-0.0779
	(0.0725)	(0.0744)	(0.0944)
Pond	0.086	0.244	-0.0591
	(0.2620)	(0.2700)	(0.2980)
Mixed	0.459*	0.558**	0.358
	(0.2610)	(0.2690)	(0.2830)
Plot Quality:			
Suitable for Rice	0.176***	0.197***	0.154***
	(0.0461)	(0.0474)	(0.0510)
Land Gradient	-0.126***	-0.167***	-0.084**
	(0.0164)	(0.0168)	(0.0408)
Log Distance to River	0.019	0.00842	0.031*
	(0.0134)	(0.0138)	(0.0173)
Log Distance to District Headquarter	-0.178***	-0.251***	-0.058
	(0.0264)	(0.0333)	(0.1090)
Log Distance to Foot Trails	-0.032***	-0.039***	-0.022
	(0.0108)	(0.0111)	(0.0141)
Log Distance to EWH	0.361***	0.295***	0.404***
	(0.0590)	(0.0601)	(0.0713)
Elevation	-0.000	-0.000***	0.000
	(0.0001)	(0.0000)	(0.0000)
F-Statistics on Instrument			20.53
Probability>F			0.000
District Fixed Effect	Yes	Yes	Yes
R Squared	0.540	0.511	0.510
Number of Plots	6710	6745	6710

τ **Log Distance to the Line** is the excluded instrument.

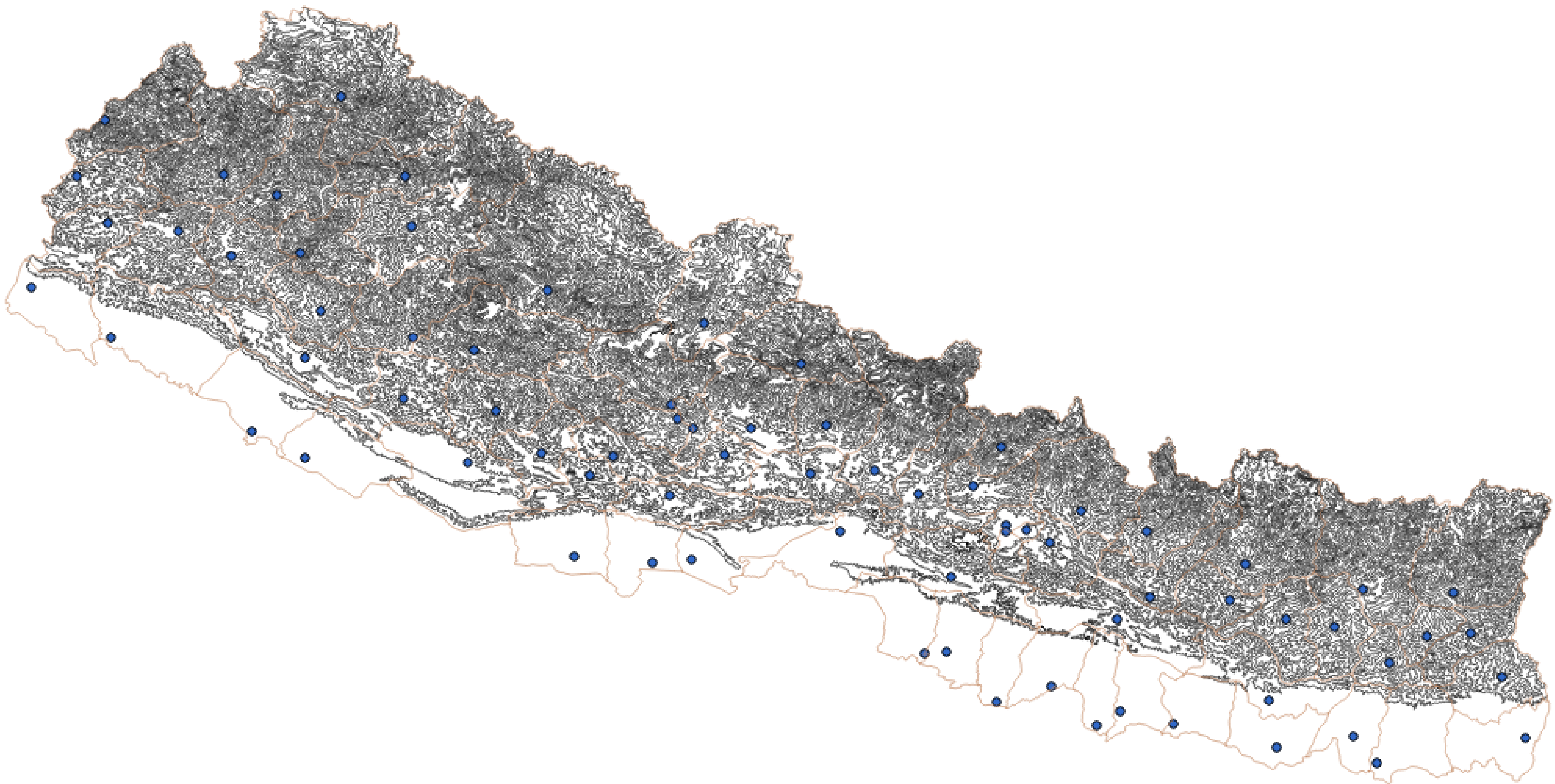
*significance at the 10 percent level ** significance at the 5 percent level *** significance at the 1 percent level

Table 4: Travel Time to Road and Distance to the Line (First Stage)

	(1) 10 Blocks	(2) 12 Blocks
Log Distance to the Line	0.176***	0.167***
	(0.0355)	(0.0370)
Log Plot Area	0.061**	0.055**
	(0.0267)	(0.0267)
Irrigation:		
Year-Round	0.432***	0.418**
	(0.1660)	(0.1660)
Seasonal	0.311**	0.291**
	(0.1490)	(0.1480)
Mode of Irrigation:		
Tubewell	-0.483	-0.451
	(0.3040)	(0.3030)
Canal	-0.532***	-0.523***
	(0.1410)	(0.1410)
Pond	-1.129**	-1.142**
	(0.5100)	(0.5100)
Mixed	-0.730	-0.752
	(0.5100)	(0.5100)
Plot Quality:		
Suitable for Rice	-0.162*	-0.153*
	(0.0898)	(0.0899)
Land Gradient	0.323***	0.314***
	(0.0318)	(0.0318)
Log Distance to River	0.090***	0.086***
	(0.0261)	(0.0261)
Log Distance to District HQ	0.730***	0.736***
	(0.0618)	(0.0631)
Log Distance to Foot Trails	0.081***	0.072***
	(0.0211)	(0.0211)
Log Distance to EWH	0.338***	0.347***
	(0.1150)	(0.1150)
Elevation	0.001***	0.001***
	(0.0000)	(0.0000)
District Fixed Effect	Yes	Yes
R Squared	0.445	0.445
Number of Plots	6710	6710

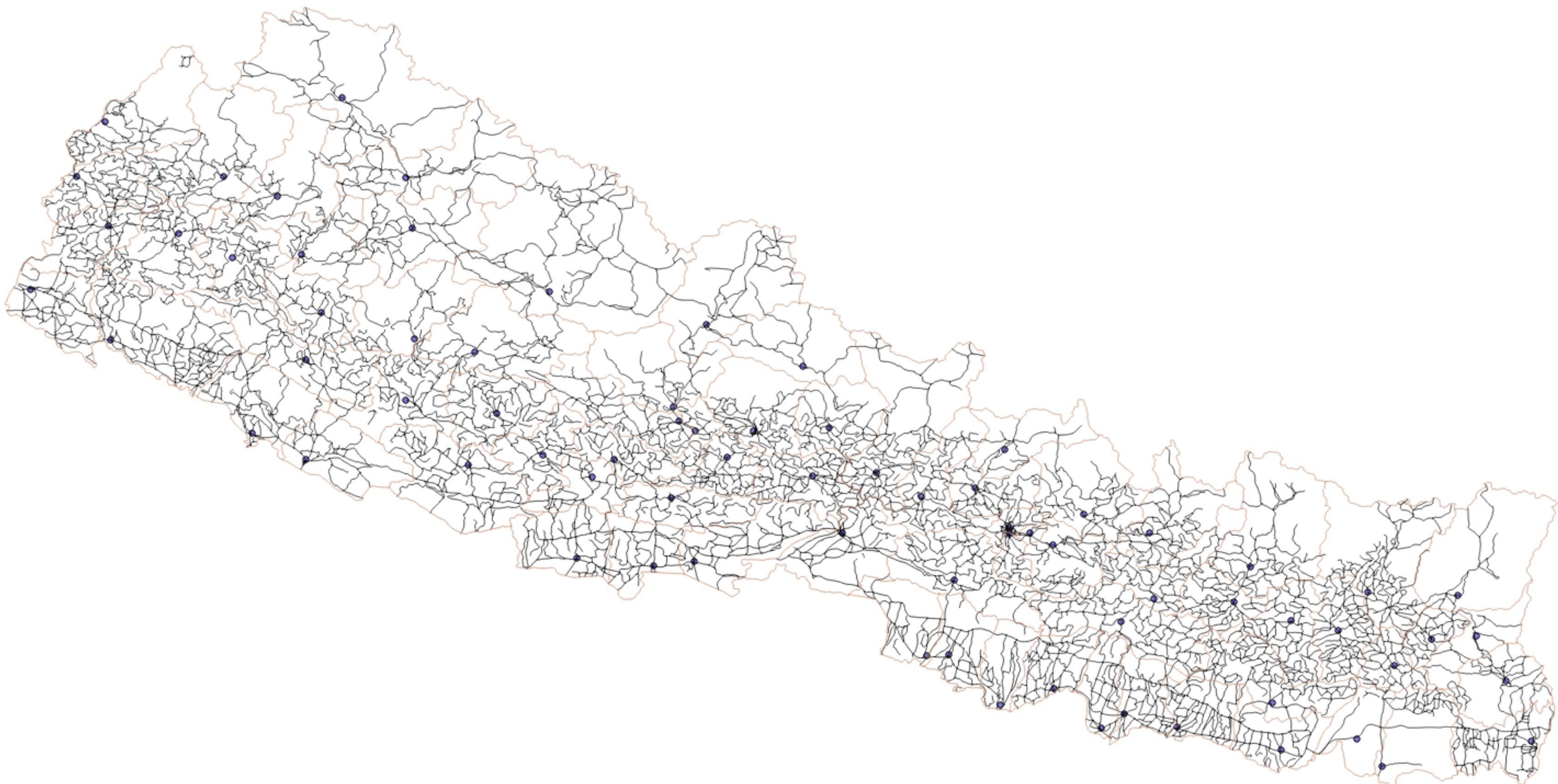
* indicates significance at the 10 percent level ** indicates significance at the 5 percent level
*** indicates significance at the 1 percent level

Figure 1: The Physical Map of Nepal



Notes: The figure illustrates the ruggedness of the terrain. While the thin southern stretch of the country is flat and uniform, the land surface north of the Terrai plain is characterized by sharp changes in elevation as illustrated by the compactness of contour lines.

Figure 2: Historical Trade Routes and Walking Trails



Notes: The figure plots the walking trails that span the country. The district headquarters are illustrated by dotted points on the map. The foot trails stretch in a north-south as well as an east-west directions.

Figure 3: Lines Constructed by Connecting District Headquarters (Using 10 Blocks Algorithm)

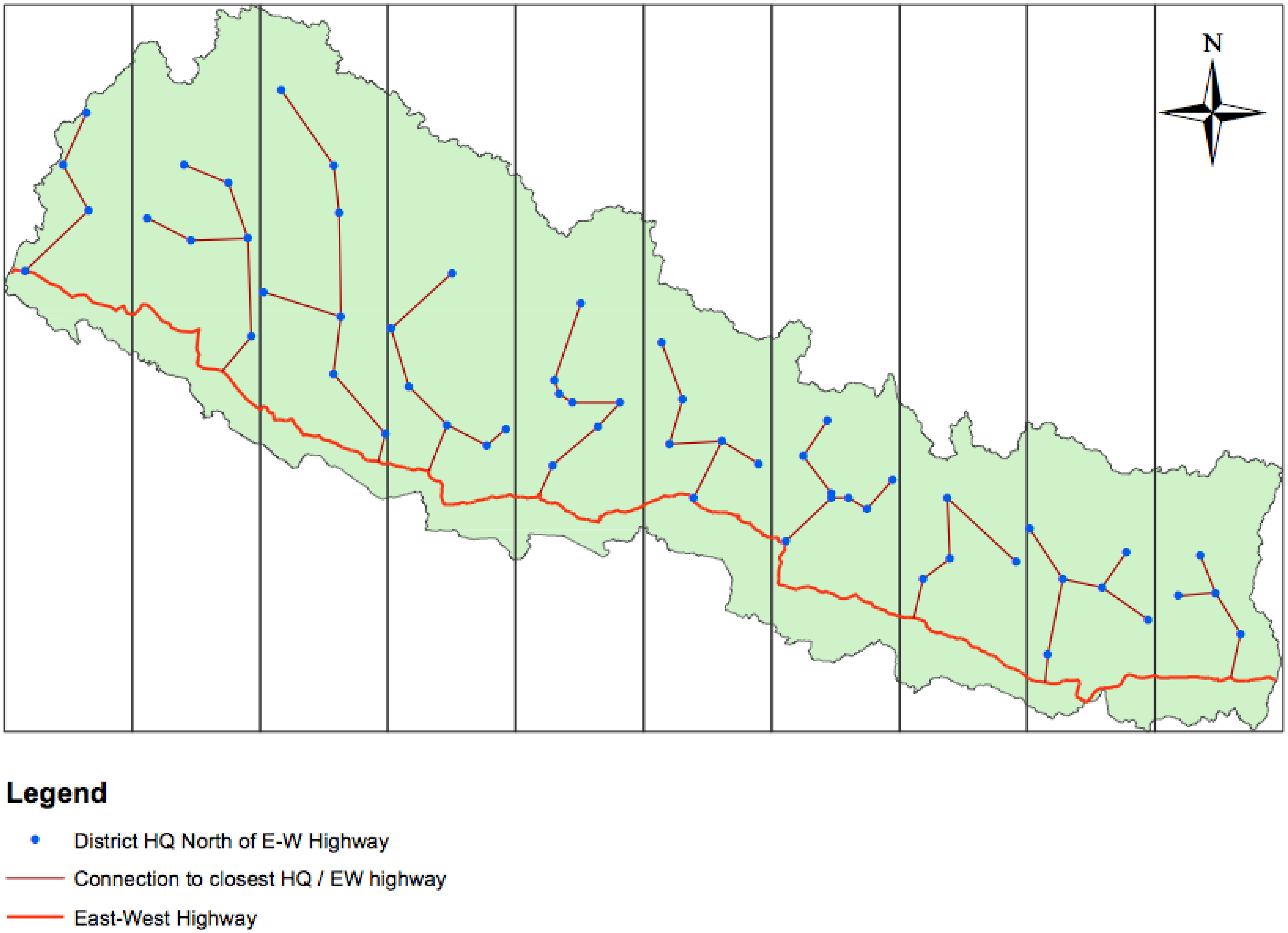


Figure 4: Five Development Regions of Nepal

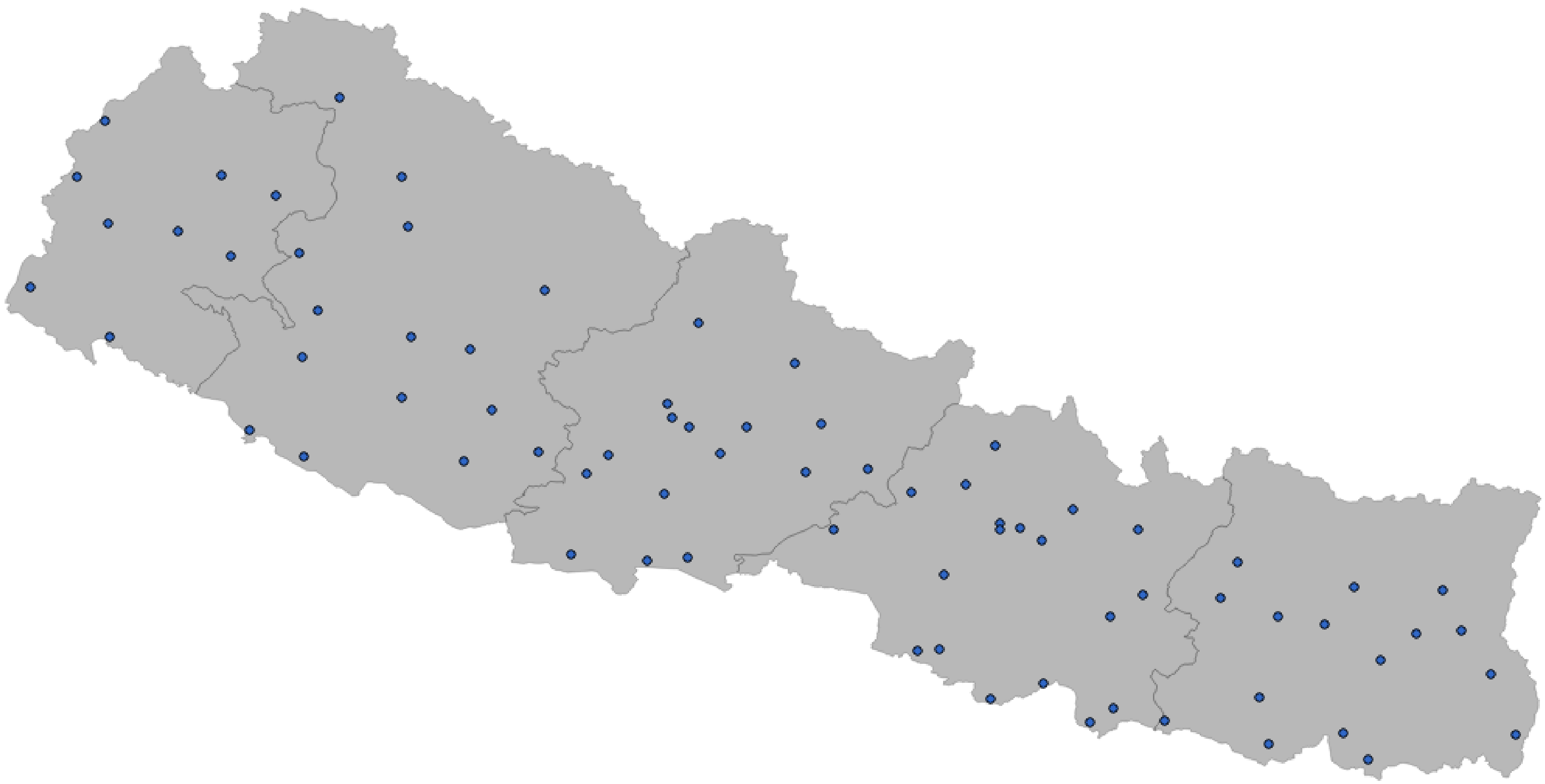


Figure 5: Lines Constructed by Connecting District Headquarters (Using 12 Blocks Algorithm)

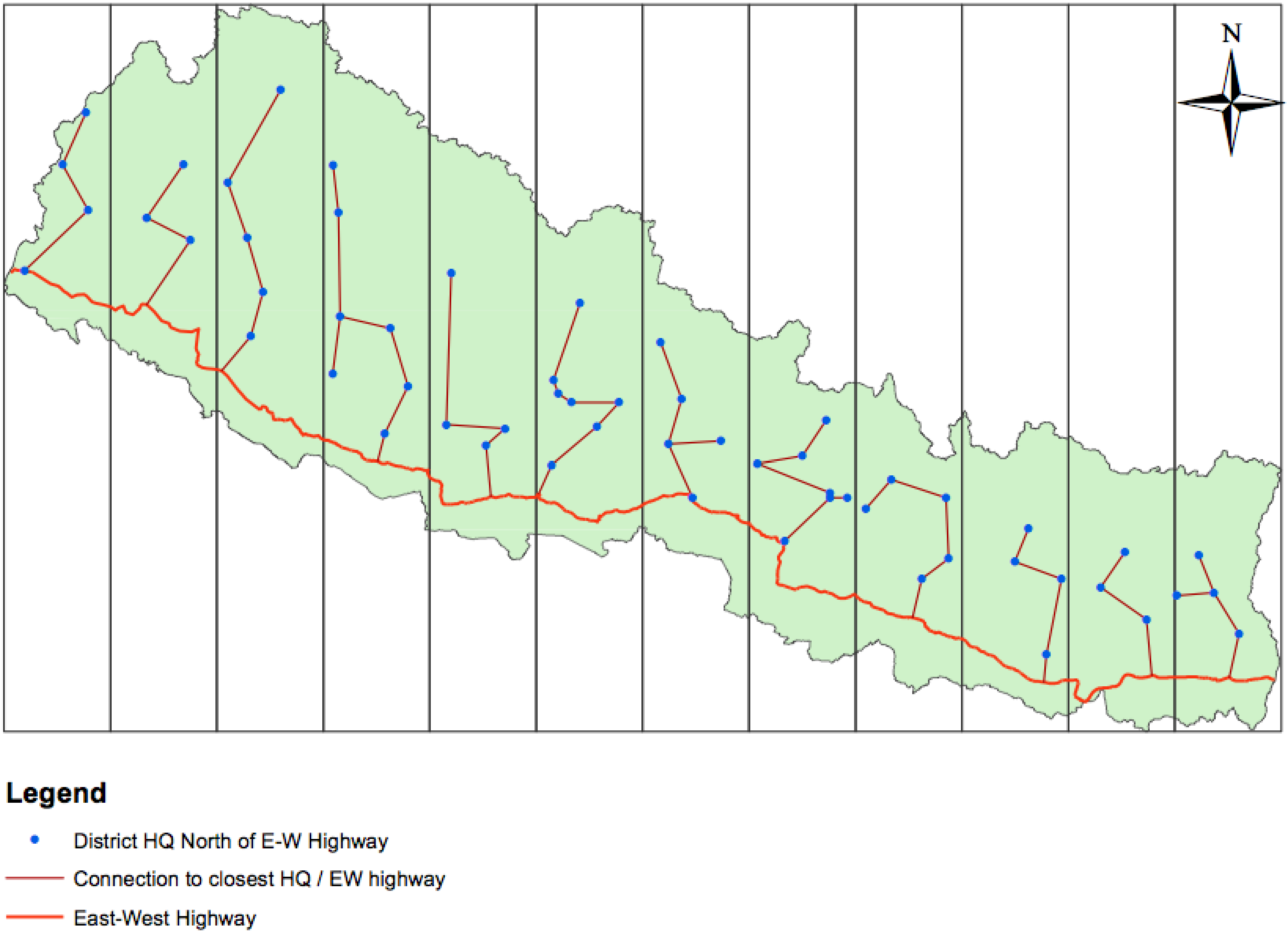


Figure 6: Flow of Rivers and Streams

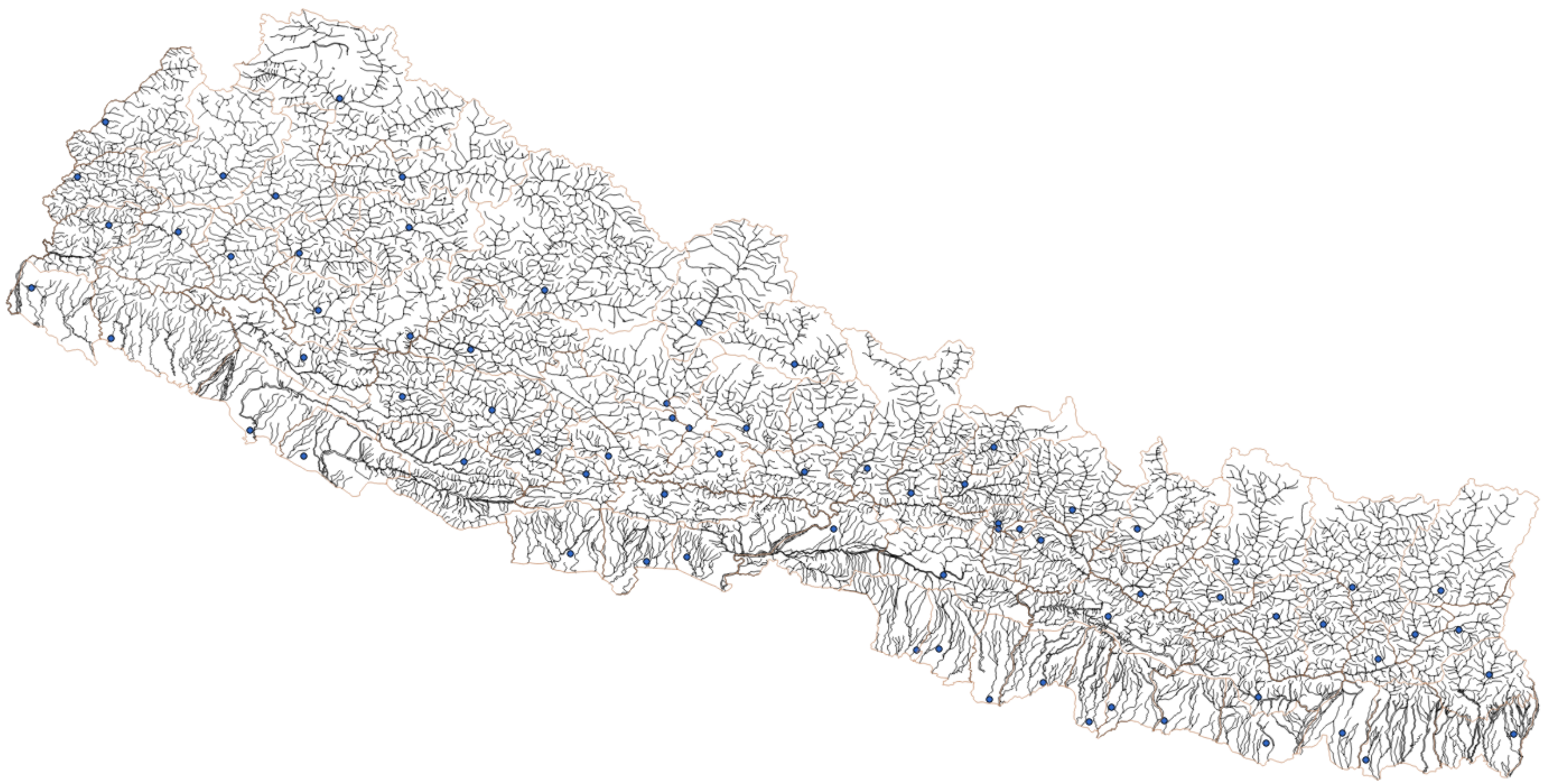
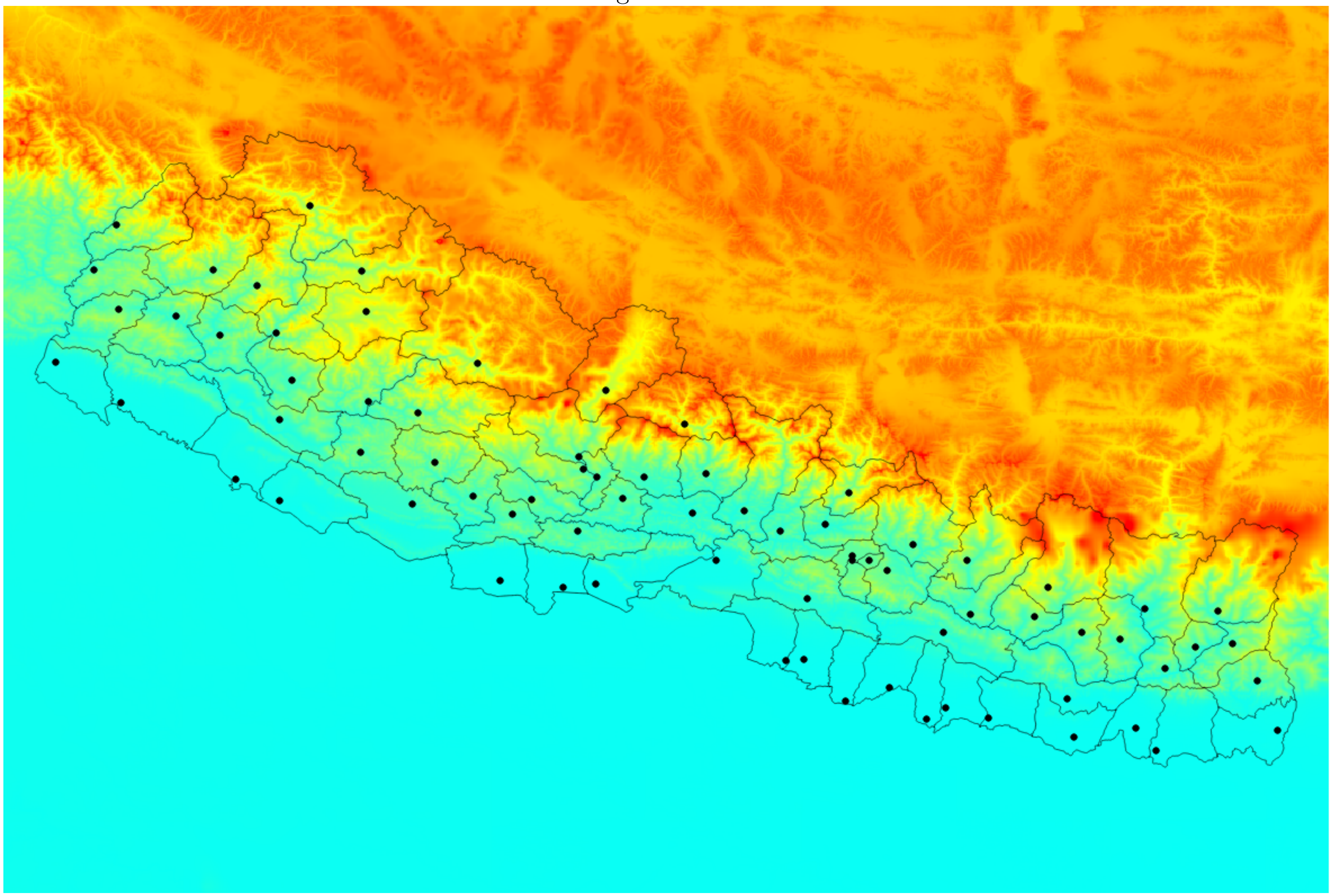


Figure 7: Elevation



Notes: Blue indicate low elevation land and red indicates high elevation. The elevations changes drastically going from north to south, while the elevation remains fairly constant going from east to west.