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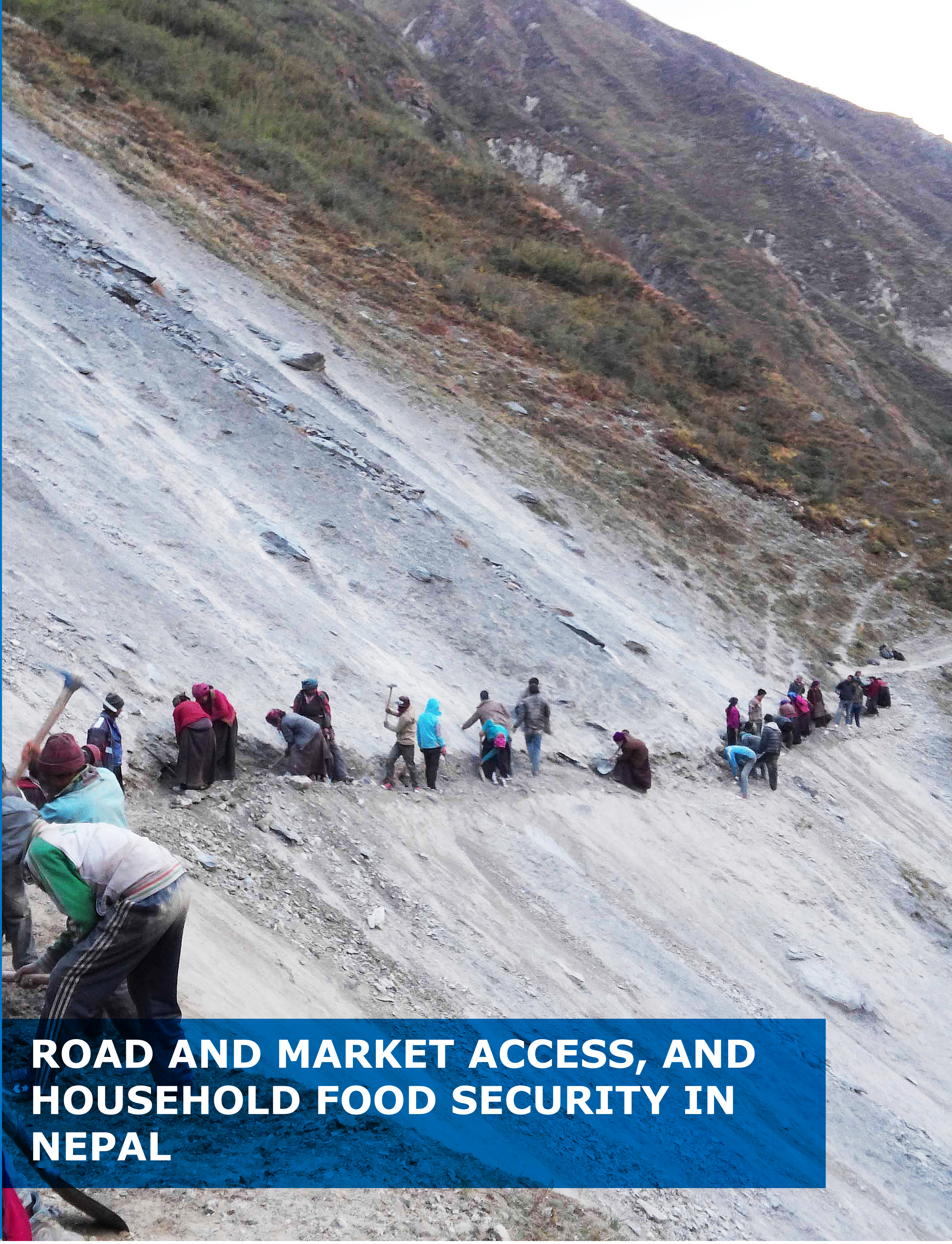

ROAD AND MARKET ACCESS, AND HOUSEHOLD FOOD SECURITY IN NEPAL

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कार्यकारी सारांश

बिशेषगरी हिमाल र पहाडमा बस्ने धेरै नेपालीहरू भौगोलिक र आर्थिक रुपमा पृथक (अलग) रहेका छन्। दुर्गम क्षेत्रमा बस्ने बासिन्दाहरू सडक र बजार नजिक बस्नेहरूभन्दा खाद्य असुरक्षा र जीविका चलाउन कम अवसरको सामना गरेका हुन्छन्। बालबालिकाको शारीरिक विकास समावेश भएका पोषण सूचकहरू यी पृथकतासँग जोडिएका हुन्छन्। २०१५ को भूकम्प प्रतिरोधी टोलीले उल्लेख गरेको छ कि अलग रहेका बासिन्दाभन्दा राम्रो पहुँच र यातायात पूर्वाधार नजिक रहेकाहरूले विपतको व्यवस्थापन छिटो गरे। सडकको राम्रो सुधार पहुँच र बजार भएको क्षेत्रको महत्वलाई पहिचान गर्दै दातृ निकाय र नेपाल सरकारले समग्र विकास नीतिको यातायात विकास लगानी भूमिकामा नयाँ ढंगले ध्यान दिएको छ।

डब्लुएफपी नेपालले हालै समुदाय भौतिक पूर्वाधार र आयआर्जन गतिविधि कार्यक्रम (२०१३-२०१७) को भागको रुपमा दीर्घकालीन राहत र पुनःप्राप्ति (२०१३-२०१७) र अरु परियोजनाहरू कार्यान्वयन गर्दै आएको छ। डब्लुएफपीले दुई आधारभूत पहुँच कार्यक्रम अपनाएको छ : सम्पत्तिका लागि परम्परागत खाना र नगद सहयोग (एफएफए/सीएफए) कार्यक्रम र व्यावसायिक इन्जिनियरिङ परियोजनाहरू। दोस्रो पहुँचसहित डब्लुएफपीको इन्जिनियरिङ युनिटले २०१५ को भूकम्पमा कार्यसंचालनसहित काम गऱ्यो। भूकम्प प्रभावित जिल्लाहरूमा 'छिटो जित्ने' र 'पहिले जस्तै राम्रो स्थिति निर्माण' को भागको रुपमा बाटोको स्तरोन्नती काम मुख्य हुन्। देशको रणनीतिक योजना अन्तर्गत डब्लुएफपीका गतिविधि र समुदायमा भौतिक पूर्वाधारमा लगानी जानकारी दिन, यो प्रतिवेदनले कसरी सडकको र बजारको पहुँचमा सुधार र सामान्य रुपमा राम्रो यातायात पूर्वाधारले ग्रामीण क्षेत्रका बासिन्दा र उनीहरूको जीवनस्तरको सूचक र खाद्य सुरक्षासँग जोडिएको छ भन्ने कुरा मूल्याङ्कन गरेको छ।

डब्लुएफपीको तत्काल धेरै चासो बाटो सुधारमा छ। दूर्भाग्यबश, त्यहाँ धेरै दैनिक जीवनमा कस्तो असर पारेको छ, असरमा प्रयोगसिद्ध प्रमाण छैन। नेपाल वा अरु क्षेत्रमा पनि बाटोका प्रभावको सावधानीपूर्ण अध्ययन गर्ने त्यो समयमा अपर्याप्त तथ्याङ्क छ, वास्तवमा नेपालमा। यसको सट्टा यो अध्ययनले पक्की सडक र बजार केन्द्रमा पहुँचमा केन्द्रित गरेको छ, यसमा व्यापक क्षेत्रमा तथ्याङ्कको प्रयोग गर्दै, नेपाल जीवनस्तर सर्वेक्षण (एनएलएसएस) २०११ सहित र सडक बिभाग (डीओआर) बाट पुल र सडकको जिल्ला स्तरका सूचना प्रयोग भयो। हामीले सडक र बजार पहुँचमा परिवर्तनशील वस्तु प्रयोग गरेका छौं, यात्राको समयको मापन गरियो र फरकफरक सडक गुणस्तरका लागि प्रयोग भएको तौल, सूचकांक घनत्व लेखाजोखा गरियो र तिनीहरूले अपनाएका छन्। हामीले जिल्लाभर पूर्वाधार प्रभावमा स्थानीय सामाग्री मापन र लेखाजोखा गरेका छौ। हामीले किसान परिवारमा केन्द्रित गरेका छौ, जो पहुचको मापनसँग सम्बन्धित छन् र उनीहरूबीच व्यापक रुपमा खाद्य सुरक्षा र जीवनस्तर सूचकका लागि पूर्वाधार सम्बन्धित छन्। उनीहरूबीचमा क्यालोरी खपत, मुख्य खाना र सहायक खाना सेवन र भोजन विविधताबारे केन्द्रित भएका छौ। यसका साथै उनीहरूको बजारसँग सहभागिता, गैर कृषि गतिविधि, भाडामा मजदुर लिने र बसाइ सराइ सूचकहरू पनि समावेश छन्। हामीले पाँच वर्ष मुनिका बालबालिकाको वृद्धि मापन रेखाको पनि अध्ययन गरेका छौं। हामीले ती सूचकमा सडकको प्रभाव र बजार पहुँचलाई मापन गर्न तथ्याङ्कीय श्रेणीको प्रयोग गरेका छौं। त्यो अनुसन्धान नीति निर्माता तह र अरु मुख्य संस्थाहरूलाई मात्रात्मक अनुभवसहित उपलब्ध गराएको छ।

यो विश्लेषण नेपालका ७१ जिल्लाका ३,९३७ घरधुरी र २,३९४ बालबालिकाको तथ्याङ्कमा आधारित छ। युसको मुख्य निश्कर्ष निम्नअनुसार छ :

- गरिब सुधारिएको पहुँचसँग जोडिएको छ । औसतमा, पक्की सडक नजिक भएका घरधुरी वा बजार केन्द्र (एक घण्टा कम दुरीको समयमा) रहने घरधुरी धेरै टाढा बस्ने घरधुरीभन्दा कम गरिब देखिएका छन् । लगभग आधाजस्तो घरधुरी पक्की सडकको पहुँचबिना गरिबीको रेखाभन्दा तल छन् र यदि पक्की सडकको पहुँच पुऱ्यायो भने गरिबीको रेखामाथि उक्लिन सक्नेछन् । धेरै घटनाहरूमा, बजारको पहुँचले सडकको मात्र पहुँचभन्दा केही बढी फाइदा दिएको छ, र दुर्गमताको हदको पहुँचबाट सुधार भएको प्रभाव देखिएको छ ।

- गैर प्रमुख खानाको खपत हिस्सा करिब ०.१९ प्रतिशतले घटेको छ, यो बजारसम्म पहुँच यात्रा समयको प्रत्येक अतिरिक्त एक घण्टाको दुरीको हो । औसतमा, सडक र बजार नजिक बस्ने घरधुरीले गैरप्रमुख खाना र पोषण विविधताको २.४ प्रतिशत बढी खपत हिस्सा प्रदर्शन गरेका छन् । पक्की सडकसम्म पुग्न प्रत्येक अतिरिक्त घण्टा आवश्यक पर्छ, यो रू. २६८ ले उपभोग खपतको वार्षिक आय घट्नेसँग सम्बन्धित छ । मासिक उपभोग खपत नजिकको सडक यात्रा गर्ने समयको अतिरिक्त एक घण्टाका लागि एक प्रतिशतले घटेको छ ।

- प्रत्येक अतिरिक्त घण्टामा पक्की सडक पुग्न पाँच वर्ष मुनिका बालबालिकाको शारिरिक विकास ०.०२ बिन्दुले घटेको देखिएको छ। पक्की सडक वा बजार केन्द्र नजिक बस्ने बालबालिकाको औसत रुपमा ०.२६-०.४९ बिन्दुले बढेको छ, यो ग्रामीण क्षेत्रमा बस्ने वा यस्तै बालबालिकाको बिन्दुभन्दा बढी हो । उच्च जिल्ला तहको सडक घनत्व वृद्धिरेखाभन्दा ठूलोसँग जोडिएको छ ।

- पक्की सडक नजिक बस्ने बालबालिकाहरू एक घण्टाभन्दा टाढा बस्ने बालबालिकाभन्दा ६ प्रतिशत देखि १० प्रतिशतसम्म कम अविकसित छन्, बजार नजिक बस्ने वालवालिका सम्भवतः १२ देखि १५ प्रतिशत अविकशित भएका छन् । विकास रोक्ने फैलावट बजार केन्द्रसम्मको यात्रामा प्रत्येक एक घण्टाको वृद्धिसँगै १.४ प्रतिशतले वृद्धि भएको छ। उच्च जिल्ला तह सडक घनत्व वृद्धि रोकावटको कम संभावनासँग जोडिएको छ । परिणामले ग्रामीण भेगमा बालबालिकाका लागि पक्की सडकको पहुँचबाट वृद्धि रेखा सुधारमा ०.३३ बिन्दु सम्भावनाको सुझाव गरेको छ र त्यो सम्भावना अविकसित बालबालिकाको करिब १० प्रतिशत माथि राम्रो पहुँच छ र गम्भीर रुपमा अविकसित बालबालिकाका सम्बन्धित सीमाभन्दा ४८ प्रतिशत माथि पहुँच छ ।

- पक्की सडक वा बजार केन्द्रमा बस्ने घरधुरीले बढी श्रमिकलाई काममा लगाएका छन् र धेरै ग्रामीण क्षेत्रका घरधुरीभन्दा कम हिस्सा श्रममा भरोसा गरेका छन् । यो परिणामको प्रभावहरू साना छन् तर तथ्याङ्कको हिसाबले उल्लेखनीय छन् । जिल्लामा व्यक्तिगत हिसाबले सडकको कम घनत्व भएको क्षेत्रमा बसाइसराई दर बढी छ ।

- सडक र बजार नजिक भएर व्यापारिक गतिविधिमा सहभागी घरधुरी टाढा बस्नेभन्दा बढी दर छ । तिनीहरू सानो रुपमा बजार गर्छन् तर कृषि उत्पादनको हिसा धेरै उल्लेखनीय छ । उच्च जिल्ला तहको पुल घनन्व कृषि व्यावसायिकरणको दर ठूलो रुपमा जोडिएको छ । सडकले पनि कृषिको व्यापारिककरणको दरहमा स्थानीय रुपमा सकरात्मक प्रभाव फैलाएको छ, बजारमा सहभागी गराउने पहुँचमा सकरात्मक र व्यापक सुझाव दिएको छ ।

ROAD AND MARKET ACCESS, AND HOUSEHOLD FOOD SECURITY IN NEPAL

Report prepared for the World Food Programme

Gerald Shively
Ganesh Thapa
30 July 2017

Abstract. Multiple pathways link transportation and market access to food security. These include agricultural performance, food availability, prices and incomes. This report uses data from the 2011 Nepal Living Standards Measurement Survey to identify connections between improvements in road and market access and nutrition and livelihood outcomes. We estimate a series of multilevel regressions and dose-response functions to measure the effects of road and market access on indicators associated with food security and rural activity. These indicators include household calorie consumption, food budget shares, staple reliance, agricultural commercialization and child linear growth. Evidence shows that isolation strongly undermines household food security. Road and market access are correlated with a wide range of indicators related to food security, household livelihoods and child nutrition. Poverty prevalence falls by 0.50% for each one-hour reduction in travel time to a well-paved road, and by 1% for each one-hour reduction in travel time to a market center. Furthermore, each one-hour reduction in the travel time required to reach a market center is associated with a 0.2% increase in the non-staple food expenditure share. Stunting prevalence increases by 1.4% with each additional hour of travel time to a market center, and each additional hour needed to access a well-paved road is associated with a 0.02 point reduction in linear growth (height-for-age z score) in children under age 5. Overall results suggest a potential 0.33-point improvement in linear growth resulting from paved road access for children in the most remote locations, and the potential for improvements in access to roads and markets to move approximately 10% of stunted children and 48% of severely stunted children above their respective linear growth thresholds.

Prepared for the World Food Programme (WFP), Kathmandu, Nepal. We acknowledge the helpful comments and suggestions of Pippa Bradford, Kurt Burja, Selwyn Heaton, Man Bahadur Kshetri, Ian McDonald, Sridhar Thapa and WFP seminar participants. Opinions expressed herein are those of the authors and do not necessarily reflect the views of the World Food Programme.

A porter carrying chicklets on a trail reconstructed by WFP.

Photo credit : WFP/Santosh Shahi

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A Women in Terai harvest cauliflower.

Photo credit : WFP/Samir Jung Thapa

ABBREVIATIONS

ATT	Average Treatment Effect on the Treated
BACI	Before-After-Control-Intervention
BMI	Body Mass Index
CFA	Cash-Assistance-for-Asset
DOR	Department of Roads
DR-NCD	Diet-Related Non-Communicable Disease
DRF	Dose-Response Function
FFA	Food-Assistance-for-Asset
GHI	Global Hunger Index
GPS	Generalized Propensity Score
HAZ	Height-for-Age Z score
ICC	Intra-Class Correlation Coefficient
MDGs	Millennium Development Goals
MOAD	Ministry of Agricultural Development
NDHS	Nepal Demographic Health Survey
NE	Northeast
NFC	Nepal Food Corporation
NLSS	Nepal Living Standards Survey
NPC	Nepal Planning Commission
NW	Northwest
RAO	Remote Access Operation
ROI	Return on Investment
RPCFC	Real Per Capita Consumption
RTI	Road Traffic Injury
SE	Southeast
SI	Simpson's Index
SRN	Strategic Road Network
SW	Southwest
U5	Child Below Five Years of Age
VDC	Village Development Committee
WFP	World Food Programme
WHZ	Weight-for-Height Z score

DEFINITIONS OF KEY TERMS

The literature on access and infrastructure does not always provide precise definitions for the concepts and terms used in this report. Unless stated otherwise, we use the following definitions in this report:

Road: a generic term generally corresponding to a surface that supports motor vehicle traffic, without regard to quality, reliability or year-round use. In Nepal, the term is generally understood to include the country's Strategic Road Network (SRN) as well as numerous village roads, agriculture roads and district roads that have been constructed by various organizations and local bodies. A reliable database of all roads in Nepal is not currently available in a consolidated form, although some maps provide coverage that extends beyond the SRN.

Paved or sealed road: a road with a durable surface intended to sustain traffic over time. In Nepal, where roads are not always well maintained, a road designated as paved may or may not be in good condition.

Well-paved road: the primary indicator of road access used in the analysis. In the NLSS, respondents reported access time to a well-paved road, a subjective indicator that may have meant different things to different respondents.

All-season road: a road passable during all seasons, including, in Nepal, the monsoon season. A paved or well-paved road would generally be expected to meet this definition, although it might not. In practice, a well-constructed gravel road with proper drainage could be passable in all seasons, and might prove to be more reliable than an unmaintained paved road.

Earthen road: a type of unpaved road consisting of a bare earth surface. Depending on construction and drainage, such surfaces are highly vulnerable to rutting and washouts, and are likely to be unpassable during the rainy season.

Gravel road: a type of unpaved road surfaced with gravel or crushed stone. A well-constructed gravel road with proper drainage could be passable in all seasons.

Strategic Road Network (SRN): defined by the Department of Roads (DOR), Nepal, as national and feeder roads. As of 2015, the SRN consisted of "three main east-west corridors and several north south corridors" (ADB 2015). Feeder roads link mid-hill districts and provide routes to the main population centers in the hills.

Trail: a path intended for human foot traffic and the movement of livestock and pack animals. In Nepal, there is little formal differentiation between foot trails and mule tracks, or between trails and tracks. The quality and reliability of trails varies considerably; some may be intended for use by trekkers and others for use by Nepalis moving between villages or from villages to roads.

Access: a term used to convey information about the proximity of a household to basic services. The NLSS measures a household's self-reported access as the time required for one-way travel to a location, irrespective of the mode of transport (i.e. foot or vehicle). A shorter indicated access time to a well-paved road or market center indicates better access for the household. In practice, access times may reflect differences in subjective estimates made by survey respondents or differences in the fitness of individual respondents. Similar access times reported in the NLSS may represent similar distances and methods of travel, different distances and different speeds and/or methods of travel, or different distances and different qualities of trails, roads and bridges. The respondents in the NLSS reported access times ranging from 0 to more than 20 hours. For analysis, all access times reported as greater than 16 2/3 hours have been truncated at 16 2/3 hours.

Remoteness or isolation: terms used in the report to represent relative access times to a well-paved road or market center. The most remote households are those with access times of 16 2/3 hours. More generally, since access time is a continuous measure, any household with an access time greater than that of a comparison household is considered more remote or more isolated, although this may not necessarily coincide with physical distance.

Market: a general term representing a place, whether permanently or temporarily established, where goods may be purchased, sold or exchanged. Local markets (haat bazaars) operate at regular intervals on certain days of the week and are especially popular in the Terai. The majority of households in the hills and mountains do not report information on haat bazaars, and this information is not used in the analysis.

Market center: the primary indicator of market access used in the analysis. In the context of the NLSS, access time to reach a market center is often but not always synonymous with access time to the district headquarters. In the NLSS, respondents reported access time to a market center in hours, using typical methods of transportation. As a result, estimated time to reach a market center is a subjective indicator that may have meant different things to different respondents.

WFP rebuilds a bridge in Sindupalchowk after the 2015 earthquakes.

Photo credit : WFP/James Giambrone

EXECUTIVE SUMMARY

Many Nepalis, especially those in the hills and mountains, remain geographically and economically isolated. Households living in remote areas face greater food insecurity and have fewer livelihood opportunities than those living near roads and markets. Nutrition indicators, including stunting rates for children, are often correlated with isolation. Following the 2015 earthquakes, response teams reported that households in areas with better access and better transportation infrastructure recovered from the disaster more quickly than those in more isolated locations. Recognizing the importance of improved access to roads and markets, donor agencies and the Government of Nepal have placed renewed attention on the role of transportation investments of all forms in Nepal's overall development strategy.

WFP Nepal is currently implementing community infrastructure and asset creation activities as part of the Country Programme (2013-2017), the Protracted Relief and Recovery Operation (2016-2018) and other projects. WFP uses two basic approaches: traditional food- and cash-assistance-for-assets (FFA/CFA) programmes and commercial engineering projects. The second approach includes operations implemented by WFP's Engineering Unit following the 2015 earthquake. Key among these is upgrading trails as part of the "Build Back Better" and "Quick Win" projects in earthquake-affected districts. To inform WFP's activities and ongoing investments in community infrastructure and asset creation under the Country Strategic Plan, this report assesses how improved access to roads and markets, and better transportation infrastructure in general, are associated with food security indicators and markers of living standards and rural livelihoods.

Much of WFP's current attention focuses on trail improvements. Unfortunately, there is almost no empirical evidence on the impacts of trails on livelihoods – for Nepal or elsewhere – and insufficient data at this time to undertake a careful study of the impacts of trails, per se, in Nepal. Instead, this study focuses on access to well-paved roads and market centers, making use of a wide range of data, including the 2011 Nepal Living Standards Survey (NLSS) and district-level information on roads and bridges from the Department of Roads (DOR), Nepal. We use variables on road and market access, measured in terms of travel time, and compute road density indices using weights that account for different road qualities and the travel times that they imply. We also measure and account for spatial spillovers in infrastructure impacts across districts. We focus on agricultural households, relating the measures of access and infrastructure to a wide range of household food security and livelihood indicators, among them calorie consumption, staple and non-staple food expenditures and dietary diversity, as well as indicators of market participation, non-agricultural activity, labor hiring and migration. We also study linear growth in children under age five years. We use a range of statistical methods to measure the effects of road and market access on these indicators. The findings provide value to policy makers and others by quantifying empirically the magnitude of key associations.

Analysis is based on data from 3,937 households and 2,394 children residing in 71 districts of Nepal. Major findings include the following:

- Improved access is associated with a lower likelihood of being poor. On average, households living near a well-paved road or market center (travel time less than 1 hour) are less likely to be poor than more remote households with similar characteristics. Approximately half of households below the poverty line and without immediate access to a paved road would move above the poverty threshold if provided with access to a well-paved road. In most cases, market access confers somewhat larger benefits than road access alone, and impacts from improved access increase with the degree of remoteness.
- Expenditure shares for non-staple foods decrease by approximately 0.19% with each additional hour of travel time to a market center. On average, households living near roads and markets exhibit a 2.4% higher expenditure share on non-staple foods and have greater dietary diversity. Each additional hour needed to reach a well-paved road is correlated with a Rs 268 reduction in annual real per capita consumption expenditure. Monthly food consumption declines by approximately 1% for each additional hour of travel time to the nearest road.
- Each additional hour to reach a paved road leads to a 0.02-point reduction in linear growth (HAZ) for children below age five. Children living near a well-paved road or market center exhibit, on average, linear growth 0.26-0.49 points higher than do more remote children with similar household characteristics. Higher district-level road density is associated with greater linear growth.
- Children living near a well-paved road are, on average, 6%-10% less likely to be stunted (HAZ < -2) than those more than one hour away, and children living near a market center are 12-15% less likely to be stunted. Stunting prevalence increase by 1.4% with each one-hour increase in travel time to a market center. Higher district-level road density is associated with lower probability of stunting. Results suggest a potential 0.33-point improvement in linear growth from paved road access for children in the most remote locations, and the potential for better access to move approximately 10% of stunted children and 48% of severely stunted children above their respective thresholds.
- Households living near well-paved roads and market centers hire more labor and rely less on shared labor than more remote households. The magnitudes of these effects are small, but statistically significant. Individuals in districts with low road densities migrate at higher rates.
- Households living near roads and markets participate in commercial activities at greater rates than those at a distance. They market a small but significantly larger share of agricultural output. Higher district-level bridge density is associated with a greater rate of agricultural commercialization. Roads also have positive spatial spillover effects on rates of agricultural commercialization, suggesting broad and positive influences from market access on market participation.

A woman planting paddy.

Photo credit : WFP/James Giambrone

1 INTRODUCTION

Nepal, like many low-income countries, suffers from poor transportation infrastructure, especially outside of core urban areas. Understandably, Nepal's road density is far less than one finds in middle- and high-income settings. For example, Nepal and Switzerland have similar topographies and population densities, but Switzerland's total road density (173 km/100km^2) is 12 times that of Nepal's (14 km/100km^2) (IRF 2010). Nepal's sparse road network is widely perceived as impeding access to markets, raising local food prices (FAO/WFP 2007). For example, Shively and Thapa (2016) find that roads and bridges are important for moderating price levels and price volatility in Nepal's rice and wheat markets, and that differences in transport infrastructure explain roughly half of the spatial and temporal variation in price mark-ups between regional and local markets. Limited transport also limits employment opportunities and access to health and educational facilities (NMOHP 2011; 2014), further undermining agricultural development and social progress (Gurung 2010; Sanogo 2008).

According to the World Bank (2015), transport is an important driver of economic growth, poverty reduction, and progress toward attainment of the Millennium Development Goals (MDGs). A focus on transportation infrastructure in Nepal is especially critical given the country's high prevalence of child malnutrition, overall patterns of food security risk (see Figure 1), and the widespread recognition that many of the country's development challenges emanate from poor access (WB 2010).[1] To visualize the latter issue, Figure 2 compares the prevalence of child stunting in 2006 and 2011 (upper panel), a primary indicator of food insecurity and malnutrition, to the distribution of roads in 2014 (lower panel). A comparison of these maps clearly illustrates that the probability of child stunting is much higher in hilly and mountainous regions of the country, where there are few roads, most of which are of gravel or earthen construction, compared with the Terai, where the network is much denser and many roads are sealed.[2] Using data from the 2006 and 2011 Nepal Demographic and Health Surveys, Shively and Thapa (2017) measure the connections between the quantity and quality of roads on the one hand, and nutrition outcomes on the other. They find that child weight-for-height is more sensitive to transportation treatment at an earlier age (below age 3) than at a later age (above age 3) and that, on average, each additional increase in sealed-road-equivalent density of roads (100km/km^2) in a district is associated with a 0.22-0.28 point higher average height-for-age z score in that district. Increases in quality-adjusted road density, from the lowest values observed to the highest levels observed, were associated with a ≈ 1.0 z score improvement in expected HAZ and WHZ. Using a spatial econometric model, they also observe positive nutrition spillovers from roads across districts.

Multiple pathways link roads to improved living conditions. These include agricultural performance, food availability, and food prices and incomes, among others. To identify how improvements in access might lead to better health and nutrition outcomes, this report extends previous analyses using multiple sources of data, including data from the 2011 Nepal Living

1 Although Nepal's stunting rate decreased by 16 per cent between 2001 and 2011, 41% of children less than five years of age remain stunted and 12% are wasted based on the most recent Nepal DHS data (NDHS 2011). The stunting rate is even higher in mountain districts. In 2016, Nepal's Global Hunger Index (GHI) score was 21.9 (ranked 72 out of 118 countries) highlighting the ongoing seriousness of food insecurity in the country (IFPRI 2016).

2 The importance of Nepal's road network was underscored by the earthquakes that struck on April 25 and May 12, 2015. In remote locations, help was delayed, stored harvests were buried, markets were closed, immediate food assistance was hampered, and timely delivery of key agricultural inputs such as seeds and fertilizers was undermined, placing subsequent harvests at risk.

Standards Measurement Survey. We organize our work at the household and child levels, accounting for transportation infrastructure at the district level. We choose these levels of analysis because the benefits of increased access are likely to be broad in geographic scope and because infrastructure development is likely to occur at a district-level. At the same time, policy makers are likely to have interest in impacts felt at the level of individuals and households, requiring a microeconomic perspective on outcomes. We recognize that road construction is not likely to be fully exogenous with respect to our outcome variables of interest, either because economically and politically favored districts are more likely to receive attention and public funds and to have less overall deprivation, or because projects may specifically target underdeveloped districts (Van de Walle 2009). Accordingly, in the analysis reported below we use a generalized propensity score (GPS) approach to minimize potential bias associated with the purposeful construction of roads.

We use two measures of access, defined at the household level and measured in terms of travel time. The first corresponds to access to a well-paved road. The second corresponds to access to a market center. We use these variables to derive discrete and continuous measures of household-specific treatment, and then relate these treatment variables to a broad range of indicators of interest. We estimate a series of multilevel (hierarchical) regressions to measure average effects associated with being near a well-paved road or market center. We then estimate dose-response functions (DRFs) to measure the effects of continuous treatment on a range of food security and livelihood outcomes, including linear growth for children below age five.

We also recognize that roads and road networks might have geographically dispersed effects on social and economic outcomes. This is especially true in Nepal, where road density is low and modest additions to the stock of roads, bridges, and trails could reduce access time to markets and services, with potentially wide impacts on opportunities and outcomes, both within a district and in adjacent districts. To identify and account for these potential geographic spillovers, we use spatial econometric methods. Our overall results put access into a larger development context, and quantify the benefits of improved access on a range of development, food security, and livelihood indicators.

A woman sells her produce at the local market.

Photo credit : WFP/James Glambrone

2

TRANSPORTATION INFRASTRUCTURE AND THE PATHWAYS TO FOOD SECURITY

Historically, Nepal has had one of the lowest road densities in South Asia. In 1998, the total strategic road network (SRN) length was 4,740 km and the road density was only 3 km per 100 km^2, among the lowest in the world. In the early part of this century, substantial improvements in the network were made.[3] Nevertheless, it remained the case that, as of 2010, less than half of Nepal's population had access to all-weather roads (CBS 2011). Figure 3 shows the extent of Nepal's complete road network in 1996 (upper panel) and 2014 (lower panel). This road network is not distributed evenly throughout the country, even accounting for population. Road density is very low in the far west and in mountainous regions, and as of 2015, two mountain districts (Humla and Dolpa) remained unconnected with the rest of the country, except by trails. Furthermore, most all-season roads are concentrated in either the Terai or the capital region. In mountainous districts, several hours or days of walking or travel on earthen roads may be required to reach the district headquarters (CBS 2011). In such places, the movement of goods requires airlifts or conveyance by mules and porters, adding to transport costs. Figures 4 and 5 show average access times, by district, to well-paved roads and market centers, as reported for 401 villages in the 2011 Nepal Living Standards study. For villages included in the NLSS sample, the average travel time was 37 minutes to a well-paved road and more than 2½ hours to a market center. Table 1 reports these average travel times by ecological zone.[4]

The isolation typical of rural Nepal undermines efforts to support local communities, reduces the effectiveness and reach of community-based and national child nutrition interventions, and reduces access to health facilities and personnel (NMOHP 2014). According to Suvedi et al. (2009), isolation directly contributes to high rates of maternal mortality. Many individuals, especially children and women of child-bearing age, face multiple risks.[5] Evidence of this negative association between isolation and nutritional outcomes is provided by figures 6 and 7, which plot village-average linear growth for children below age 5 years against travel time to a well-paved road (Figure 6) and market center (Figure 7). Understanding the strength of these patterns, and the pathways by which improved access to roads and markets might affect food security and livelihoods, is the focus of the analysis below.

2.1 Physical attributes of trails, roads and bridges and impact on travel time

Transportation infrastructure (consisting of walking trails for people, trails suitable for mules and other animals, roads and bridges) can be described in terms of quality, proximity and density. In Nepal, one finds locations at one end of the distribution that are characterized by a

3 *From 2003 to 2013 total road length increased 58% (from 16,018 km to 25,265 km) and the length of sealed, gravel and earthen roads expanded by 129%, 18%, and 47%, respectively (DOR 2012; 2013). For comparison, in 2010 road densities in Bangladesh, Bhutan, India, Pakistan, Sri Lanka and Nepal were 171, 36, 125, 32, 163, and 14 (World Bank 2010).*

4 *The NLSS sample was designed to be representative of population, not geography. As a result, information derived from the sample of VDCs included in the survey sometimes conflicts with intuition about average access times in geographically remote districts, where sparsely populated VDCs are underrepresented in the data. Appendix Table A1 lists average household-reported access times by VDC, for those VDCs covered by the 2011 NLSS.*

5 *Gaire et al. (2016) combined the 2011 DHS with district-level disaster data and found that even after controlling for a wide range of confounders, floods had a positive association with child stunting, in part due to the ways local flooding contributed to isolation.*

low number of sparse, uneven foot trails, mule trails, and unimproved dirt roads over rough and steep terrain. River crossings are unreliable (and often seasonal) and travel is arduous, time consuming, and risky. Connectivity is low. At the other end of the distribution, travel relies on a dense network of all-season or well-paved roads and well-anchored bridges. These minimize travel time, accommodate vehicular traffic, and result in comparatively lower costs of accessing and moving goods and people across the landscape. Figure 8 provides a stylized view of how proximity and quality might combine in a synergistic way to generate improved outcomes for some metric of interest. Figure 8 simply communicates that a dense network of high quality roads is likely to generate better access and outcomes than a sparse network of high quality roads, or a dense network of low quality roads.

2.2 Pathways to food security and improved nutrition and health

A particular stock of transportation infrastructure can influence food security, nutrition and health though multiple direct and indirect channels influencing access to private and public goods and services. Direct channels are often obvious and highly visible. Food, for example, may move from surplus to deficit areas and appear in local markets. Medicine, vaccines, doctors, and nurses may move from urban centers to rural areas where and when they are needed. Conversely, people may travel from remote locations to access medical services in urban areas. Indirect channels of influence may be less obvious: market prices reflect the costs of transporting goods; agricultural productivity reflects access to seeds, fertilizer and knowledge; incomes reflect opportunities; and decisions that affect nutrition and health reflect literacy rates, access to education, and flows of information.

2.3 Temporal dimensions

The impacts of transportation infrastructure may occur over a relatively short time, or may be longer in duration, or accumulate over time. Short run impacts include the movement of foods and agricultural inputs into markets, or the delivery of food aid, emergency relief or medicines into areas of critical immediate need. From a nutrition point of view, short-term impacts are likely to manifest themselves in terms of short-run indicators, such as weight gain, as measured by body mass index (BMI) or weight-for-height z scores (WHZ). Long-run impacts may include literacy rates, livelihood opportunities, household incomes, or cumulative effects of nutrient intake, dietary diversity, or long-run health. From a nutrition point of view, these long-term impacts are likely to appear in long-run indicators, such as linear growth, as measured by height-for-age z scores (HAZ) or rates of stunting (HAZ < -2.0).

To operationalize the combination of proximity and quality on access, and at the same time account for the potential for delayed impacts, Shively and Thapa (2017) used data on strategic roads (national highways and feeder roads) published by the Department of Roads (DOR), Ministry of Physical Planning, Works and Transport Management. Since each district in Nepal has a linear stock of roads of varying quality, a road density index was calculated using weights that account for different road qualities and the travel time that they imply. Figure 9 plots these district-level road indices against district-average child growth outcomes in Nepal, based on data from the 2006 and 2011 Nepal Demographic and Health Surveys. As the left panel of Figure 9 shows, height-for-age z scores (HAZ) in 2011 were positively associated with the quality-adjusted index of road density in 2006. The right panel of Figure 9 shows that the change in the index between 2006 and 2011 was positively correlated with weight-for-height z scores (WHZ) in 2011. These patterns suggest a potentially greater importance for historical, rather than contemporaneous, infrastructure patterns in determining HAZ – a long-term measure of child health – and greater sensitivity of WHZ – a short-term measure of weight gain – to changes in infrastructure. The logic of these patterns informs the empirical approach we employ in this paper. Among the key indicators that we consider are those that embody, to varying degrees, the direct, indirect, short-term and long-term effects of transportation. These include calorie intake, dietary diversity, food budget shares, reliance on staples, rates of agricultural commercialization, incomes, and linear growth. Unlike previous work, which relied on district-level indicators of transportation network density, in this paper we use household-specific measures of travel time to roads and markets, which provide more highly resolved information regarding access.

2.4 Spatial dimensions and spillovers

Additionally, it is useful to recognize that roads, road networks and bridges can have geographically dispersed effects on social and economic outcomes. This is likely to be especially true in Nepal, where in most districts road density is low and modest improvements in access might generate large impacts on opportunities and outcomes, both within a district and in adjacent districts linked by roads. Properly addressing such geographic spillovers is statistically challenging, and requires the use of spatial econometric techniques. There are two general conceptual concerns with respect to spatial dimensions and spillovers. The first arises when an observed outcome in one area has an influence on a similar observed outcome in a different area. This is often the case in spatial studies of economic activity where, for example, the clustering of firms or businesses in one area tends to promote or discourage the growth of businesses in adjacent areas. In the current context, it seems unlikely that household or child outcomes in one location would influence average outcomes in households in neighboring districts, and so we do not pursue the inclusion of spatial lags of dependent variables in our analysis. However, we do believe a second spatial concern is worth our attention. In some settings, correlation could exist between infrastructure in one location and outcomes in a different location. As an example, Duran-Fernandez and Santos (2014) found significant spatial spillovers between road infrastructure and manufacturing in Mexico. Accordingly, we use a cross-regressive model that includes spatial lags of the road index variable to account for potential spillover effects, if any, from infrastructure in one district on indicators of neighboring districts.

2.5 Drivers of road & bridge construction & placement as confounders

When considering the potential causal linkages between access and outcomes, it is necessary to understand that roads are almost never placed randomly, and households rarely settle randomly near roads following road construction. This can make it difficult to differentiate the factors that lead to road construction from those that drive livelihood outcomes. In short, roads simultaneously generate economic activity and are themselves the result of economic activity. This means one must interpret any correlation between access and outcomes with caution, since establishing unambiguous unidirectional causality from access to outcomes can be difficult. Most studies, including this one, rely on observational data collected *after* road and bridge construction, and it is nearly impossible to establish a clear counterfactual scenario of what would have happened in the absence of improved access. Collecting baseline data in advance of road construction, and then randomizing subsequent road placement would provide better insights into actual impacts, but this approach is rarely available as a research option. Instead, researchers must rely on quasi-experimental evaluation methods to estimate the impact of differences in access on differences in outcomes.

Additionally, several key drivers of road placement can influence outcomes of interest, which – if not properly accounted for in the analysis – could lead to misattribution of effect. For example, if policy makers target road construction in areas with high agricultural productivity, and those areas are later observed to have above average nutrition outcomes, the cause might be underlying agricultural productivity, not better access. Similarly, high-income areas or those that are economically or politically favored might benefit from road placement, but might also benefit from other underlying advantages or public investments. In contrast, rural development projects may target for road construction those underdeveloped regions with high underlying poverty rates (Lipton and Ravallion 1995), meaning the beneficial impacts of transport infrastructure might be unfairly underestimated.

Regional development aid can determine levels of infrastructure investment, suggesting that regions with low incomes may receive greater infrastructure investments (Hart 1993). In Europe, Rietveld and Boonstra (1995) found regional population size and gross domestic product to be the main drivers of railway and highway supply. Using sub-regional data from a large cross-section of countries, Ramcharan (2009) found that countries with rougher terrain had less developed road and rail networks. The literature on political economy also suggests that some politicians may direct public funds toward locations they favor due to birthplace, ethnicity, or connections in order to reward loyalty and influence voting patterns in subsequent elections. Burgess et al. (2015) found politicians in Kenya to exhibit clear favoritism for areas that shared their own ethnicity when allocating funds for road investments. Nguyen et al. (2011) found greater government investments in infrastructure (such as roads, marketplaces, sanitation, and irrigation) in towns where Vietnamese officials occupied higher ranks of government.

In Nepal, road networks mainly have their origins in densely populated or favored areas. Trails initially connect small villages to larger villages. Roads later connect these villages to district headquarters, and district headquarters to each other, the capital, and major international border crossings. In addition, road density varies widely according to agro-ecological conditions. The Terai has the highest road density, reflecting low costs of road construction and proximity to India. In contrast, road networks are very sparse in the mountains, where construction is costly due to harsh topography. Furthermore, population is a confounder for road placement, since in most situations roads are built where people reside. However, even after accounting for population, road length (in km/km^2/capita) varies substantially across districts in Nepal. Figure 10 shows population-adjusted road densities, by district, for Nepal, where adjustment uses the district population of children below age two. The observed variation suggests that population alone has not driven road placement in Nepal.

3 A REVIEW OF EXISTING EMPIRICAL EVIDENCE

Studies on the economic impacts of bridges are rare. However, there is a rich literature on assessing the economic impact of roads. All of these studies find positive impacts from transportation infrastructure on various economic development outcomes of interest, although a number of studies also document negative externalities and unintended consequences. At the end of this section, we outline some of these negative and unintended consequences. Before doing so, we review the evidence regarding positive impacts, under some key major headings. In each case, we review the global evidence first, followed by any evidence specifically reported for Nepal. Problematically, the literature does not use a uniform definition of what constitutes a road (e.g. whether earthen, gravel, all-weather or sealed). Furthermore, where the term "rural road" is used, it is rarely defined, which precludes careful cross-study comparisons. Furthermore, simply finding positive benefits from road development does not necessarily mean that roads can be justified everywhere, or that every remote village should be connected via a road. As Van de Walle (2002) argues, benefit-cost analyses are required when considering road projects to ensure that benefits of road construction exceed costs, and that the scale of the project is set such that benefits exceed costs at the margin.

3.1 Evidence regarding economic impacts of roads and bridges outside Nepal

Impacts on income and poverty

Worldwide, a majority of poor people reside in rural areas, many of them in remote areas poorly served by infrastructure. By some estimates, nearly a third of the world's rural population – one billion people – live isolated from markets and more than 2km from an all season road (World Highways 2011). As a result, poor people are likely to benefit from new investments in infrastructure, especially those that improve access to goods and services. According to a study conducted among 40,000 poor women and men in 50 countries across the world, respondents speaking about their situation reported isolation, not poverty, as their more pressing concern (World Highways 2011). The same report found physical, social and political isolation as core features of rural poverty traps. Edmonds (1998) identifies access as "a key determinant both of poverty itself and of opportunities to escape from poverty." Faiz (2012) illustrates how rural roads improve rural connectivity, reduce poverty, sustain rural livelihoods, enhance livability, and catalyze overall economic growth. Wang and Wu (2015) found that the Qingzang railway in China led to a 33% increase in GDP in counties directly connected to the railway, with portions of these gains coming from reduced transportation costs and part coming from the railway's effects on urbanization, market integration and industrial agglomeration. Manufacturing industries were the main beneficiaries.

Several empirical studies have found roads to be associated with poverty reduction. Jalan and Ravallion (2002) found that road density was a significant determinant of household-level prospects of escaping poverty in rural China. Dercon et al. (2009) studied the impact of roads on poverty in fifteen Ethiopian villages, and found that access to all-weather roads reduced poverty by 6.9%. Jacoby and Minten (2009) measured the benefit of lower transportation cost in Madagascar. They showed that reductions in transport costs (of approximately 75 US dollars per ton) raised household incomes by about 50 per cent for the most remote households. Improving access to roads was found to reduce poverty in Papua New Guinea (Gibson and

Rozelle 2003), where each one-hour reduction in travel time to the nearest road was associated with a 10% increase in real consumption, a 7% increase in the price of marketed sweet potato, and a 2.6% increase in the average number of income-earning activities. Fan and Hazell (2001) found that investment in rural infrastructure had large impacts on poverty reduction in China and India. Khandker et al. (2009) examined the impacts of rural road projects in Bangladesh, and found that public investments in rural roads reduced poverty through multiple pathways, including higher agricultural production, higher wages, higher output prices, and lower input and transportation costs.

A number of studies have assessed the impact of roads on indicators that could affect household welfare and child nutrition indirectly. Stifel and Minten (2008) documented an inverse relationship between isolation and agricultural productivity in Madagascar, suggesting high transportation-induced transaction costs as a cause. Mu and Van de Walle (2011) found a significant average impact from rural roads on local market development in Vietnam. Duran-Fernandez and Santos (2014) found that improved road infrastructure led to higher industrial production in Mexico; differences in infrastructure endowments partially explained regional gaps in industrial worker productivity. Similarly, Fan et al. (2002, 2004) found that road investments led to agricultural growth and a more robust non-farm sector in China and Thailand.

Past studies also have found that improvements in road quality are associated with significant improvements in household welfare indicators and other metrics. For example, Bell and van Dillen (2014) studied the effects of all-season rural roads in Orissa, India, and report that, after gaining access to all-weather rural roads, households received higher prices for output, reported higher rates of school attendance, and received more frequent and timely hospital treatment. Dercon et al. (2009) found that access to all-weather roads increased consumption growth by 16.3% in Ethiopia. Olsson (2009) found a substantial benefit from road improvement in the Philippines, including lower transportation costs, faster delivery times, improved market access, lower post-harvest losses, and higher agricultural productivity and production. Warr (2008) found large poverty reduction effects from all-weather roads on in Laos. Aoun et al. (2015) found a statistically significant negative relationship between travel time to health facilities in Rwanda and height-for-age z scores of children, concluding that improved access to health facilities is a potential pathway to reduce stunting.

Impacts on transport costs and market access

Improving access to markets through better rural road infrastructure has long been considered an effective way to improve the well-being of the rural poor in developing countries (WB 2012). From a conceptual point of view, differences between farm-gate and market prices depend in part on the quality of rural infrastructure, with larger differentials in areas with poorer infrastructure (de Janvry et al. 1991). As a result, greater economic isolation has been associated with higher transaction costs in many settings, including Kenya (Renkow et al. 2004) and Senegal (Goetz 1992). Minten and Kyle (1999) found that transportation costs (as determined, in part, by road quality) explained a significant proportion of food price variation between producer regions in Zaire.

For a landlocked country, the level of infrastructure development strongly influences transport costs and may limit trade. In a global study of bilateral trade, Limao and Venables (2001) found that a deterioration in infrastructure from the 50th percentile to 75th percentile increased transport cost by 12% and decreased trade volume by 28%. Poor infrastructure accounted for up to 60% of the predicted transport cost for landlocked countries in their study, and low trade flows in Africa were attributed mainly to poor infrastructure. Cosar and Demir (2016) found that better internal transportation infrastructure reduced the cost of shipping and improved access to international markets in Turkey. Mu and Van de Walle (2011) assessed the impacts of rural roads on local market development in Vietnam and found a significant average impact on the development of local markets. Datta (2012) showed that firms in India gaining access to higher-quality highways produced more efficiently and had lower inventory costs. Transport infrastructure was found to increase the probability of exporting by small and medium-sized firms in Spain (Albarran et al. 2013). In a firm-level study, Martincus et al. (2017) found that transport infrastructure increased exports and job growth in Peru.

Impacts on agriculture

Improving access leads to improvements in agricultural productivity by providing better access to input and output markets and by reducing transportation and transaction costs, which in turn reduces the cost of purchased inputs and raises the price of output for sellers. Poor infrastructure reduces the return to invested capital, and undermines incentives to invest. Using a stylized agricultural household model, de Janvry et al. (1991) argue that higher transportation costs may drive potential sellers out of the market, resulting in subsistence farming. In a study from Siaya district, in Kenya, Omamo (1998) found that smallholders chose low-yielding food crops rather than cash crops due to high transport costs associated with getting products to market. Minten et al. (2013) found that, compared with households with good market access, the implicit price of chemical fertilizer was about 50% higher and fertilizer use was about 75% lower for the most remote households in northwestern Ethiopia. High transport costs reduced profitability of chemical fertilizer for *teff*, millet, and sorghum, and led remote households to use fewer inputs and produce less agricultural output. Improvements in road quality were found to increase the use of fertilizer in Bangladesh (Ahmed and Hossain 1990), China (Benziger 1996), and Madagascar (Stifel et al. 2003), and to boost agricultural output in India (Binswanger et al. 1993).

Transportation infrastructure has contributed to the historical pattern of agricultural development in the United States (Donaldson and Hornbec 2016). Qin and Zhang (2016) studied the effect of road access on farmers' agricultural production patterns, input uses, agricultural incomes and rates of rural poverty in China. Their results indicate that access to roads facilitated specialization in agricultural production, increased the use of fertilizer, boosted labor demand, improved households' agricultural incomes, reduced poverty and increased nonfarm income for relatively poor households. Khandker et al. (2009) found that the reductions in transport cost brought about by improved road access in Bangladesh reduced the price of fertilizer. In Malawi, Zeller et al. (1998) found that a higher transaction cost to access the nearest parastatal market outlet for agricultural commodities created a disincentive for allocating planted area to hybrid maize. This shows that improvements in rural infrastructure and better access to agricultural markets are important for new technology adoption and transformation of subsistence-oriented farming. In a study of 15 Ethiopian villages, Dercon and Hoddinott (2005) illustrate the importance of rural-urban linkages. They found that households residing farther from the market town were less likely to purchase inputs or sell output. Road quality improvements increased the probability of purchasing crop inputs by 29% to 34%, depending on the season.

Impacts on overall economic activity

At the broadest levels, improved access can have several multiplier effects. Due to these multiplier effects, and the promising impacts of roads on various development indicators, international aid agencies have frequently argued in favor of road investments (Mayne 2006). In Morocco, improved access to basic services led to increased rates of school attendance for girls, overall improvements in the quality of education and health, and increased numbers of teachers and medical personnel in rural areas (World Highways 2011). Improved rural road infrastructure has been traced to improved health outcomes in settings as diverse as Bangladesh (Ahmed and Hossanin 1990) and the United States (Lokshin and Yemtsov 2005). Bird and Straub (2014) studied the impact of roads on the growth and spatial allocation of population and economic activities across the municipalities in Brazil. Road development led to increased concentration of economic activities and growth in the population in the main economic centers. Such road development helped to spur the emergence of secondary economic centers in the less developed parts of the country, indicating the significant positive spillover effects of roads. The study estimated that between 1960 and 2000, roads accounted for half of the per capita GDP growth of the country, whilst simultaneously reducing spatial inequality. Rephann and Isserman (1994) examined the regional economic effects of interstate highways in the US and found that highway construction increased overall economic growth. Donaldson (2010) estimated the economic impact of railroads in India, and found that the construction of railroads reduced transport costs, increased international trade, helped households cope with rainfall shocks and raised the level of real agricultural income by 18% in districts with rail links. Atack et al. (2010) found that access to railroads led to urbanization in the US. Fernald (1999) suggests that transport-intensive industries in the US are more likely to benefit from state-level road investment and have higher productivity. Michaels (2008) found that counties connected with the interstate highway system in the US experienced more trade than non-connected counties, thereby raising the relative demand for skilled workers. Fan and Xhang (2004) found that rural infrastructure played a major role in explaining the rural nonfarm productivity variation across counties in China. They argue that, because the rural nonfarm economy is one of the major determinants of rural income, increasing rural infrastructure increases rural incomes. They also found that the level of rural infrastructure significantly explained productivity differences in western regions of China. A study from China found a decrease of 6% in per capita income when distance to a hypothetical trade route was doubled (Banerjee et al. 2012). In Korea, a one per cent increase in the road stock was associated with a 0.01% reduction in production costs in the manufacturing sector (Kim and Shin 2002). At the macro-level, road networks are positively associated with national per capita incomes (WB 1994). Gonzalez-Navarro and Quintana-Domeque (2010) examined the effects of road pavement in Mexico. Homes in areas that received pavement obtained more credit and had higher per capita expenditures than those in untreated locations.

For the US, Donaldson and Hornbeck (2016) found that counties linked by rail witnessed a 34% increase in average agricultural land rents compared with untreated counties in the same state and year. Chandra and Thompson (2000) found the US interstate highway network affected spatial allocation of economic activity, raising the economic activity of counties that they passed through while drawing activity away from adjacent counties. They found a 6-8% increase in firm earnings in counties located adjacent of the interstate highway network. The farm wage increased by about 3% for those countries served by a railroad (Haines and Margo 2006). Duranton and Turner (2012) found that a 10% increase in interstate highway length in the US led to a 1.5% increase in employment between 1983 and 2003. A one standard deviation increase in the initial level of roads was associated with 15% greater employment growth over 20 years.

Compared with specific investments in agriculture, education, or health, rural roads were found to generate greater economic impacts in India, Thailand, China, Ethiopia and Uganda, (World Highways 2011). In Indonesia, better road networks improved household welfare, as measured by consumption and income; roads created jobs in the manufacturing sector, led to occupational shifts from agriculture into manufacturing, and raised agricultural profits (Gertler et al. 2014).

Impacts on food, nutrition and prices

Stifel and Minten (2017) found that access to roads increased household welfare in Ethiopia. More specifically, remote households consumed 55% less (mostly food), had lower dietary diversity scores, and 25% lower school enrollment compared to households located nearer to the market. Gibson and Rozelle (2003) found that a 1-hour increase in travel time to the nearest transport facility Papua New Guinea reduced real consumption by 10%. Hirvonen et al. (2017) found that better nutrition knowledge among caregivers improved dietary diversity of children in Ethiopia, but only in areas with relatively good market access. One reason why consumption might be relatively lower in remote regions is the difficulty of consumption smoothing over seasons and time. For example, Darrouzet-Nardi and Masters (2015) found that remoteness in the Democratic Republic of Congo was associated with more variability in household consumption across the year.

Bell and van Dillen (2014) report that, after gaining access to all-weather rural roads, households in Orissa, India received higher prices for output (5% higher or more), reported higher school attendance and received more frequent and timely hospital treatment. Minten (1999) found that communities in Madagascar without basic infrastructure received lower prices during the harvest season and faced higher intra-annual price variability. Calmette (2009) argues that road construction addressed crop failures in Ethiopia, where transport significantly interacted with crop failures and food aid. When crops failed in one area and food aid was centrally supplied, outcomes depended on the quality of rural-rural linkages.

In a rare study of bridges, Tuladhar (2007) examined the effect of bridge construction in Bhutan. Data show that traffic increased by 100% after construction of 23 bridges. It was estimated that time savings amounted to 11,748 hours per day, equivalent to 528,660 man-days per year. Average household income rose by 32% and the total value of domestic output increased by 133%.

3.2 Evidence regarding the impacts of roads and bridges in Nepal

To date, only a very small number of descriptive and econometric studies have attempted to assess the overall benefits of rural roads in Nepal. The UNDP (2011) conducted a benefit-cost analysis of roads in selected districts and found that roads had positive financial and economic returns. Dillon et al. (2011) used hedonic and panel data approaches to estimate the impact of access to infrastructure and extension services in rural Nepal and found that rural road investments had a strong positive effect on household welfare. Jacoby (2000) estimated the household-level benefits of road projects using the relationship between the value of farmland and distance to agricultural markets. His findings revealed that poor households received greater benefits from the market access provided by roads than did better-off households. Lower transport costs increased non-farm production in Nepal (Fafchamps and Shilpi 2003). In a study using data from the 2006 and 2011 Nepal Demographic and Health Surveys covering 4,038 children under age five, Thapa and Shively (2016) found positive associations between district-level road density and both linear growth and weight gain. In a small study from Mustang District, Charlery et al. (2016) found positive income effects from new roads.

Dixit (2017) indicates that poor infrastructure has posed a significant challenge for Nepal's economic development, and that Nepal would need to invest over a billion USD annually (8-12% of GDP) until 2020 to build its infrastructure at a satisfactory level. According to the NPC (2014), uneven investments in roads, education and health have created spatial inequalities in development.

As a measure of household well-being, NPC (2014) created a household well-being index. The Nepal Human Development report indicates that two households identical in all aspects except their location are likely to have different productive abilities due to different levels of access to roads, schools, hospitals, information systems, etc., which play a vital role in determining the productive ability of a household. Few firms are located in the mountainous and hilly regions of the country. Lack of physical infrastructure (such as roads, electricity, health services) and market access constrain industrial development in these regions. Faiz (2012) underscores the importance of trails and suspension footbridges in remote hilly and mountainous regions of Nepal. Although constructing all-weather roads can improve access and mobility, Faiz (2012) suggests that accessibility can be achieved without roads that support vehicular traffic. Where the cost of constructing motorable all-season roads is high, Faiz (2012) argues that trails and suspension foot bridges have significantly reduced travel time and improved access to markets and basic facilities. Shively and Thapa (2016) studied the effect of transportation infrastructure on rice and wheat prices and price volatility in 37 markets in Nepal. They found that improved road infrastructure reduced means and variances of rice and wheat prices. Differences in road densities across time and space explained roughly half of the variation in price mark-ups between regional and local markets. These findings suggest that the benefits of improved access may be greatest for households that are net-buyers of food. In a study from Nepal and Uganda, Shively (2017) found that transport infrastructure mitigated the sensitivity of children's physical growth to local variations in rainfall.

WFP (2016) conducted a qualitative study of the importance of roads and market access on improving the household welfare indicators in the Karnali region. Sixty-four per cent of traders in Karnali reported high transportation cost to be the major problem affecting their business. Due to poor market access and price information, about 50% of agricultural output was sold at the farm-gate price, which was often far below the market price. A high proportion (60%) of traders reported that the road linking Jumla to urban centers decreased transportation costs, reduced food prices and led to increased sales.

Relatively less attention has been devoted to the study of bridges in Nepal. Tuladhar (2007) studied three bridges in Nepal and estimated returns on investment ranging from 18% to 169%. He argues that the construction of bridges increased production of different agricultural crops in the bridge influence zones by 6% to 17% and promoted commercialization of cash crops such as oranges, apples and chilies. Bridges led to the introduction of new crops, facilitated exports, increased access to grazing lands and forests, and led to larger livestock populations. School enrollment increased by 12%, visits to health facilities increased by 18%, access to market centers from remote villages greatly improved and the number of retail outlets increased (Tuladhar 2007).

3.3 Evidence regarding the specific impacts of trails

The body of empirical research on the impacts of trails is quite small. Most of it relates to trails constructed in industrialized counties for recreational purposes and, as such, may not provide many direct insights for trail improvement in Nepal. A review of this literature reveals mostly positive impacts from trail construction. Building trails can help to generate and support local businesses such as restaurants and recreation-oriented services. Recreational trails also have been found to increase property values near trails. Bichis-Lupas (2001) indicates that trails generate multiple benefits by attracting visitors and stimulating the local economy. They facilitates the opening of new businesses and strengthen existing ones via increased visits and sales. According to National Transportation Enhancements Clearinghouse (2002), the opening of the Mineral Belt Trail in Leadville, Colorado led to a 19% increase in sales tax revenue and prevented Leadville from succumbing to an economic downturn by promoting recreation and tourism opportunities. Lee (1999) found that users of greenway trails in the US reported positive emotional experiences. In populations at risk for inactivity, trails increase physical activity (Brownson 2000). For example, Wolter and Lindsey (2001) found that 70% of trail users in Indiana increased their levels of physical activity after beginning to use a trail. Owen et al. (2004) and Sallis et al. (2015) argue that trails promote behavioral choices oriented toward physical activity. Not surprisingly, the establishment of walking trails has been identified as a cost-effective public health intervention to meet physical activity recommendations in areas where individuals have adopted more sedentary lifestyles (Librett et al. 2006).

Some evidence point to negative impacts from trail construction. Trails can lead to soil erosion (Buchwal et al. 2009) and the spread of non-native and invasive species (Adkison and Jackson 1996; Bhuju and Ohsawa 1998; Hill and Pickering 2006; Potito and Beatty 2005). Trails are also likely to influence hydrology (Sutherland et al. 2001) and fragment the landscape (Leung and Louie 2008). In a rare study from Nepal, an examination of trail impacts in Sagarmatha National park found a strong positive correlation between the number of trail users and the level of trail degradation, underscoring the importance of sound trail construction and regular maintenance (Nepal 2003). Clearly, any negative environmental effects arising from trail construction depend on the design and methods of construction of the trail. Proper trail construction minimizes local impacts on natural resources and enhances durability (Marion and Olive 2006; Olive and Marion 2009).

3.4 Rates of return on investments in roads and trails

Although the literature contains studies reporting the rate of return from investments in roads, little of this work is relevant to trail construction and rehabilitation in Nepal. Work from industrialized countries document a number of positive effects, including employment multiplier effects and effects over time. Berechman et al. (2006) found that the between 1990 and 2000, highway capital investments in the United States had an average rate of return of 7.6% for 18 selected counties. Wang et al. (2005) conducted a cost-benefit analysis of recreational trails in Lincoln, Nebraska and found a benefit-cost ratio of 2.94, implying that every $1 investment in trails directed at physical activity returned a benefit of $2.94 in avoided medical expenses.

More relevant to Nepal, Stifel et al. (2012) estimated the benefits of access to feeder roads for rural households in Ethiopia. They found that a hypothetical 10-year all-weather gravel road constructed midway through the study would generate an internal rate of return (IRR) of 12-34 per cent. In a study from rural India, Fan et al. (2008) found that road investments had an estimated benefit-cost ratio of 6. Fan et al. (2004) found a higher impact on rural poverty reduction from low-grade roads (such as feeder roads) that from high-grade roads (sealed roads). They also found that the construction of one additional kilometer of feeder road would lift about 20 poor people above the poverty threshold. However, other studies point out that it may not always be economical to increase the length of road networks, especially in rural areas. In a study from Uganda, Raballand et al. (2009) indicated that massive investment would be needed to achieve rural accessibility such that all households were less than 2 kilometers from a road, arguing that it would be more cost-effective to maintain existing rural roads than to push new roads into sparsely populated areas. More generally, this underscores that the return on investment (ROI) from improved access may be quite low in the most remote locations, due to the high costs of reaching sparse populations with a low opportunity cost of labor.

3.5 Negative and unintended consequences

The economic and social costs associated with road construction and transport are widely recognized to include degradation of air quality (and increased greenhouse gas emissions), noise pollution, and accidents (Maddison, et al. 1996). Although increases in economic activity associated with roads could lead to less school attendance by some children or out-migration and depopulation of the young in rural areas, to the best of our knowledge the empirical literature does not currently support such conjectures. Environmental harms, primarily through habitat destruction and improved access to environmentally sensitive resources can also arise from transport development, and has been documented in the empirical literature. Landslides have long been associated with road construction, especially in hilly and mountainous areas (Bansal and Mathur 1976). Recently, the range of unintended harms associated with road construction has expanded to include the nutritional and health consequences of increased consumption of processed foods. We have made no attempt to measure or incorporate these negative and unintended costs in this report, but the potential harms are briefly discussed below.

Air quality degradation

Few published studies focus on air pollution impacts of road construction. Font Font, et al. (2014) report findings from air quality monitoring during road construction in the UK, where data on PM10, PM2.5, NOX, and NO2 were collected on both sides of the road to quantify air quality before, during and after road completion. PM10 increased significantly during construction compared to baseline. Levels of other monitored items were not statistically different.

More generally, active road use, as opposed to road construction, is widely associated with elevated levels of small particulate matter, Sulphur dioxide, Nitrogen oxides, ozone, benzene and lead, among others. Malla (2014) indicates that while Nepal's current level of road energy use remains among the lowest in the world, more than half of the country's total commercial energy use is associated with the transport sector, and more than half of Nepal's total energy-related CO_2 emissions originate with the transport sector. Malla (2014) argues that emissions of local air pollutants from motor vehicles are substantial and responsible for deteriorating air quality in the country, especially in urban areas.

Road traffic injuries (RTIs)

Nantulya and Reich (2002) provide a review of road traffic injuries (RTIs), reaching the conclusion that such episodes constitute a "neglected epidemic" in developing countries. They report that, for 1998, more than 85% of all deaths and 90% of all disability adjusted life years lost from road traffic injuries occurred in developing countries, and that, among children, the fatality rate (per 100,000) in low income countries was roughly six times greater than the corresponding rate in high income countries. They also found that injuries and fatalities were borne disproportionately by the poor in developing countries, as pedestrians, passengers of buses and minibuses, and cyclists. Híjar, et al. (2004) studied road traffic injuries among patients seeking emergency room attention in Mexico. Among those injured during the study period, 54% were victims of road traffic accidents. Of these, 72% were passengers and 28% were pedestrians and cyclists. Similarly, in a study of patients reporting to hospital in Nigeria, Elechi and Etawo (1990) found 82 per cent of patients were under 31 years of age. Although road traffic accidents were only the third leading cause of trauma (26% of patients), they were responsible for a disproportionate share (68%) of recorded deaths. Four recent studies document similar patterns in Nepal. Agnihotri and Joshi (2006) evaluated injury patterns among hospitalized trauma patients admitted during 2003 in Western Nepal. The majority of injuries (54%) involved motorcycles. Jha & Agrawal (2004) studied hospital admissions from road traffic accidents in two hospitals of eastern Nepal. They reported that the highest percentage of cases (29%) were in the 20-29 year age group, with laborers and students the most frequently injured groups. Approximately 17% of drivers were found to have consumed alcohol 2-3 hours prior to the accident. Buses (31%), trucks (12%) and bicycles (11%) were the most frequently involved vehicles. In a country-wide population-based survey (n=2,695) conducted by Nepal et al. (2015), 3% of Nepalese adults selected at random reported having experienced road traffic injuries. Of all injuries reported in the sample, 20% resulted from a road traffic accident. Motorcycle crashes were the most common (48%), followed by car, truck, or bus crashes (27%), and pedestrian or bicycle crashes (25%). Of 80 family deaths reported for the previous year, 7.5% were due to road traffic injuries, a larger proportion than previously reported based on police reports, suggesting under-reporting. Finally, in a comprehensive review covering more than 20 individual articles, 95,000 crashes, 100,000 injuries and 14,000 deaths over the 12-year period 2001-2013 in Nepal, Karkee and Lee (2016) report that fatalities were highest on highways outside the Kathmandu valley, and caused largely by bus crashes in hilly districts. They conclude that the problem of RTIs in Nepal is substantial and growing. However, they find that the majority of published studies on RTIs in Nepal are descriptive and hospital based, indicating the need for more thorough investigations of causes, more systematic recording of crashes, and greater knowledge of circumstances surrounding crashes (such as alcohol use or improperly maintained vehicles) in order to identify and develop effective interventions.

Environmental externalities

Roads, if not constructed in the most suitable areas, can cause serious harm to local environments and ecosystems. Roads can be a source of chemical pollutants (Pratt et al. 2007), and the construction process can have serious consequences for local soils (Olander et al. 1998), hydrology and aquatic ecosystems (Iwata et al. 2003). Various studies have found negative effects from roads constructed into wilderness areas, or where ecosystems and national parks are dominated by native vegetation (Laurance et al. 2001; Blake et al. 2007; Laurance et al. 2009; Adeney et al. 2009). Roads have been identified as a primary driver of deforestation in the Amazon basin (Laurance et al. 2001; Cattaneo 2001; Chomitz and Thomas 2003; Pfaff 1999). In the Brazilian Amazon, for example, Pfaff (1999) found that new roads constructed in one county increased deforestation in the census tracts of neighboring counties. Higher road densities in one county were also associated with greater rates of deforestation in that county and in neighboring counties (Pfaff 1999). Laurance et al. (2001) found that roughly 95% of deforestation and forest fires took place within 50 km of highways or roads in Brazilian Amazonia. Blake et al. (2007) found greater elephant poaching in areas close to roads in the Congo Basin. Laurance et al. (2006) and Blake et al. (2008) also report higher hunting intensity near roads, thereby affecting populations of exploited species.

Weinhold and Reis (2008) found the impact of changes in transport costs on forest clearing in the Amazon depended on initial land use. Where large proportions of forest had already been cleared, roads reduced subsequent forest clearing. In less disturbed areas, reductions in transport costs were more likely to increase deforestation. Laurance et al. (2014) combined a wide range of information, including wildlife habitats, biodiversity hotspots and agricultural yield gaps to identify benefits and environmental risks associated with potential roads globally. Although they did not identify specific countries or locations, their maps suggest that many parts of Nepal fall into a category with above-median values for both agricultural benefits and environmental costs. This highlights the environmentally sensitive nature of road construction and improvement in Nepal.

Nutritional risks

Improved access may lead to negative and unintended nutritional consequences. Grocke and McKay (2016) studied the consequences of new roads on availability of foods and dietary patterns of individuals in Humla district, one of the most isolated parts of Nepal. Although roads provided additional food sources, increased regional food access, and reduced the uncertainty of the local food supply, the overall quality of diets decreased, especially in terms of nutrient densities. Processed foods, including white flour and noodles, as well as inferior foods high in sugar, have been gradually replacing traditional diets, which the researchers judged to consist of nutritionally superior foods. Ethnographic data suggest that new roads led villages to seek out, purchase and rely upon processed oils. Based on consumption patterns documented in the study, the researchers warn that children in the area are at increased risk for developing diet-related non-communicable diseases (DR-NCDs).

A mother feeding her child nutritious food.

Photo credit : WFP/Santosh Shahi

4 EMPIRICAL APPROACH

In our empirical approach, we use household-reported data on travel time to roads and markets as indicators of access. We use this information to derive discrete and continuous "treatment" variables. Our discrete treatment variables correspond to whether a household reported a travel time of one hour or less from home to a well-paved road or market center. Our continuous treatment variables are total travel times (in hours) needed to reach a well-paved road or market center, using normal methods of travel. We use these treatment variables in conjunction with household-level outcome indicators for household food security and overall household welfare. Before describing the statistical approach, we describe the data and their sources.

4.1 Data definition and sources

As control variables in our regressions, we use district-level data on road and bridge density. Road data come from the Department of Roads (DOR 2011; 2012), Ministry of Physical Planning, Works and Transport Management. Road data published by the DOR mainly focus on strategic roads (national highways and feeder roads). Since each district has strategic roads of varying quality, we constructed a road density index using weights that account for different road qualities and the travel times that they imply. Following Shively and Thapa (2017), we assume that a sealed (blacktopped) road is five times faster than a gravel road and that a gravel road, in turn, is ten times faster than an earthen road. Recalling the stylized view presented in Figure 8, our aim is to create a nuanced measure of transport infrastructure that combines key aspects of quantity and quality. We also generate a spatial lag of the road index for all districts using a spatial weights matrix. This is a 75 x 75 matrix that is row standardized. The weights are equally distributed and sum to one for all neighboring districts (those sharing a boundary) while for non-neighboring districts, the matrix elements are zero. This allows us to measure and account for local spillover effects from roads, if any, across neighboring districts. Bridge data come from the DOR Bridge Management System, administered under Nepal's Strategic Road Network (SRN) program. All available bridge data have been geo-referenced. Road and bridge data represent cumulative construction through 2011.

Our outcome indicators come from the most recent Nepal Living Standard Survey (NLSS). The Central Bureau of Statistics (CBS), Nepal conducted the 2011 NLSS following the methodology of the World Bank's Living Standard Measurement Survey using a two-stage stratified random sampling technique. CBS (2011) outlines the sampling frame and survey approach. The survey asked questions related to agriculture, food consumption and expenditure, farm and off-farm income, migration, labor, demographic features, loans, access to facilities and market infrastructures, and other welfare measures at both the individual and household levels. A total of 5,988 households were surveyed in 2011. We also extracted child anthropometric indicators and accompanying data for 2,394 children below the age of five who were measured as part of the NLSS in 2011. In our analysis for which the empirical interest is household-level agricultural indicators, we with work with the sub-sample of agricultural households who owned or rented farmland (n=3,937). For child-level regressions, we work with the full sample of NLSS children.

We obtained two access-related variables from the NLSS 2011: the household's self-reported travel time (when walking or using basic methods) to reach the nearest well-paved road and the household's travel time (again, whether walking or using basic methods) to reach the nearest market center. We also extracted from the NLSS information necessary to construct four household food security indicators, plus an additional two nutrition indicators for households with children.[6] These are: (i) calorie consumption (in Kcal/person/day); (ii) non-staple food expenditures (the share of monthly expenditures on non-staple foods including fruits, vegetables, pulses, and animal-sourced foods);[7] (iii) dietary diversity (computed as a Simpson's index); (iv) food consumption (average weekly household expenditure in Rs.); (v) linear growth (height-for-age z score for children below 5 years); and (vi) stunting (child HAZ< -2). We also constructed from the NLSS data seven household livelihood and welfare indicators: (i) whether the household is poor (according to Nepal's poverty line, defined as real consumption expenditure per person per year of Rs 19,261); (ii) food expenditure (Rs/person/month); (iii) an indicator of market participation (agricultural products sold divided by agricultural products produced, in kgs); (iv) non-agricultural activity (total non-agricultural income in ten thousand rupees); (v) labor hiring (a binary indicator of whether the household hired labor or not); (vi) labor sharing (a binary indicator of whether the household exchanged labor with another household); and (vii) migration (an indicator of whether any member of the household had migrated, irrespective of whether migration was temporary or permanent, and regardless of whether it was to a domestic or international destination).

As a dietary diversity indicator, we computed Simpson's index (SI) as:, where is the share of expenditure computed across eleven different food sub-groups indexed by *i*: cereals, legumes/pulses, eggs, milk/milk products, fat/oil, vegetables, fruits, fish, meat, spices/condiments, and sugar/sugar products. The SI value lies between 0 and 1; a value of zero indicates a household has consumed food from only one sub-group, whereas a value approaching one indicates equal expenditure shares among all food sub-groups.

To supplement DOR and NLSS data we add several other pieces of information. Data on total food storage capacity of warehouses located in different districts of Nepal come from the Nepal Food Corporation (NFC). We also use rainfall data obtained from the Department of Hydrology and Meteorology, information on food availability and agricultural production from the Ministry of Agriculture Development (MOAD), and several items from the Nepal Census.

4.2. Regression framework

Multilevel model

We employ a multilevel model to study the effects of access on the households' food security, welfare and livelihood indicators. We consider three levels: the household (the unit of analysis), the community (second level) and the district (third level). In the case of child nutrition outcomes variables, the unit of analysis is the child.

Food security outcomes for different households residing in the same community can be highly correlated because these households observe similar growing conditions, similar food prices, and similar market access. Moreover communities dispersed within a district still share many district-level characteristics, including agro-ecological characteristics. Use of a multilevel model allows us to correctly account for effects arising at these higher levels. We also compute intra-class correlation coefficients (ICCs) to assess whether coefficients from different levels are statistically significant. These coefficients measure how much of the variation in the primary-level data is explained by each level of the multilevel regression model. The estimated ICCs provide evidence that supports our use of a multilevel model.

6 The NLSS directly provides all of the indicator variables except the monthly non-staple expenditure share, HAZ, the stunting indicator, and sales ratio, non-agricultural income and the Simpson's index. We computed these indicators using NLSS variables.

7 When calculating the non-staple food share, we include in the denominator of the ratio the value of all purchases and production, where the latter is the market value of the production stated by the household.

We begin with a parsimonious model that includes only the transportation infrastructure and access-related variables. This provides evidence regarding the potential importance of transportation and access, but probably generates an upper bound estimate on the role of transportation because the model does not account for other important factors, and may therefore overstate the role of access. We subsequently compare these naïve models to more complete models that control for a range of household, community and district level characteristics. The full model is expressed as follows:

$$y_{jkl} = \beta_{000} + \sum_{c=1}^{c} \beta_{0,owl} Q_{w,kl} + \sum_{t=1}^{Tcw} \beta_{00t} D_{t,kl} + (\gamma_{001} + \gamma_{0kl} + e_{jkl}) \quad (1)$$

where Y_{jkl} are the outcome indicators (Simpson's index, total kilocalories, expenditure share of non-staple food, monthly food expenditure, sold ratio and non-agricultural income) for the j^{th} household in k^{th} community from the l^{th} district. $H_{c,kl}$ represents the household level characteristics, $Q_{w,kl}$ represents the community level characteristics and $D_{t,kl}$ represents the district level characteristics. γ_{001} is the error term at the district level; γ_{0kl} is the error term at the community level; and e_{jkl} is the error term at the household level. We assume that these errors are independently and identically distributed, and uncorrelated across levels.

The intra-class correlation coefficients (ICCs) can be computed for the community and district levels, respectively. Denoting the variance of e_{jkl} as σ^2, that of γ_{0kl} as σ_u^2, and that of γ_{001} as σ_v^2, the percentage of variation at the household level explained by the higher levels (community and district) can be calculated as follows:

$$\rho_c = \frac{\sigma_u^2}{\sigma^2 + \sigma_u^2 + \sigma_v^2} \quad (2)$$

$$\rho_d = \frac{\sigma_v^2}{\sigma^2 + \sigma_u^2 + \sigma_v^2} \quad (3)$$

where ρ_c and ρ_d denotes the ICCs for the community and the district levels, respectively. The remaining proportion of the variance that can be explained at the first level can be calculated as $1 - \rho_c - \rho_d$.

For the multilevel model with binary dependent variables (poverty outcomes, household migration outcomes, labor sharing), we use a multilevel mixed-effects logistic regression model. The basic approach is similar to that described above, except that we assume responses conditional on the random effects follows a Bernoulli distribution. The response probability is determined by the logistic cumulative distribution function. Since the log likelihood for such model has no closed form, it is approximated using adaptive Gaussian quadrature.

Propensity Score Approach

From a conceptual point of view, the ideal way to measure the impact of access would be to randomly assign the placement of roads and bridges, and then randomly distribute households across the landscape so that some households (those "treated") receive access and others (the "controls") do not. Since this experiment is unavailable to us, we instead use a synthetic method that relies on matching treated and untreated households on observable characteristics. We look for untreated households in the sample (i.e. those without nearby road or market access) who otherwise look like treated households (i.e. those adjacent to a well-paved road or market center). We then measure differences in outcomes between these groups. If we can accurately account for all variables that might otherwise influence outcomes, then we can attribute differences in outcomes to treatment, rather than to other observable factors or features of households or communities.

We use the propensity score matching technique to estimate the impacts of road and market access on the household food security, livelihood and welfare indicators as follows. First, we define two treatment variables as binary indicators. The first binary indicator takes the value 1 if the household was capable of reaching a well-paved road within one hour of travel using normal methods (typically walking), and zero otherwise. The second binary indicator takes the value 1 if the household was capable of reaching a market center within one hour of travel, and zero otherwise.[8] We build the model in steps. We first estimate probit regressions using our binary indicators as the dependent variables, incorporating key covariates. Based on these covariates, we then predict the household's probabilities of living in proximity to a well-paved road or market center (travel time < 1 hour). Equipped with these predicted probabilities, we assess the region of common support, searching for significant overlap of propensity scores between treatment and control groups. Once support is established, we partition the entire sample into blocks (6 in the case of road access; 8 in the case of market access). We then test whether the mean propensity score is the same for treatment and control groups in each block. We use this balancing test to ensure that the average propensity scores and the means of covariates are the same within each block of the propensity score distribution. Once the balancing property has been satisfied, we use a set of three different matching techniques (nearest-neighbor, stratification and radius) to estimate the average treatment on the treated households (ATT) as follows:

$$E[Y_{1i} - Y_{0i} \mid D_i = 1] = E[Y_{1i} \mid D_i = 1] - [Y_{0i} \mid D_i = 1] \qquad (4)$$

Here the first term, $E[Y_{1i} \mid D_i = 1]$ is the average outcome indicator for the treated households ($D_i = 1$). The second term $[Y_{0i} \mid D_i = 1]$ is the average outcome that we estimate would have been observed among treated households, had they not been located within the travel time of 1 hour. Since this cannot be observed, we create this counterfactual result using the propensity score matching technique, thereby providing an estimate of the average effect of the treatment on the treated (ATT). This is a consistent measure of the binary treatment effect. Our assumption is that we have included all relevant variables in our regression model that might be correlated with D_i.

Dose-Response Function (DRF)

The propensity score provides us with the average impact of improved access when we measure access as a binary treatment. We recognize, however, that treatment impact may vary according to travel time. To add an additional dimension to the analysis, therefore, we use a dose-response function (DRF) to estimate the continuous impact of incremental improvements in access on key outcome variables for household food security and livelihoods. This approach allows us to estimate the impact of each level of treatment on the outcome of interest. We conduct this analysis at the household level. In this case, the continuous treatment variable is the travel time required to reach the nearest well-paved road or market center. In this sense, increasing levels of "treatment" are undesirable and confer a disadvantage on the household. Greater treatment equals a longer travel time, and we therefore expect to find a negative relationship between treatment and desired outcomes.

8 *The NLSS measures a household's reported access to a certain facility in terms of time taken for one-way travel to that facility, irrespective of the mode of transport (i.e. foot or vehicle). Market centers are all cities and towns declared by the government as municipalities and are mainly district headquarters. Local markets (haat bazaars) are local markets that operate at regular intervals on certain days of the week and are especially popular in the Terai. The majority of households in hilly and mountainous regions do not report information on haat bazaars, and therefore we do not include this information in our analysis. About 43% of the households from Terai reported the same travel time to reach the market center and the local haat bazaar.*

We follow the approach proposed by Hirano and Imbens (2004). The model requires that we first estimate the generalized propensity scores (GPS) at each level of treatment using a suitable set of pre-treatment covariates. We assume that the treatment, conditional on the covariates, follows the normal distribution:

$$T \mid X_i \approx N(\beta_0 + \beta_1 X_i, \sigma^2) \qquad (5)$$

where represents the household-level covariates. The GPS is defined as the conditional density of the treatment given the covariates. This is specified as:

$$(\hat{g}\hat{p}\hat{s}) = Ø(T_i \,;\, X_i) = R \qquad (6)$$

As in the case of the propensity score for binary treatments, a balancing property for the GPS must be satisfied. The balancing test assures that, within strata and with the same value of , the probability that = does not depend on the value of . Once the balancing test is satisfied, we estimate the conditional expectation of the outcome indicator as a function of two scalar variables – the treatment level and R (the):

$$E[Y|T = t, R = r] = E[Y(t) \mid r(t, X) = r] = \beta(t,r) \qquad (7)$$

We then specify a regression of our variables (the outcome indicators) on the treatment and . At the same time, we include all second-order moments of treatment and *pscore* variables. The estimating equation is:

$$E[Y|t, r] = b_0 + b_1 T_i + b_2 pscore + b_3 T_i^2 + b_4 pscore^2 + b_5 pscore \times T_i \qquad (8)$$

After estimating equation (8), we calculate the outcome at each particular level of the treatment . This is:

$$\hat{\mu}(t) = E[Y] = \tfrac{1}{N}\sum_{i=1}^{N} \hat{b}_0 + \hat{b}_1 t_1 + \hat{b}_2 \rho score_i + \hat{b}_3 t_i^2 + \hat{b}_4 \rho score_i^2 + \hat{b}_5 \rho score_i^2 X t_i \qquad (9)$$

We can do this for each level of continuous treatment and derive the entire mean-weighted dose-response function, using as weights each *pscore* associated with a specific treatment value *t*. We compute standard errors and 90% confidence intervals using a bootstrapping technique. We compute marginal effects of treatment on the treated as follows:

$$\hat{0}(t) = \hat{\mu}(t) - \hat{\mu}(\tilde{t}) - \hat{\mu}(\tilde{t}) \forall \varepsilon T \qquad (10)$$

where is a benchmark travel time, the shortest travel time recorded in the data to reach a well-paved road or market center. All analysis is conducted using Stata 13 and the Stata commands gpscore and doseresponse.

A man walking on the rural road next to Beri River.

Photo credit : WFP/James Giambrone

Mules are used to transport food in Nepal's rough geographical terrain.

Photo credit : WFP/Santosh Shahi

5

RESULTS AND DISCUSSION

5.1 Descriptive data

Table 2 presents descriptive data for the variables included in the analysis.[9] We restrict our investigation to the sample of households that owned or rented agricultural land.[10] Appendix Figures A1-A13 provide district comparisons for all indicator variables used in the analysis and Appendix Figures A14-A24 provide district-level comparisons of key covariates used in the analysis.

In addition to reporting statistics for the entire unweighted sample of agricultural households, Table 2 also divides the sample into treatment and control subsets, defined according to the household's nearness to a well-paved road. For this purpose, we consider a household "remote" if it had a total travel time greater than 1 hour to reach a well-paved road. Approximately 54 per cent of households in the unweighted NLSS sample were remote from a well-paved road based on this definition. In addition, 58% were remote from a market center. The average household in the sample was 3 hours and 23 minutes from the nearest market center and 2 hours and 10 minutes from the nearest well-paved road. One might generally expect road density and market density to be correlated, and for increases in road density to lead to greater market establishment over time.[11] Although the correlation between travel times to roads and markets is positive, large and significant ($\rho=0.67$; $t=13.6$), the variables do appear to convey different information, as the simple bivariate plot in Figure 11 indicates.[12] Across numerous important dimensions, households differ substantially according to whether they are remote from roads. Those more than one hour from a well-paved road were twice as likely to be poor (28% vs. 15%), five per cent less likely to occupy small landholdings (28% in the small farm category vs. 23%), and reported half as much non-agricultural income (Rs 96K vs. Rs 185K) as their less remote counterparts.

For the child-level regressions, the dependent variables are height-for-age z score (HAZ) and a binary indicator of stunting (HAZ < -2.0). The average HAZ in the NLSS sample is -1.52.[13] Approximately 40% of children in the 2011 NLSS sample are stunted. Eight per cent of children experienced diarrhea in the two weeks prior to measurement and nineteen per cent experienced a fever. Forty-nine per cent of children in the sample are male and the average age is 30 months. Thirty-two per cent of children sampled were born in the monsoon season.

Variables of interest at the household level include food security and livelihood indicators. These include calorie consumption (mean = 2,673 Kcal/person/day), dietary diversity (mean = 0.74), monthly expenditure share for non-staple foods (mean = 0.39), the household weekly food budget (mean = 1,721 Rs/week), an indicator of commercialization (mean = 0.08

9 *For comparison, population-weighted descriptive statistics are reported in Appendix Table A2. Note that all analysis contained in this report is based on unweighted NLSS data. Statistical conclusions are accurate for the sample of households studied, but may not always accurately represent Nepal as a whole, or specific geographic sub-regions.*

10 *This constitutes the sample of "agricultural" households, although we recognize that it could potentially exclude landless households who worked as agricultural laborers. We have excluded 70 households from our sample that lived in rural areas but reported zero cultivated area and zero farm income.*

11 *Unfortunately, we are not aware of data for Nepal that would allow us to reliably analyze the relationship between road density and market density.*

12 *In 1,889 cases (33%) the values coincide. For both measures, the raw NLSS data contained observations with implausibly high values for travel time. In the full sample, 149 values for time to market and 440 values for time to road are arbitrarily set equal to 16.67.*

13 *This compares to average HAZ = -1.71 in the full, unweighted 2011 Nepal DHS sample.*

kg sold/kg produced), non-agricultural income (mean = 137,000 Rs/year), food expenditure (mean = 1,640 Rs/person/month), a poverty indicator (22% poor based on a poverty line corresponding to a real consumption expenditure less than 19,261 Rs/person/year), whether the household engaged in labor sharing (mean = 33%) and whether any household member had migrated (mean = 56%).

Three-quarters of the sample households were male headed, the average age of the household head was 47 years, and families had 5 members on average. In terms of household ethnicity, the largest percentage were Mongolian (28%), followed by Unprivileged (26%), Brahmin (14%) and Madhesi (11%). On average, 41% of the households used improved fertilizer, 58% of had access to irrigation and 10% received agricultural advice. Approximately one-third of mothers were literate, with somewhat lower literacy rates in the remote sub-samples. Approximately 17 per cent of sample households resided in an area designated as urban.

Figure 12 provides univariate frequency distributions for the travel time variables and continuous household indicator variables.[14] To provide additional perspective on the bivariate relationships between the travel time variables and the indicators, Figure 13 presents a series of bivariate scatter plots of household indicator variables against travel time (to market center). Superimposed on the scatter plots are linear regression lines associated with access times to a well-paved road (solid, in red) and a market center (dashed, in black), respectively. The plots illustrate wide heterogeneity in outcomes, but some consistent underlying unconditional patterns, namely that non-agricultural income, calorie consumption, food expenditures, dietary diversity, non-staple expenditure shares and household commercialization all decline with access time. The plots reveal minor differential responses of the chosen indicator variables to changes in access time, depending on whether one measures access time to a well-paved road or to a market center.

14 For 146 households, the value of nonagricultural income exceeds Rs 1,000,000. These observations are omitted from the histogram in Figure 11, but included in the analysis.

Community level variables of interest include crop diversity, access to irrigation and food price index variables. On average, 19 crops are grown in a village and 61% of households have access to irrigation. The average price index ranges from 0.83 to 2.12. NLSS computes this price index using survey data on the price of the food items and housing in various parts of the country. The price index accounts for spatial-cost-of living adjustments since spatial variations in prices are substantial in Nepal. All households within a ward receive the same price index. The price index for the sample of agricultural households (mean = 0.96) is significantly lower ($p < 0.001$) than for the sample of non-agricultural households (mean = 1.44).

District-level controls of interest are the road density index (mean = 14km/km^2), the spatial lag of the road index (mean = 153km/km^2) and the bridge density (mean = 0.013/km^2). Although forty-four per cent of districts in Nepal are identified as being in cereal deficit, meaning overall cereal requirements exceed production, a somewhat smaller proportion of households in our sample (38%) reside in cereal deficit districts. This indicates slight underrepresentation of households from these areas in our sample. Public grain storage capacity in remote districts (mean = 2.87 kg/person in the sample) is statistically lower than that of non-remote districts (mean = 4.05). The sample proportions from the Hills, Mountains and Terai are 52%, 8% and 40%, respectively.

5.2 Multilevel regression results for key indicators

To assess the associations between our access variables and indicators of interest, while controlling for factors at household, village and district levels, we estimated several multilevel regression models. Whenever the dependent variable of interest is a binary indicator, we used a mixed-effect logistic regression model. Below, we only report and discuss access and infrastructure-related coefficients that are statistically significant at a 10% test level or greater. Models denoted "A" are parsimonious models that include the access and transportation variables; models denoted "B" are fully-specified models with a complete set of covariates.

Table 3 displays results for regression models measuring the relationship between access and the livelihood outcome indicators. We find robust evidence for the associations of market access on the poverty indicator (Models 1A and 1B). An increase in travel time to reach a market center is positively correlated with the likelihood of being below the poverty line. Similar results hold for the effects of access to a well-paved road, although the correlation is found to be significant only in the case of the parsimonious model (Model 1A). Higher road density is negatively correlated with household poverty. This suggests that households living in a district with a greater road density index (indicating proportionately greater linear road distance and better road quality) are less likely to be poor. Each additional hour needed to reach a well-paved road is correlated with an annual Rs 268 reduction in real per capita consumption (RPCFC).[15] Put in terms of the sample, this suggests that at the most remote locations, corresponding to roughly 16-hours of travel to a well-paved road, a household experiences a Rs 4282 lower RPCFC compared with a household residing adjacent to a well-paved road. In this sample, 875 households (22%) are poor (RPCFC < 19,261). Of these, 145 households (17%) are poor and reside more than 16 hours from a well-paved road. The regression results suggest, therefore, that providing immediate access to a well-paved road would move 73 of these households (50% of those identified as poor) above the poverty line.

15 In results not shown, we used Stata's xtmixed logit model to regress annual per capita real household consumption expenditure on the access and infrastructure variables and a number of control variables. We find that each additional hour of travel time to reach a well-paved road is associated with a reduction in annual per capita consumption of Rs 268. The coefficient is statistically different from zero at a 95% confidence level.

Results for models 2A and 2B suggest that increases in travel time to reach a well-paved road increases the probability that a household engages in labor sharing and that a higher bridge density is negatively correlated with the probability of labor sharing. These results suggest that better access and road infrastructure are likely to reduce the probability of labor sharing between households. Road density is negatively correlated with the likelihood of having a family member who had migrated (models 3A and 3B).

Table 4 reports results for the effects of access on food security outcomes. Increases in travel times to reach a market center or a well-paved road are correlated with less diverse diet outcomes (as proxied by Simpson's index). Better transportation infrastructure in a district (as measured by the road density index) is positively correlated with dietary diversity. The coefficient of the spatial lag of the road index is positive and weakly significant in the parsimonious model (Model 4A). This indicates positive spillover effects from roads in one district to outcomes in adjacent districts. In other words, a dense road network in one district has a positive influence on the dietary diversity of households living in neighboring districts. Although we find positive effects of bridge density in the parsimonious model (Model 4A), we do not find the coefficient to be significantly different from zero after controlling for other covariates (Model 4B). We find a robust and positive association between improvements in market access and a household's monthly non-staple food expenditure share (Model 5A). This is important from a nutritional perspective as it indicates reduced overall reliance on staple foods as access improves, pointing to the inclusion of food items in the household's basket that increase dietary diversity and likely provide nutritional advantages. Similarly, we find a positive effect of bridge density on the non-staple food expenditure share. Although an increase in travel time to a well-paved road is negatively associated with the non-staple expenditure share, the effect is statistically weak in the fully-specified regression model (Model 5B). We find a negative association between the road density index and per capita daily kilocalorie consumption (Model 6A). One cause could be higher reliance by remote households on staple foods, which tend to be more dense in calories.[16] Remaining access and transportation infrastructure coefficients are not significantly different from zero in the full model (Model 6B).

Table 5 reports results for the models of agricultural outcome indicators. We find robust evidence of a positive effect of district road density on food expenditure. Results from both Model 7A and Model 7B show that the road density index is positively correlated with the per-capita monthly food expenditure. The bridge density is also positively correlated with the commercialization ratio (models 8A and 8b), suggesting a positive effect of bridges on getting agricultural output to market. We also find positive spillover effects of the road index on agricultural commercialization in models 8A and 8B, which also suggests broad and positive influence from roads on market participation as a seller. Results from the parsimonious model (Model 9A) suggest that improved access to well-paved roads and markets boosts non-agricultural income, although the significance of the association is weaker when we include a full set of covariates in the model (Model 9B).[17] We find similar results for the road density index.

Table 6 reports regression results for the models of child nutrition outcomes. Results from both the HAZ and stunting models show that improved access to a well-paved road or market center is correlated with higher linear growth and lower probability of stunting (models 10A-11B). Each additional hour needed to reach a well-paved road is correlated with a 0.02 point reduction in HAZ (Model 10B). Put in terms of the sample data, this suggests that at the most isolated locations, corresponding to 16-hours or more of travel to a well-paved road, a child experiences a z score 0.33 points lower (one-third of a standard deviation) than a child residing less than one hour from a well-paved road. In this sample, 951 children (40%) are stunted (HAZ < -2). Of these, 155 children (6% of the total) are stunted and reside more than 16 hours from a well-paved road, and 65 (2.7%) are severely stunted (HAZ < -3) and reside more than 16 hours from a well-paved road. The regression results suggest, therefore, that providing these children with immediate access to a well-paved road would move 15 of them (10% of those stunted) out of the stunted category and 31 (48% of those severely stunted) out of the severely stunted category. We additionally find that, controlling for travel time, a higher district-level road density is associated with a higher HAZ and lower probability of stunting (Models 10A, 10B and 11A). The HAZ findings are highly robust to the inclusion of the complete set of control variables, showing the fundamental importance of isolation and lack of access in undermining child growth.

To summarize the regression findings, Table 7 reports key associations among the indicators and the various infrastructure and access treatments. For ease in interpreting the results, all coefficient estimates are reported in elasticity form, such that the effect magnitudes can be directly compared. In each case, the elasticity indicates the percentage change in the indicator resulting from a 1% change in the treatment variable, holding constant all other variables. Only statistically significant relationships are included in the table. These elasticities are also reported in graphical form in Figure 14. Many of the elasticity magnitudes are small, but in line with expectations regarding size and sign. The strongest associations are between district-level road density and the likelihood of a household being poor, and district-level bridge density and the probability that households rely on shared labor. In general, better access confers a wide range of benefits on households, as does greater density of transportation infrastructure.

Finally, we estimated intra-class correlation coefficients (ICC) for all multilevel models. Table 8 reports these. The ICCs were estimated using the estat icc command in Stata 13. For models with binary dependent variables, Stata reports two ICCs for a three-level nested model. For models with continuous dependent variables, Stata reports three ICC's for a three-level nested model. For a majority of models, we find food-security and livelihood outcomes to be highly correlated within village and less highly correlated within district.

5.3 Results from the Propensity Score Approach

We used a propensity score approach to estimate the impact of proximity to a road and market on food security and livelihood outcomes. In this part of the analysis, the treatments we consider are binary, and take the value zero and one depending on whether a household had the potential to reach a well-paved road or market center within a total travel time of one hour or less. Using observed covariates, we first estimate propensity scores. These scores simply represent the predicted probability of a household living within one hour of a well-paved road or market center, conditional on observed household characteristics. Given these probabilities, we then match each household to cohorts, using three different matching techniques (nearest-neighbor, radius and stratification). Table 9 lists the covariates used for estimating the propensity scores, as well as the results from the balancing tests used to judge the accuracy of the matching process. To ensure accuracy of the approach, following matching we should not find significant differences in the means of the observed covariates between treated and control households. Our matching process reduces the mean difference of the observable covariates for control and treated households by at least 25%. For the discussion that follows, the terms "access," "nearness" or "proximity" are used synonymously, and understood to mean travel times of one hour or less; "remoteness" indicates travel time of more than one hour.

Table 10 shows the impact of access on household welfare and livelihood outcomes. Controlling for observable household characteristics, households living near a well-paved road or market center are at least 5% less likely to be poor; sell at least 1% more of their output and have higher monthly food expenditures. Households living near the road or market hire more labor (at least 2% more) and rely less on shared labor (at least 2% less). Overall these results confirm marginally higher welfare and livelihood outcomes for households living in close proximity to a well-paved road or market center.

Table 11 shows the impact of nearness on the food security indicators. We find lower average calorie intake for households living close to roads and markets. Households living near a well-paved road or market center have at least a 2.4% higher expenditure share on non-staple foods. Similarly, we find higher weekly food expenditures and greater dietary diversity among households living in close proximity to roads and markets. Children living near a well-paved road have, on average, linear growth that is 0.26-0.33 points higher than that of remote children. The effect of proximity to a market center is stronger still, with children living near a market center exhibiting a HAZ that is 0.40-0.49 points higher than that of remote children. Those living near a well-paved road are, on average, 6%-10% less likely to be stunted. Those living near a market center are 12-15% less likely to be stunted. Comparing estimates of the average treatment effect on the treated (ATT), market access appears to confer slightly greater benefits than road access, at least in terms of food

16 We note, however, that the correlation between total calorie consumption and the non-staple share in this sample is positive.

17 In particular, including regional fixed effects, the community level price index, mother's literacy and TV in the regression renders the transportation variables insignificant,

security and growth outcomes.[18] Overall, the signs of our impact estimates are robust to the use of different matching techniques, although they vary slightly in magnitude depending on the method used.

5.4 Dose-response models and figures

Results from the dose-response models are most easily interpreted when presented in graphical form. We present these main results in a series of three figures, each of which contains four diagrams (12 diagrams of results in total). To construct each diagram we place one of the access variables on the x axis and one of the indicator variables of interest on the y axis. We then plot the curve corresponding to response of each indicator to the treatment of interest. In all cases, treatment represents travel time. Unlike in models using propensity score matching, a greater level of treatment here represents something undesirable, i.e. greater remoteness. We therefore expect to see undesirable effects from treatment, or beneficial effects from lower levels of treatment. To assist in interpreting the precision of the estimated response, we also provide 90 per cent confidence bands for the estimates.

Figure 15 presents results where treatment is travel time to the nearest well-paved road (in hours). The response of food expenditures (in Rs/person/month) appears in the NW panel, the prevalence of labor hiring (in %) in the NE panel, poverty prevalence (in %) in the SW panel, and stunting prevalence among children below age 5 (in %) in the SE panel. Broadly speaking, relationships are as expected. Food expenditures (measured here as the total value of food consumed in a month, whether purchased or consumed from own production) decline with time to the nearest well-paved road. This likely reflects several patterns: (i) households near a well-paved road are also nearer to urban or semi-urban centers, where more food is purchased (at presumably higher cost); (ii) households near a well-paved road have a wider variety of high-quality (but more expensive) foods available, leading to more nutritious food baskets purchased at higher cost; and (iii) at remote locations, households rely more heavily on own-produced staples, which are generally of low value. However, the overall responsiveness of food expenditures to changes in travel time to a well-paved road is modest across the sample.

The NE diagram in Figure 15 shows the responsiveness of household hiring to road proximity. In general, we observe a strong decline in hiring as access time rises – from approximately 55 per cent of households where proximity is close, to less than 35 per cent of households where remote. Both poverty and stunting prevalence rise with time from roads, although the highest poverty rates are not necessarily associated with the most remote locations, and considerable heterogeneity in stunting rates are found at access times beyond 4-5 hours.

Figures 16 and 17 explore the patterns with respect to travel time to a market center. Nearly all patterns are non-linear, with an especially pronounced U-shape in the relationship between food expenditures and travel time to a market center. In part, this likely reflects a pattern greater expenditure on purchased foods near markets, and higher costs of food in general far from markets. Calorie consumption is relatively flat across the distribution of travel times, although somewhat lower in the most remote locations. The lower panels of Figure 16 add additional dimensions to the food expenditure story. The expenditure share of staple foods rises sharply with time to a market center, reflecting high reliance on own-produced grains and starchy roots in remote locations. The opposite pattern prevails for non-staple foods, wherein households nearer market centers have a much larger expenditure share for non-staple food items than more remote households. In part, this suggests a potentially more favorable expenditure pattern, in dietary terms, closer to markets.

Figure 17 contains a series of graphs in which indicators (on the vertical axis) are plotted against travel time to a market center (on the horizontal axis): commercialization (the ratio of agricultural sales to total agricultural output); dietary diversity (Simpson's index); linear growth in children below age 5 (HAZ); and stunting prevalence. We find a very low rate of commercial activity across the entire sample, but somewhat higher ratios of sales to production near a market center. The production diversity index declines steadily with time from a market center, suggestive of less nutritious diets in remote locations. As an aside, it is worth comparing the chart in the NE corner of Figure 17 to Figure 18, which plots the observed values of the dietary diversity index against travel times to a well-paved road and market center. Two features are noteworthy. First, the adjusted (model-predicted) dose-response for dietary diversity is downward sloping, but somewhat flatter than the observational data suggest. This underscores the need to remain cautious when inferring patterns from unadjusted data. Second, Figure 18 suggests that being remote from markets is more detrimental to dietary diversity than being remote from roads, per se.

Patterns in the lower panels of Figure 17 echo those of the poverty curve in Figure 15. We find that after controlling for other features of households and children, the lowest values of linear growth, and the highest prevalence of stunting are not necessarily in the most remote locations. However, at locations with travel times greater than 6-8 hours, the confidence bands around the estimated responses are quite wide, suggesting considerable variability in outcomes among the most isolated children. Figure 19, which plots the responsiveness of the overall food budget share to the travel time to a market center, suggests at least one part of the underlying story. Food budget shares in Nepal are quite high and rise very steeply as one moves into the most remote locations, approaching 70 per cent, on average. In fact, among all households in the full NLSS sample, roughly 10 per cent have food budget shares that exceed 75% of total consumption. Among those in the agriculture-only sample studied in this report, this proportion exceeds 17 per cent of households. Such a pattern suggests that a large proportion of rural households in Nepal must allocate a substantial share of their budget to food, leaving little discretionary income for health, housing or other basic needs. Figure 20, which plots the observed basic needs price index against the time to market, provides additional evidence that the most remote households also face the highest prices outside of urban areas (where a high index results in part from the high cost of housing).

5.5 Distributional considerations

Who is likely to gain the most from improvements in access? In general, because the most isolated households in Nepal are also among the poorest, expanding access to roads, markets, and the goods and services they provide is likely to have broad benefits for the rural poor. At the same time, even within poor communities some households and individuals are in a better position to take advantage of market opportunities than others. Although we have insufficient data to provide a complete analysis of the likely distributional changes associated with improved access, our conjecture is that investments that improve access in remote locations will reduce economic inequalities between isolated and non-isolated

18 In terms of raw numbers, we find 1,823 households in our sample (46%) with no immediate access to a well-paved road or market center, 443 (11%) with access to a well-paved road but not immediate access to a market center, 297 (8%) with market access but not paved road access, and 1,374 (35%) with both road and market access. Among these households, the likelihood of being poor are 30%, 21%, 18% and 14%, respectively.

villages, but potentially increase inequality among households within those villages that benefit directly from improved access. Complicating matters is that distributional shifts in outcomes and directional changes in indicators across the income distribution may differ depending on the indicator under consideration. This makes prediction difficult.

To assess current distributional patterns in outcomes, Table 12 provides mean values of indicators, disaggregated by income quintiles and three arbitrary but indicative levels of access: less than 1 hour to a well-paved road (46% of households), 1-5 hours from a well-paved road (37% of households), and greater than 5 hours to a well-paved road (17% of households). The entries in Table 12 were constructed by first assigning all households in the sample to an income quintile, where all households in quintile 1 and some of those in quintile 2 are classified as poor based on the Nepali expenditure threshold, and quintile 5 contains the households in the sample with the highest per capita monthly expenditures (our proxy for income). Households were then assigned to sub-groups depending on their reported access time to a well-paved road. The entries in Table 12 represent average indicator values for the respective sub-groups. In most cases, the least favorable average values of the indicators are found among those households that are both in the lowest quintile and in the most remote locations. Conversely, the most favorable average values of the indicators are found among those in the highest quintile and the least remote locations (e.g. 61% vs. 11% of households relying on shared labor; diversity scores of 0.62 vs. 0.81; non-staple expenditure shares of 30% vs. 45%; and stunting rates of 53% vs. 20%). One way to contemplate potential changes resulting from improvements in access is to compare the differences in means for groups of households that share socio-economic status but report different access times, to those of groups with similar access times but different socio-economic status. Although one cannot draw strong conclusions from the table regarding the distributional impacts of improved access, some patterns emerge. These suggest that isolation and access may be more important than relative income in some situations. For example, moving from the lowest access category in the table (five hours or more) to the highest (less than one hour) results in an 17% improvement in the average dietary diversity index score for households in the lowest expenditure quintile (35% vs. 30%) but only a 5% improvement for households in the highest expenditure quintile (45% vs. 43%). Similarly, comparing HAZ and stunting rates across these dimensions one finds relatively similar outcomes across quintiles among those more than five hours from a paved road, but relatively large changes associated with moving within quintile to a closer access group. Children less than one hour from a road in the bottom expenditure quintile have an average stunting rate that is 13% lower than for those more than five hours from a road in the same expenditure quintile (0.47 vs. 0.53). Children less than one hour from a road in the top expenditure quintile have an average stunting rate that is one-third the rate for those in the same expenditure quintile more than five hours from a road (0.20 vs. 0.59). One might reasonably conclude that raising incomes and improving access are both important, and likely go hand-in-hand, but that reductions in access times might generate larger improvements in indicators of interest than modest gains in income alone. To put it more directly, having additional income to spend on a more diverse diet or on health- and nutrition-enhancements, is relatively useless if a household does not have easy or rapid access to such goods and services.

To generate a different perspective on the potential distributional implications of improved access for remote households we can recalculate the elasticities reported in Table 7 at different levels of remoteness. Doing so reveals that the magnitude of the effect of increased isolation increases with travel time. Figure 21 illustrates the patterns for four indicators (dietary diversity, the non-staple budget share, linear growth, and poverty prevalence). Expected percentage changes in outcome variables are larger in magnitude when computed for households most distant (in travel time) from a well-paved road. Although the cost of reaching and improving access for the most remote households is likely to be high, these results suggest that the magnitude of the effect of improving access by reducing travel time is likely to be much larger in the most remote locations.

Local community members clear a trail blocked by a landslide in Gorkha.

Photo credit : WFP/Samir Jung Thapa

Children in remote Uhiya VDC watch their parents reconstruct a trail.

Photo credit : WFP/Santosh Shahi

6

CONCLUSIONS AND POLICY IMPLICATIONS

Nepal has an extremely low road density – far below that of middle- and high-income countries, and well below that of many of its neighbors. Especially in the hilly and mountainous regions, areas that are also characterized by harsh topography, road networks are either very sparse or mainly consist of low quality earthen roads that are subject to closure during the monsoon season. According to the Government of Nepal, only 43 per cent of the country's population has access to all-weather roads (CBS 2011). In the complete NLSS sample, 31% of households report being more than one hour from a well-paved road and among agricultural households, 54% report being more than one hour from a well-paved road. As a result, a majority of rural households face problematic access to basic facilities such as markets, schools and hospitals. This not only perpetuates severe hardship in rural areas but also undermines food security and hinders economic development. In the near-term, constructing roads into remote areas will prove difficult and costly. In light of this, constructing and improving trails and bridges will likely play a key role in improving household access to goods and services in Nepal.

Recognizing the important role of improved access to roads and markets, this study identifies some of the pathways by which improvements in access might lead to better livelihood, nutrition and food security outcomes. This report extends previous analyses of the topic (Shively and Thapa, 2016; Shively and Thapa, 2017) using multiple sources of data, including data from the 2011 Nepal Living Standards Measurement Survey. We organized our analysis at the household and child level, accounting for transportation infrastructure at the district level. We used two measures of access: (1) access to well-paved roads and (2) access to market centers. Both metrics were defined at the household level and measured in terms of travel time (in hours). We used these variables to derive discrete and continuous measures of improved household access, and then related these treatment variables to a broad range of indicators. These indicators fell into three categories: food security indicators, livelihood indicators, and child growth indicators.

The food security indicators included: (i) calorie consumption (in Kcal/person/day); (ii) non-staple food expenditures (the share of monthly expenditures on non-staple foods including fruits, vegetables, pulses, and animal-sourced foods); (iii) dietary diversity (computed as a Simpson's index); (iv) food consumption (average weekly household expenditure in Rs.); (v) linear growth (height-for-age z score for children below 5 years); and (vi) child stunting. The livelihood indicators were: (i) whether the household is poor (according to Nepal's poverty line; (ii) food expenditure (Rs/person/month); (iii) an indicator of market participation (agricultural products sold divided by agricultural products produced, in kgs); (iv) non-agricultural activity (total non-agricultural income in ten thousand rupees); (v) labor hiring (a binary indicator of whether the household hired labor or not); (vi) labor exchange (a binary indicator of whether the household engaged in labor sharing, i.e. exchanged labor with another household); and (vii) migration (an indicator of whether any member of the household had migrated).

We employed a series of multilevel (hierarchical) regressions to measure average treatment effects associated with being less than one hour from a well-paved road or market center. We also estimated potential geographic (spatial) spillovers by incorporating the spatial lag of the road index variable in the multilevel model. Finally, we estimated dose-response functions

(DRF) to measure the effects of continuous treatment on a range of food security and livelihood outcomes, including linear growth for children under the age of five.

Results from the multilevel model suggest that market access and road density both matter for rural poverty. Higher road density is negatively correlated with the probability of labor sharing between households and the likelihood of migrating. Improved access to a market center and well-paved road, and higher road density in general, are positively correlated with household dietary diversity. Moreover, improved market access and higher bridge density are positively associated with a household's monthly non-staple food expenditure share. Regarding the agricultural outcome indicators, we find a positive effect of the district road density index on per-capita monthly food expenditures, as well as a positive local spillover effect of the road index on agricultural commercialization.

Results from the child nutrition regressions show that improved access to a well-paved road or market center is correlated with greater linear growth, as measured by height-for-age z score (HAZ) and lower probability of stunting (HAZ < -2). Each additional hour needed to reach a well-paved road is associated with a 0.02-point reduction in HAZ. We also found that a higher district-level road density is associated with a higher HAZ and a lower probability of stunting. The results from propensity score matching show that households living near a well-paved road or market center are at least 5% less likely to be poor; sell at least 1% more of their output and have higher monthly food expenditures. Similarly, households living near roads and markets have higher expenditure shares on non-staple foods, greater dietary diversity, enhanced linear growth and lower likelihood of stunting. Market access appears to confer greater benefits than proximity to a road, at least in terms of food security and child growth indicators.

Results from the dose-response analysis show the impact of each level of treatment (travel time in hours needed to reach the nearest market and well-paved road) on the outcomes of interest. We found that the total value of food consumption declines by 0.95% (in Rs/month) for each additional hour of travel time to the nearest well-paved road; the expenditure share of non-staple foods decreases by approximately 0.19% with each additional hour of travel time to a market center; poverty prevalence increases by 0.5% and 1% respectively with each one-hour increase in travel time to a well-paved road and market center, and stunting prevalence increases by 1.4% with each one-hour increase in travel time to a market center. Dietary diversity decreases as time to roads and markets increases. Moreover, we find that food budget shares rise markedly as one moves into the most remote locations, leaving little discretionary income for education, health, housing, sanitation, or other basic needs. All findings point to the fundamental importance of isolation in undermining food security, child growth and livelihood opportunities for rural households. These patterns underscore the importance of including remote access infrastructure investments in the set of strategies associated with Nepal's development agenda. That the NLSS data used in this study under-represent geographically remote areas means that many of the associations we have documented and measured could be even larger for the most remote households and in the least-accessible locations and VDCs.

In conclusion, the magnitudes of association measured in this report seem plausible and reasonable. Because we have not directly considered the quality of trails in our analysis, one must exercise caution in drawing specific conclusions regarding the effects of upgrading trails and trail access. However, one might reasonably expect that any investments that result in reduced access times to well-paved roads or market centers, including trail and bridge construction, rehabilitation and improvement, would have effect magnitudes similar to those reported here. Improving trails in ways that reduce access times to roads, in this sense, is synonymous with extending roads, and will likely serve similar purposes.

7 NEXT STEPS: DESIGN OF BEFORE-AFTER-CONTROL-INTERVENTION (BACI) STUDY

This study relied on observational data to assess the impact of improved access to roads and markets on households' food security and livelihood outcomes. The underlying assumption maintained throughout the analysis is that fixed location details and observed household characteristics determine the level of a household's access to roads and markets, and that there are no additional unobserved and unaccounted for features that are correlated with both the location of roads or markets and observed outcomes. Using propensity scores, we matched those households having similar socio-economic characteristics. However, our impact estimates could be biased if we have omitted unobserved covariates that influence the propensity of households to live near roads and markets. Also, to the extent that we have reliably measured associations between our treatment variables and our outcomes of interest, we cannot claim strong evidence of causality. In the case of both the multilevel regressions and the dose-response functions, the fact that phenomena correlated with the outcome variables might be responsible for driving the placement of roads and markets means we must exercise caution in attributing all of the observed impact to proximity to a well-paved road or market center. We have tried to control for potential problems related to endogeneity and identification, but any retrospective study that relies on observational data and non-random treatment will have difficultly firmly establishing cause and effect.

Going forward, one way to improve our understanding of how infrastructure, especial remote access infrastructure, affects household behaviors and outcomes is to develop a study design that is somewhat more experimental in approach. Randomization of trail improvements and/or road and bridge construction is probably not feasible, but proper design of a Before-After-Control-Intervention (BACI) study might be.[1] In that case, the required steps would be to identify sites where trails and bridges (or roads) are likely to be constructed in the future. Ideally, this information would not be revealed in advance to villages and households whose outcomes might be directly or indirectly influenced by the project. In other words, the "treatment," when it arrived, would come as a surprise to households.[2] Simultaneously, it would be necessary to identify comparison villages that are as similar in most respe cts as possible to the target villages. These comparison villages, however, would not be expected to receive similar treatment, and therefore households in these villages could reasonably serve as "control" cases for "with" and "without" comparison, to develop an accurate counterfactual picture of outcomes in the absence of treatment.

What might the steps look like in practice? First, it would be necessary to identify two or more locations for in-depth study, including one within the treatment area and another outside the treatment area. Second, sampling frames would need to be designed, listing all villages and households likely to benefit from the project, as well as those unlikely to

1 *For a primer on impact assessment and approaches, see Jagger et al. (2010).*

2 *Otherwise, even before improvements in access take place, households might anticipate impacts and changes, and adjust their behavior accordingly. This could lead to pre-treatment changes in land and labor allocation, the value of plots, or other indicators.*

benefit, which could serve as controls.[3] Third, depending on budget and resources, a number of villages and households would be randomly selected for inclusion in the study. Fourth, a detailed baseline survey (or multiple rounds spaced across the year to account for seasonal differences in behaviors and outcomes) would be collected. The aim of this baseline study would be to assess the pre-intervention situation in the treatment and control households. The survey could include a wide range of information on households' food security outcomes and local activities. Data might include the volume and variety of items available and traded, the prices of those goods, household diet diversity, socio-economic characteristics, livelihood and market opportunities, village characteristics, land values, and travel times to well-paved roads, markets and basic facilities. Fifth, following trail improvements or bridge construction, and after some pre-determined period (perhaps one year), follow-up survey could be conducted among the same households. Because the impacts from a remote access infrastructure project are likely evolve over time or vary by season, follow-up surveys could be repeated at regular intervals, resulting in panel data that might allow analysts to observe changes over time and control for the effects of time varying factors, such as weather. A different and less attractive approach would be to conduct a purely retrospective analysis, comparing villages that have similar elevation, weather, agricultural potential and demographic composition but which differ only on the basis of access to trails, bridges and roads. Carefully administered surveys among these households might reveal new and more complete details regarding the impacts of improved access on Nepalese households, permitting better targeting of future efforts and investments.

3 *For a general guide to sampling issues, see Shively (2011).*

Following the 2015 earthquakes, corrugated iron sheets were transported to remote areas using porters.

Photo credit : WFP/ Tina Stacey

Rural communities in Humla are remote and difficult to access.

Photo credit : WFP/James Giambrone

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TABLES & FIGURES

Table 1: Average travel times to a well-paved road and market center (in hours)

	Time to well-paved road		Time to market center	
	Full sample	**Ag sample**	**Full sample**	**Ag sample**
Terai	0.80 (2.11)	1.00 (2.38)	0.84 (1.57)	1.01 (1.79)
Hills	2.78 (4.84)	4.12 (5.41)	1.79 (2.97)	2.58 (3.35)
Mountains	7.63 (6.84)	8.09 (6.88)	3.76 (5.41)	4.18 (5.59)
All	2.33 (4.53)	3.23 (2.88)	1.55 (5.09)	2.10 (3.28)

Source: NLSS 2011; standard deviations in parentheses. The number of observations for the full sample and the agricultural household subsamples are as follows: 2,275 and 1,559 for the Terai; 3,108 and 2,032 for the hills; and 397 and 346 for the mountains.

Table 2: Descriptive statistics of the variables used in the analysis

Variable	Well-paved road				Full sample	
	< 1 hour		> 1 hour			
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Child level (n= 2,394)						
Height-for-age (z score)	-1.23	1.57	-1.84	1.49	-1.52	1.56
Child stunted (=1 if HAZ < -2; else 0)	0.31	0.46	0.49	0.50	0.40	0.49
Received immunization (=1 if yes; else 0)	0.97	0.16	0.96	0.18	0.97	0.17
Diarrhea in past two weeks (=1 if yes; else 0)	0.09	0.28	0.07	0.26	0.08	0.27
Fever in past two weeks (=1 if yes; else 0)	0.22	0.42	0.15	0.36	0.19	0.39
Child is male (=1 if yes; else 0)	0.48	0.50	0.49	0.50	0.49	0.50
Child age (in months)	30.20	16.94	30.51	16.75	30.35	16.85
Monsoon season birth (=1 if yes; else 0)	0.31	0.46	0.33	0.47	0.32	0.47
Household level (n= 3,937)						
Travel time to nearest market (hrs.)					2.10	3.28
Travel time to paved road (hrs.)					3.23	5.09
Proximity to road (=1 if < 1 hr. to road; else 0)					0.46	0.50
Proximity to market (=1 if < 1 hr. to road; else 0)					0.42	0.49
Calorie consumption (Kcal/person/day)	2,731	912	2,622	1,037	2,673	982
Dietary diversity (Simpson's index)	0.77	0.09	0.72	0.12	0.74	0.11
Non-staple expenditure share (%)	41.61	11.96	37.08	13.09	39.17	12.78
Food budget (Rs/week/household)	1,860	1,045	1,603	890	1,721	974
Commercialization (ratio kg sold to kg produced)	0.10	0.19	0.06	0.14	0.08	0.16
Non-agricultural income (Rs/household/year)	185,171	9,77,746	95,759	1,109,170	137,024	1,051,375
Food expenditure (Rs/person/month)	1,749	930	1,547	853	1,640	895
Poor household (=1 if yes; else 0)	0.15	0.36	0.28	0.45	0.22	0.42
Exchanged (shared) labor (=1 if yes; else 0)	0.23	0.42	0.42	0.49	0.33	0.47
Migrant (=1 if any member migrated; else 0)	0.54	0.50	0.58	0.49	0.56	0.50
Food for work participant (=1 if yes; else 0)	0.01	0.08	0.05	0.22	0.03	0.17
Male head (=1 if yes; else 0)	0.74	0.44	0.74	0.44	0.74	0.44
Age of household head (years)	47.26	13.31	47.13	14.26	47.19	13.83
Family size (# persons)	5.06	2.41	5.00	2.31	5.02	2.35
Dependency ratio (# < 15 + # > 65 / # persons)	0.37	0.24	0.44	0.25	0.41	0.25
Brahmin (=1 if yes; else 0)	0.17	0.38	0.12	0.32	0.14	0.35
Mongolian (=1 if yes; else 0)	0.22	0.41	0.33	0.47	0.28	0.45
Madheshi (=1 if yes; else 0)	0.15	0.36	0.07	0.25	0.11	0.31
Unprivileged group (=1 if yes; else 0)	0.27	0.44	0.26	0.44	0.26	0.44
Car (=1 if own; else 0)	0.01	0.09	0.00	0.03	0.00	0.06
TV (=1 if own; else 0)	0.60	0.49	0.20	0.40	0.38	0.49
Telephone (=1 if own; else 0)	0.73	0.44	0.45	0.50	0.58	0.49
Total annual remittance (lakhs Rs)	0.54	1.80	0.53	10.93	0.54	8.11
Chemical fertilizer (=1 if used; else 0)	0.84	0.37	0.60	0.49	0.71	0.45
Improved fertilizer (=1 if used; else 0)	0.53	0.50	0.31	0.46	0.41	0.49
Irrigation (=1 if used; else 0)	0.61	0.49	0.55	0.50	0.58	0.49
Agricultural advice (=1 if received; else 0)	0.12	0.33	0.08	0.26	0.10	0.30
Livestock (=1 if owned; else 0)	0.85	0.36	0.97	0.16	0.92	0.28
Mother literate (=1 if yes; else 0)	0.69	0.46	0.62	0.49	0.65	0.48
Kitchen garden (=1 if yes; else 0)	0.68	0.47	0.74	0.44	0.71	0.45
Small farm (=1 if 0.33 ≤ farm size ≤ 0.66; else 0)	0.23	0.42	0.28	0.45	0.26	0.44

Medium farm (=1 if 0.66 ≤farm size ≤2; else 0)	0.23	0.42	0.32	0.47	0.27	0.45
Large farm (=1 if farm size >2 ha; else 0)	0.12	0.33	0.06	0.24	0.09	0.29
Farm size (hectares)	0.60	0.93	0.65	0.77	0.62	0.85
Crop diversity (# of crops grown)	11.16	5.74	13.55	5.55	12.45	5.76
Urban region (=1 if yes; else 0)	0.32	0.47	0.04	0.19	0.17	0.37
Community (n=447)						
Crop diversity (# of crops grown in village)	17.168	5.572	19.649	4.927	18.504	5.378
Irrigation (% of households with access)	64.568	26.762	57.154	31.016	60.576	29.360
Price (index)	0.997	0.268	0.922	0.068	0.957	0.193
District (n=71)						
Road density (km/km2 × 100, quality weighted)	21.222	34.959	7.403	12.846	13.781	26.461
Spatial lag road index (quality weighted)	183.441	76.842	126.585	78.377	152.825	82.674
Bridge density (#/km2 × 100)	0.024	0.025	0.010	0.017	0.017	0.022
Cereal deficit (=1 if yes; else 0)	0.376	0.485	0.406	0.491	0.392	0.488
Grain storage capacity (kg/person)	4.052	4.537	2.869	4.011	3.415	4.302
Hill (=1 if yes; else 0)	0.379	0.485	0.633	0.482	0.516	0.500
Mountain (=1 if yes; else 0)	0.015	0.123	0.150	0.357	0.088	0.283
Terai (=1 if yes; else 0)	0.605	0.489	0.217	0.412	0.396	0.489

Source: NLSS 2011; sample restricted to agricultural households only (those for which land was owned or rented).

Table 3: Multilevel regression model results for the effects of access (continuous) on livelihood outcomes

Variables	Model 1A (poverty status)	Model 1B (poverty status)	Model 2A (shared labor)	Model 2B (shared labor)	Model 3A (migrant)	Model 3B (migrant)
Travel time to market center (hrs)	0.0555*** (0.0206)	0.0507** (0.0224)	0.02 (0.0238)	-0.0050 (0.0236)	-0.0148 (0.0159)	-0.0212 (0.0155)
Travel time to well-paved road (hrs.)	0.0480*** (0.0168)	0.0130 (0.0184)	0.0685*** (0.0194)	0.0460** (0.0193)	-0.0258** (0.0116)	-0.0110 (0.0115)
Road density (index)	-0.0076* (0.0042)	-0.0133** (0.0055)	-0.0023 (0.0044)	0.0005 (0.0048)	-0.008*** (0.002)	-0.0076*** (0.0021)
Spatial lag of road (index)	0.0006 (0.0013)	0.0013 (0.0014)	-0.0009 (0.0015)	-0.0003 (0.0014)	-0.0014** (0.0007)	-0.0012* (0.0006)
Bridge density (#/km²)	1.0355 (5.0362)	1.4109 (6.6344)	-24.3967*** (6.6344)	-19.3408*** (7.3099)	0.7221 (2.5105)	0.4973 (2.9852)
Male-headed household (0/1)		-0.0597 (0.1320)		-0.1057 (0.1096)		-1.8975*** (0.1038)
Age of household head (yrs)		-0.0075** (0.0037)		-0.0086** (0.0034)		0.0253*** (0.0028)
Family Size (# persons)		0.3771*** (0.0258)		0.0615*** (0.0226)		-0.0201 (0.0175)
Dependency (ratio)		2.0191*** (0.2349)		-0.3678* (0.1901)		-0.6818*** (0.1608)
Brahmin (0/1)		-0.3670 (0.2295)		-0.7336*** (0.1748)		-0.0809 (0.1305)
Mongolian (0/1)		0.2315 (0.1763)		0.0988 (0.1462)		0.0361 (0.1123)
Madhesi (0/1)		0.6298*** (0.2332)		-0.0630 (0.2184)		-0.1699 (0.1538)
Unprivileged (0/1)		0.5750*** (0.1666)		-0.1262 (0.1477)		0.1269 (0.1159)
Received agricultural loan (0/1)		-0.7137*** (0.1735)		-0.2483* (0.1333)		-0.0634 (0.1070)
Telephone (0/1)		-2.0403*** (0.3421)		-1.1261*** (0.2086)		0.5394*** (0.1382)

Owns livestock (0/1)		0.4880** (0.2429)		0.6757***		0.3538** (0.1465)
Remittances ('00000 Rs)		-0.6012*** (0.1176)		-0.0749 (0.0493)		
Poor (0/1)				0.4721*** (0.1160)		-0.2567*** (0.0960)
Own agricultural land (0/1)		-2.4838*** (0.4475)		-0.7532** (0.3684)		
Mother illiterate (0/1)		0.3384*** (0.1050)		0.1502 (0.0937)		-0.1429* (0.0784)
Fertilizer (0/1)		-0.3644*** (0.1349)		-0.0306 (0.1234)		0.0874 (0.0941)
Improved seed (0/1)		-0.5446*** (0.1208)		-0.2059* (0.1057)		0.1183 (0.0816)
Irrigation (0/1)		-0.1036 (0.1297)		-0.1918* (0.1134)		0.2504*** (0.0923)
Agricultural advice (0/1)		-0.4036** (0.2023)		-0.1956 (0.1619)		-0.1749 (0.1237)
Urban (0/1)		-0.5330** (0.2573)		-0.6552** (0.2616)		-0.5156*** (0.1154)
Small farm (0/1)		-0.2443* (0.1307)		-0.2146* (0.1140)		-0.0259 (0.0954)
Medium farm (0/1)		-0.6302*** (0.1449)		-0.5815*** (0.1257)		0.4343*** (0.0985)
Large farm (0/1)		-1.9989*** (0.3880)		-1.1561*** (0.2807)		0.0729 (0.1360)
Production diversity (# of crops planted)				0.0542*** (0.0116)		
Home garden (0/1)				-0.1102 (0.1104)		
Price (index)		2.3096*** (0.6735)		0.4469 (0.6197)		
Village irrigation (% of households)		-0.0012 (0.0028)		0.0030 (0.0029)		-0.0003 (0.0017)
Food deficit district (0/1)		0.0489 (0.2190)		0.3304 (0.2331)		0.0702 (0.1035)
Food storage capacity (kg/person)		0.0453* (0.0250)		0.0053 (0.0266)		0.0069 (0.0115)
Hills (0/1)		0.2731 (0.3251)		0.4466 (0.3409)		0.0087 (0.1491)
Mountains (0/1)		0.4632 (0.4683)		0.2319 (0.4918)		-0.1140 (0.2166)
Net buyer of food (0/1)		0.3570** (0.1410)				
Constant	-1.8605*** (0.2376)	-4.2523*** (0.9050)	-0.7728*** (0.2744)	-1.2967 (0.8185)	0.6931*** (0.1306)	0.6974** (0.3037)
Observations	3,937	3,937	3,937	3,937	3,937	3,937
Number of groups	71	71	71	71	71	71
Random effects						
District	0.378 (0.120)	0.324 (0.114)	0.538 (0.172)	0.350 (0.135)	0.060 (0.034)	0.033 (0.027)
Ward	0.738 (0.130)	0.617 (0.134)	1.265 (0.191)	1.059 (0.174)	0.187 (0.055)	0.072 (0.049)
AIC	3838.819	3118.71	4079.874	4070.12	5300.195	4782.931

*Note: Model 1A (parsimonious): dependent variable is poverty indicator (0/1); Model 1B (full): dependent variable is poverty indicator (0/1); Model 2A (parsimonious): dependent variable is indicator of whether household exchanged labor (0/1); Model 2B (full): dependent variable is indicator of whether household exchanged labor (0/1); Model 3A (parsimonious): dependent variable is indicator of whether any household member migrated (0/1); Model 3B (full): dependent variable is indicator of whether any household member migrated (0/1); Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1.*

Table 4 Multilevel regression model results for the effects (continuous) of access on food security

Variables	Model 4A (Diet diversity)	Model 4B (Diet diversity)	Model 5A (Non-staple share)	Model 5B (Non-staple share)	Model 6A (Calories)	Model 6B (Calories)
Travel time to market center (hrs)	-0.0034*** (0.0012)	-0.0024** (0.0010)	-0.3256*** (0.1257)	-0.2093** (0.0995)	-0.0021 (0.0032)	0.0005 (0.0025)
Travel time to well-paved road (hrs.)	-0.0031*** (0.0007)	-0.0015** (0.0007)	-0.3137*** (0.0849)	-0.0958 (0.0864)	-0.0034 (0.0025)	0.0016 (0.0022)
Road density (index)	0.0002** (0.0001)	0.0001** (0.0001)	0.0225 (0.0139)	0.0159 (0.0130)	-0.0002 (0.0003)	-0.0005* (0.0003)
Spatial lag of road index (index)	0.0001* (0.0001)	0.0001 (0.0000)	0.0105 (0.0072)	0.0111* (0.0062)	0.0002 (0.0002)	0.0002* (0.0001)
Bridge density (#/km²)	0.3188** (0.1491)	0.1647 (0.1267)	40.4560* (24.4487)	63.6370** (26.0633)	1.2265* (0.7420)	-0.3042 (0.5485)
Received food for work (0/1)				-1.7667 (1.7617)		-0.0434* (0.0254)
Male-headed household (0/1)		-0.0030 (0.0035)		0.4280 (0.5101)		-0.0034 (0.0116)
Age of household head (yrs)		-0.0004*** (0.0001)		-0.0032 (0.0170)		0.0018*** (0.0004)
Family Size (# persons)		-0.0046*** (0.0008)		-0.6776*** (0.1082)		-0.0384*** (0.0035)
Dependency (ratio)		-0.0150** (0.0072)		-0.5392 (0.9555)		-0.1515*** (0.0200)
Brahmin (0/1)		0.0036 (0.0056)		0.1490 (0.9188)		0.0140 (0.0146)
Mongolian (0/1)		-0.0004 (0.0051)		-1.5370* (0.7970)		-0.0545*** (0.0159)
Madhesi (0/1)		-0.0175** (0.0071)		-2.5260** (1.0106)		-0.0158 (0.0217)
Unprivileged (0/1)		-0.0152*** (0.0053)		-2.5079*** (0.7011)		-0.0111 (0.0170)
Received agricultural loan (0/1)		0.0158*** (0.0039)		2.6093*** (0.5309)		0.0285* (0.0148)
Telephone (0/1)		0.0147*** (0.0033)		3.0886*** (0.4650)		0.0059 (0.0100)
Own livestock (0/1)		-0.0086 (0.0053)		-0.7794 (0.7606)		0.0437* (0.0233)
Remittances ('00000 Rs)		0.0003*** (0.0000)		0.0281*** (0.0102)		0.0009*** (0.0001)
Poor (0/1)		-0.0517*** (0.0046)		-5.7310*** (0.5107)		-0.3225*** (0.0177)
Mother illiterate (0/1)		-0.0039 (0.0035)		-0.4714 (0.4565)		0.0252*** (0.0096)
Urban (0/1)		0.0158*** (0.0052)		2.8367*** (0.7610)		-0.0120 (0.0223)
Production diversity (# of crops planted)		0.0034*** (0.0004)		0.4796*** (0.0560)		0.0029** (0.0014)
Home garden (0/1)		0.0118*** (0.0035)		0.9416** (0.4551)		0.0029 (0.0164)
Price (index)		-0.0302*** (0.0111)		-4.5914*** (1.0738)		0.0498 (0.0457)
Village crop diversity (# crops)		-0.0038*** (0.0005)		-0.4046*** (0.0740)		-0.0039** (0.0018)
Village irrigation (% of households)		0.0000 (0.0001)		0.0036 (0.0077)		-0.0000 (0.0002)
Hills (0/1)		-0.0211** (0.0083)		-0.0149 (1.5300)		-0.1201*** (0.0281)
Mountains (0/1)		-0.0527*** (0.0191)		-2.2981 (2.6512)		-0.0795 (0.0544)
Food deficit district (0/1)		-0.0021 (0.0086)		-0.9061		0.0483* (0.0257)
Food storage capacity (kg/person)		-0.0006 (0.0011)		0.0125 (0.1671)		-0.0043 (0.0027)
Constant	0.7378*** (0.0112)	0.8665*** (0.0182)	46.4865*** (1.5513)	55.0857*** (2.7205)	7.8033*** (0.0322)	8.0601*** (0.0653)
Observations	3,937	3,937	3,937	3,937	3,937	3,937
Number of groups	71	71	71	71	71	71
Random effects	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
District	.0010 (.0003)	.0006 (.0001)	24.56 (4.855)	18.57 (3.645)	.0082 (.0022)	.0045 (.0015)
Community	.0010 (.0002)	.00079 (.00017)	19.11 (2.603)	13.586 (2.111)	.0062 (.0020)	.0058 (.0015)

Household	.008 (.0005)	.0070 (.0004)	137.22 (4.592)	116.877 (3.676)	.1139 (.0050)	.0781 (.0035)
AIC	-7264.911	-7891.36	31021.42	30398.47	2899.4	1491.81

*Notes: Model 4A (parsimonious): dependent variable is Simpson's index; Model 4B (full): dependent variable is Simpson's index; Model 5A (parsimonious): dependent variable is expenditure share for non-staple foods; Model 5B (full): dependent variable is expenditure share for non-staple foods; Model 6A (parsimonious): dependent variable is Kcal/person/day; Model 6B (full): dependent variable is Kcal/person/day; Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1.*

Table 5 Multilevel regression model results for the effects (continuous) of access on agricultural outcomes

Variables	Model 7A (Food expend.)	Model 7B (Food expend.)	Model 8A (Sold ratio)	Model 8B (Sold ratio)	Model 9A (Non-ag inc.)	Model 9B (Non-ag inc.)
Travel time to market center (hrs)	-0.0044 (0.0058)	0.0030 (0.0033)	-0.0003 (0.0014)	0.0006 (0.0014)	-0.0295** (0.0116)	-0.0047 (0.0096)
Travel time to well-paved road (hrs.)	-0.0095*** (0.0034)	0.0000 (0.0021)	-0.0009 (0.0011)	0.0002 (0.0011)	-0.0344*** (0.0095)	-0.0058 (0.0068)
Road density (index)	0.0030*** (0.0003)	0.0015*** (0.0004)	-0.0005*** (0.0001)	-0.0001 (0.0001)	0.0071*** (0.0017)	0.0000 (0.0012)
Spatial lag of road density (index)	-0.0003 (0.0003)	-0.0001 (0.0001)	0.0002*** (0.0001)	0.0001** (0.0001)	0.0002 (0.0006)	-0.0001 (0.0004)
Bridge density (#/km²)	-1.5132* (0.8459)	0.2460 (0.6703)	1.1065*** (0.3159)	0.6534** (0.2767)	-1.8109 (1.8073)	-1.1272 (1.5565)
Male-headed household (0/1)		0.0133 (0.0136)		0.0170*** (0.0061)		-0.1028* (0.0579)
Age of household head (yrs)		0.0016*** (0.0004)		0.0004** (0.0002)		0.0001 (0.0014)
Family Size (# persons)		-0.0544*** (0.0035)		-0.0028*** (0.0010)		0.1084*** (0.0132)
Dependency (ratio)		-0.1747*** (0.0261)		0.0032 (0.0091)		-0.3725*** (0.1067)
Brahmin (0/1)		0.0044 (0.0202)		-0.0088 (0.0107)		0.0336 (0.0818)
Mongolian (0/1)		-0.0096 (0.0193)		-0.0048 (0.0077)		-0.0109 (0.0623)
Madhesi (0/1)		-0.0361 (0.0260)		0.0156 (0.0119)		-0.1088 (0.0732)
Unprivileged (0/1)		-0.0245 (0.0195)		-0.0073 (0.0077)		0.0186 (0.0649)
Car (0/1)		0.1281 (0.0999)		0.0838 (0.0769)		1.0176*** (0.3609)
TV (0/1)		0.1078*** (0.0140)		0.0097* (0.0057)		0.5611*** (0.0629)
Phone (0/1)		0.0352*** (0.0106)		-0.0056 (0.0067)		0.5575*** (0.0484)

Own livestock (0/1)		-0.0311 (0.0230)		-0.0201 (0.0128)		-0.4179*** (0.0900)
Remittances ('00000 Rs)		0.0025*** (0.0004)		-0.0003*** (0.0001)		0.0210*** (0.0078)
Poor (0/1)		-0.5474*** (0.0206)		-0.0238*** (0.0049)		-0.3616*** (0.0630)
Fertilizer (0/1)				0.0205*** (0.0066)		0.0013 (0.0504)
Improved seed (0/1)				0.0172** (0.0073)		-0.0082 (0.0568)
Irrigation (0/1)				0.0168** (0.0068)		0.0194 (0.0434)
Agricultural advice (0/1)				0.0370*** (0.0118)		0.0739 (0.0806)
Mother illiterate (0/1)		0.0124 (0.0110)		-0.0049 (0.0049)		-0.1706*** (0.0443)
Urban (0/1)		0.0719*** (0.0279)		0.0093 (0.0105)		0.2010** (0.0967)
Production diversity (# of crops planted)		0.0082*** (0.0016)		0.0041*** (0.0008)		-0.0045 (0.0056)
Home garden (0/1)		0.0108 (0.0136)		-0.0073 (0.0067)		-0.0138 (0.0549)
Price (index)		-0.0411 (0.0726)		-0.0366 (0.0223)		0.3510* (0.1993)
Food deficit district (0/1)		-0.0285 (0.0296)		-0.0062 (0.0095)		-0.0199 (0.0724)
Hills (0/1)		0.0403 (0.0430)		-0.0356** (0.0140)		0.0120 (0.1059)
Mountains (0/1)		0.1607*** (0.0592)		-0.0148 (0.0216)		0.0634 (0.1500)
Production diversity (# crops cultivated in village)		-0.0082*** (0.0021)				
Village irrigation (% of households)		0.0003 (0.0002)				
Food storage capacity (kg/ person)		-0.0063** (0.0024)				
Received food for work (0/1)						0.4035*** (0.0920)
Constant	7.3596*** (0.0571)	7.6660*** (0.0885)	0.0465*** (0.0113)	0.0312 (0.0313)	1.5897*** (0.1282)	0.8740*** (0.2544)
Observations	3,937	3,937	3,937	3,937	3,937	3,937
Number of groups	71	71	71	71	71	71
Random effects						
District	.0211 (.0039)	.00484 (.00149)	.00026 (.00023)	.00009 (.00015)	.0637 (.0296)	.0054 (.0094)
Community	.0287 (.0050)	.009120 (.00189)	.0042 (.0007)	.004416 (.00075)	.2469 (.0465)	.1284 (.0302)
Household	.1836 (.0060)	.10021 (.00328)	.0215 (.0019)	.020102 (.00173)	2.008 (.09293)	1.702 (.0884)
AIC	4975.071	2497.48	-3462.503	-3674.55	14290.79	13565.27

*Note: Model 7A (parsimonious): dependent variable is log of monthly food expenditure (Rs/person); Model 7B (full): dependent variable is log of monthly food expenditure (Rs/person); Model 8A (parsimonious): dependent variable is ratio of production to sales (in kg); Model 8B (full): dependent variable is ratio of production to sales (in kg); Model 9A (parsimonious): dependent variable is log of non-agricultural income (Rs/year); Model 9B (full): dependent variable is log of non-agricultural income (Rs/year); Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1.*

Table 6: Multilevel regression model results for the effects of access (continuous) on child nutrition outcomes

Variables	Model 10A (HAZ)	Model 10B (HAZ)	Model 11A (Stunting status)	Model 11B (Stunting status)
Travel time to well-paved road (hrs)	-0.0278*** (0.0089)	-0.0170* (0.0105)	0.0309** (0.0145)	0.0118 (0.0177)
Travel time to nearest market center (hrs)	-0.0231* (0.0137)	-0.0141 (0.0135)	0.0529** (0.0209)	0.0509** (0.0250)
Road density (index)	0.0040*** (0.0007)	0.0014** (0.0006)	-0.0050** (0.0021)	-0.0013 (0.0022)
Spatial lag of road density (index)	0.0001 (0.0006)	0.0002 (0.0004)	-0.0006 (0.0009)	-0.0013 (0.0010)
Bridge density (#/km^2)	1.5045 (1.7382)	3.2081 (2.0060)	-2.8992 (3.2263)	-6.5067 (4.4625)
Received immunization (0/1)		0.1778 (0.1538)		-0.5800 (0.3648)
Diarrhea in past two weeks (0/1)		-0.1765 (0.1100)		0.4272* (0.2211)
Fever in past two weeks (0/1)		-0.0660 (0.0740)		0.0938 (0.1542)
Child is male (0/1)		0.0421 (0.0494)		0.0883 (0.1140)
Child age (months)		-0.1186*** (0.0071)		0.1766*** (0.0193)
Child age squared (months squared)		0.0014*** (0.0001)		-0.0022*** (0.0003)
Monsoon season birth (0/1)		-0.2159*** (0.0566)		0.4506*** (0.1245)
Monthly expenditure on food (Rs/person, logged)		0.2339*** (0.0876)		-0.1916 (0.1824)
Dietary diversity (Simpson's index)		-0.0753 (0.3305)		0.2126 (0.6643)
Urban (0/1)		0.2466*** (0.0941)		-0.4548** (0.1898)
Brahmin (0/1)		-0.0493 (0.1076)		-0.0534 (0.2414)
Mongolian (0/1)		-0.0908 (0.0807)		0.4244** (0.1986)
Madhesi (0/1)		-0.1163 (0.1378)		0.3494 (0.2620)
Unprivileged (0/1)		-0.2391*** (0.0857)		0.4852** (0.1978)
Family Size (# persons)		-0.0358** (0.0152)		0.0161 (0.0315)
Dependency (ratio)		-0.2681 (0.2034)		0.5687 (0.4033)
Age of household head (yrs)		0.0021 (0.0024)		-0.0031 (0.0046)
Mother illiterate (0/1)		-0.1702*** (0.0630)		0.1985 (0.1354)
Own livestock (0/1)		-0.1281 (0.1393)		0.3734* (0.2107)
Irrigation (0/1)		0.0487 (0.0649)		-0.0865 (0.1448)
Fertilizer (0/1)		-0.1201 (0.0746)		0.0978 (0.1534)
Marginal farm (0/1)		-0.0400 (0.0733)		-0.0766 (0.1995)
Small farm (0/1)		0.0456 (0.0968)		-0.1884 (0.2320)
Medium farm (0/1)		-0.0047 (0.0983)		0.0922 (0.2242)
Remittances ('00000 Rs)		0.0081 (0.0153)		-0.0127 (0.0297)
Poor (0/1)		-0.2788*** (0.0693)		0.6139*** (0.1591)
District health density ('000 pop)		-0.0050 (0.0425)		0.0755 (0.0821)
Public food storage in district (kg/person)		0.0146** (0.0073)		-0.0027 (0.0181)
Districts food deficit status (1/0)		-0.0379 (0.0907)		-0.2177 (0.1637)
Rainfallin prior year (mm May to September)		0.0005** (0.0002)		-0.0019*** (0.0006)
Mountain (0/1)		-0.0688 (0.1888)		0.3794 (0.3617)
Hill (0/1)		-0.0226 (0.1321)		-0.0254 (0.2364)
Constant	-1.523*** (0.1147)	-1.4341* (0.8083)	-0.4123** (0.1704)	-1.7409 (1.7922)
Observations	2,368	2,368	2,368	2,368
Number of groups	70	70	70	70
Random effects				
District	.033 (.015)	.008 (.014)	.107 (.049)	.049 (.0513)
Household	.259 (.1010)	.432 (.087)	.544 (.2659)	1.265 (.4483)
Child	2.035 (.1426)	1.34 (.105)		
AIC	8722.245	8131.92	3082.792	2803.26

*Note: Model 10A (parsimonious): dependent variable is HAZ; Model 10B (full): dependent variable is HAZ; Model 11A (parsimonious): dependent variable is stunting status; Model 11B (full): dependent variable is stunting status; Robust standard errors in parentheses*** p<0.01, ** p<0.05, * p<0.1. To maintain a large sample of children, the regressions reported here include both agricultural and non-agricultural households.*

Table 7: MLM regression results in elasticity form

Indicator	Time to market center (hours)	Time to well-paved road (hours)	Road density (index)	Spatial lag of road (index)	Bridge density (#/sq. km)
Calories (Kcal/person/day)	--	--	0.01	--	--
Non-staples (expenditure share)	-0.01	--	--	--	0.03
Dietary diversity (Simpson's index)	-0.01	-0.01	0.01	--	--
Commercialization (Ratio of sales to production, in kg)	--	--	--	0.10	--
Linear growth (HAZ for U5s)	0.02	--	-0.01	--	--
Stunting (likelihood)	--	0.02	--	--	--
Poor (likelihood)	0.05	--	-0.09	--	--
Shared labor (likelihood)	--	0.08	--	--	-0.22
Migrant labor (likelihood)	--	--	-0.04	-0.04	--

Note: elasticities measure percentage change in indicator resulting from a one per cent change in treatment; all elasticities computed at the sample means using 2011 NLSS data; table entries include on elasticities that are statistically significant at a 95% confidence level or greater.

Table 8: Intra-class correlation coefficients

Indicator	Intra-class correlation coefficient (ICC)	Standard error
Poverty (0/1)		
District	0.113	0.029
Community | District	0.289	0.031
Exchange labor (0/1)		
District	0.212	0.041
Community | District	0.432	0.035
Migration (0/1)		
District	0.045	0.014
Community | District	0.093	0.017
Dietary diversity (index)		
District	0.194	0.036
Community | District	0.304	0.031
Consumption (Kcal/person/day)		
District	0.081	0.018
Community | District	0.130	0.019
Linear growth (HAZ)		
District	0.042	0.012
Household | District	0.160	0.039
Stunting (0/1)		
District	0.067	0.018
Household | District	0.207	0.058
Non-staple expenditure (share)		
District	0.185	0.033
Community | District	0.300	0.029
Expenditure (Rs/person/month, log)		
District	0.124	0.025
Community | District	0.249	0.024
Non-agricultural income (Rs/year, log)		
District	0.063	0.016
Community | District	0.175	0.019
Commercialization (sales/output)		
District	0.042	0.014
Community | District	0.202	0.018

Table 9: Balancing test of covariates used in estimating the propensity scores, treatment is whether households can reach a market center in less than 1 hour

	Unmatched (U) or matched (M)	Mean		% bias	% reduction |bias|
		Treatment	Control		
Household size	U	5.02	5.02	-0.2	
	M	5.02	5.02	-0.1	34.7
Dependent ratio	U	0.37	0.44	-26.0	
	M	0.37	0.40	-11.5	56.0
Male head*	U	0.75	0.73	3.5	
	M	0.75	0.74	1.9	46.7
Age	U	47.39	47.05	2.5	
	M	47.39	47.39	-0.0	98.2
Unprivileged*	U	0.26	0.27	-1.5	
	M	0.26	0.28	-4.5	187.8
Brahmin*	U	0.16	0.13	10.7	
	M	0.16	0.14	6.2	42.3
Illiterate mother*	U	0.29	0.39	-21.1	
	M	0.29	0.33	-8.6	59.3
Net buyer*	U	0.64	0.77	-28.7	
	M	0.64	0.69	-10.6	63.1
Remittance*	U	1.66	1.70	-8.6	
	M	1.66	1.67	-2.1	75.8
Migration*	U	0.22	0.06	46.2	
	M	0.22	0.12	29.2	36.8
Small farm*	U	0.22	0.28	-13.2	
	M	0.22	0.25	-5.1	61.1
Medium farm*	U	0.23	0.31	-18.0	
	M	0.23	0.26	-6.4	64.6
Farm area	U	0.62	0.63	-0.3	
	M	0.62	0.63	-0.3	-20.6
Irrigation*	U	0.60	0.56	9.7	
	M	0.60	0.60	0.9	90.2
Agricultural loan*	U	0.13	0.14	-1.3	
	M	0.13	0.13	0.0	98.3
Agricultural advice*	U	0.12	0.08	13.0	
	M	0.12	0.10	4.9	62.3
Improved seed*	U	0.50	0.35	30.6	
	M	0.50	0.45	10.5	65.8
Livestock*	U	0.01	0.01	2.4	
	M	0.01	0.01	2.5	4.4
Mountain*	U	0.05	0.11	-21.9	
	M	0.05	0.08	-9.6	56.1
Hill*	U	0.37	0.63	-54.2	
	M	0.37	0.48	-23.8	56.1

*Note: *indicates binary variable.*

Table 10: Impact (ATT) of access on household welfare and livelihood outcomes in Nepal

Indicator	Matching technique	Well-paved road (travel time < 1hr)				Market center (travel time < 1hr)			
		Treatments (#)	Controls (#)	ATT	Std. err.	Treatments (#)	Controls (#)	ATT	Std. err.
Poor (proportion)	Nearest Neighbor	1817	794	-0.06	0.02	1671	854	-0.07	0.02
	Stratification	1817	2050	-0.07	0.02	1671	2266	-0.06	0.02
	Radius	1811	2050	-0.09	0.02	600	690	-0.05	0.02
Food Expenditure (Rs/month)	Nearest Neighbor	1817	794	164.5	46.7	1671	854	193.4	43.4
	Stratification	1817	2050	155.0	36.3	1671	2266	168.5	34.1
	Radius	1811	2050	167.0	31.9	600	690	124.8	50.5
Commercialization (sales-ratio)	Nearest Neighbor	1817	794	0.01	0.01	1671	854	0.01	0.01
	Stratification	1817	2050	0.02	0.01	1671	2266	0.01	0.01
	Radius	1811	2050	0.03	0.01	600	690	0.01	0.01
Labor exchange (proportion)	Nearest Neighbor	1817	794	-0.07	0.02	1671	854	-0.12	0.02
	Stratification	1817	2050	-0.06	0.02	1671	2266	-0.11	0.02
	Radius	1811	2050	-0.11	0.02	600	690	-0.16	0.03
Hired labor (proportion)	Nearest Neighbor	1817	794	0.03	0.03	1671	854	0.07	0.03
	Stratification	1817	2050	0.03	0.02	1671	2266	0.07	0.02
	Radius	1811	2050	0.06	0.02	600	690	0.09	0.03

Note: Sample includes only agricultural households.

Table 11: Impact (ATT) of access on household food security outcomes in Nepal

Indicator	Matching technique	Well-paved road (travel time < 1hr)				Market center (travel time < 1hr)			
		Treatments (#)	Controls (#)	ATT	Std. err.	Treatments (#)	Controls (#)	ATT	Std. err.
Calorie Intake (Kcal/p/day)	Nearest Neighbor Stratification Radius	1817 1817 1811	794 2050 2050	-79.8 -76.3 -2.9	54.8 39.4 35.5	1671 1671 600	854 2266 690	-21.2 -44.1 -45.6	48.1 36.2 56.0
Non-staple Expenditure (%)	Nearest Neighbor Stratification Radius	1817 1817 1811	794 2050 2050	2.5 2.4 2.9	0.7 0.5 0.5	1671 1671 600	854 2266 690	2.67 2.53 3.41	0.611 0.463 0.723
Diet Diversity (Simpson's Index)	Nearest Neighbor Stratification Radius	1817 1817 1811	794 2050 2050	0.02 0.02 0.03	0.01 0.01 0.01	1671 1671 600	854 2266 690	0.02 0.02 0.02	0.01 0.00 0.01
Food Expenditure (Rs/week)	Nearest Neighbor Stratification Radius	1817 1817 1811	794 2050 2050	199.0 176.6 206.8	52.4 44.9 34.6	1671 1671 600	854 2266 690	189.5 186.2 188.2	48.4 40.7 57.7
Linear Growth (HAZ)	Nearest Neighbor Stratification Radius	720 720 713	336 1045 1042	0.26 0.26 0.33	0.14 0.09 0.08	655 655 480	364 1154 675	0.49 0.40 0.40	0.12 0.08 0.10
Stunting (proportion HAZ < -2)	Nearest Neighbor Stratification Radius	720 720 713	336 1045 1042	-0.06 -0.07 -0.10	0.05 0.03 0.03	655 655 480	364 1154 675	-0.15 -0.12 -0.13	0.04 0.03 0.03

Note: Sample includes only agricultural households, except in the case of HAZ and Stunting, for which children from all households are included.

Table 12: Indicator values by expenditure quintile and access time to a well-paved road (in hours)

Quintile	Labor sharing (%)	Migrant (%)	Diet diversity (index)	Non-staples (%)	Daily onsumption (Kcals)	Monthly food expenditure (Rps/hh)	Sales to harvest (ratio)	Non-ag income (Rps)	Daily food expend. (Rps/p)	Stunted (%)	Linear growth (HAZ)
Access time to a well-paved road less than 1 hour											
1 (poorest)	33	47	0.70	35	1893	812	0.05	6.34	1205	0.469	-1.743
2	38	48	0.74	39	2303	1083	0.09	7.29	1468	0.391	-1.522
3	28	49	0.76	41	2569	1428	0.09	23.25	1698	0.256	-1.155
4	22	56	0.78	43	2798	1745	0.12	14.90	1885	0.232	-0.948
5 (richest)	11	62	0.81	45	3300	2621	0.12	28.81	2377	0.195	-0.784
Access time to a well-paved road greater than 1 hour and less than 5 hours											
1 (poorest)	48	51	0.67	33	1867	766	0.04	3.74	1050	0.550	-2.031
2	46	57	0.71	36	2329	1117	0.05	5.90	1401	0.461	-1.847
3	38	65	0.75	39	2567	1430	0.07	8.52	1598	0.450	-1.635
4	29	68	0.77	41	2994	1899	0.08	8.39	1853	0.391	-1.449
5 (richest)	18	67	0.79	44	3753	2935	0.09	32.98	2086	0.383	-1.529
Access time to a well-paved road greater than 5 hours											
1 (poorest)	61	42	0.62	30	1792	785	0.02	4.89	1172	0.530	-2.006
2	58	43	0.67	33	2228	1142	0.06	8.36	1466	0.541	-1.983
3	51	59	0.72	37	2664	1538	0.06	6.15	1799	0.438	-1.715
4	46	53	0.72	37	3108	2014	0.06	7.42	1985	0.563	-1.683
5 (richest)	28	75	0.75	43	3952	3019	0.10	9.90	2332	0.588	-2.136

FIGURES

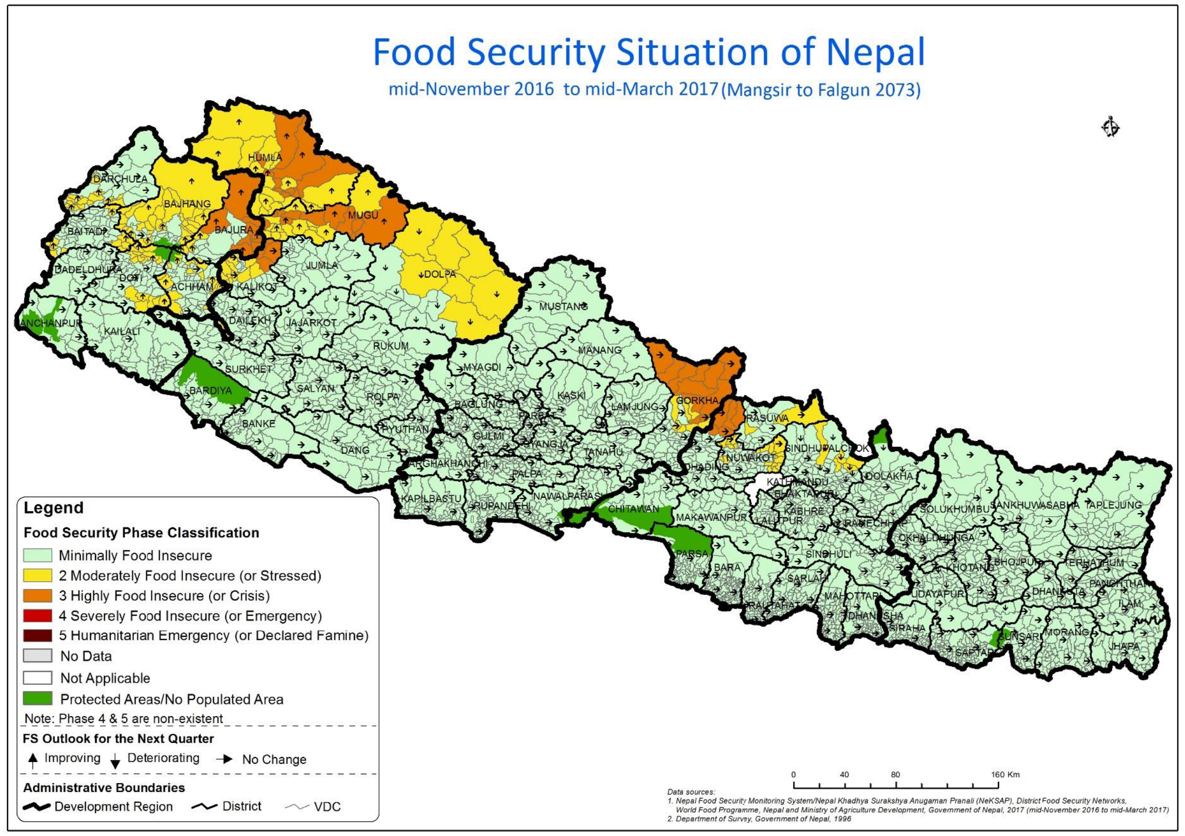


Figure 1 Map of Food Security Situation of Nepal as of March 2017.
Source: Brief on the Food Security Situation in Nepal, Mid-November 2016-mid-March 2017, Ministry of Agricultural Development (MoAD) and World Food Programme (WFP) Nepal Food Security Monitoring System.

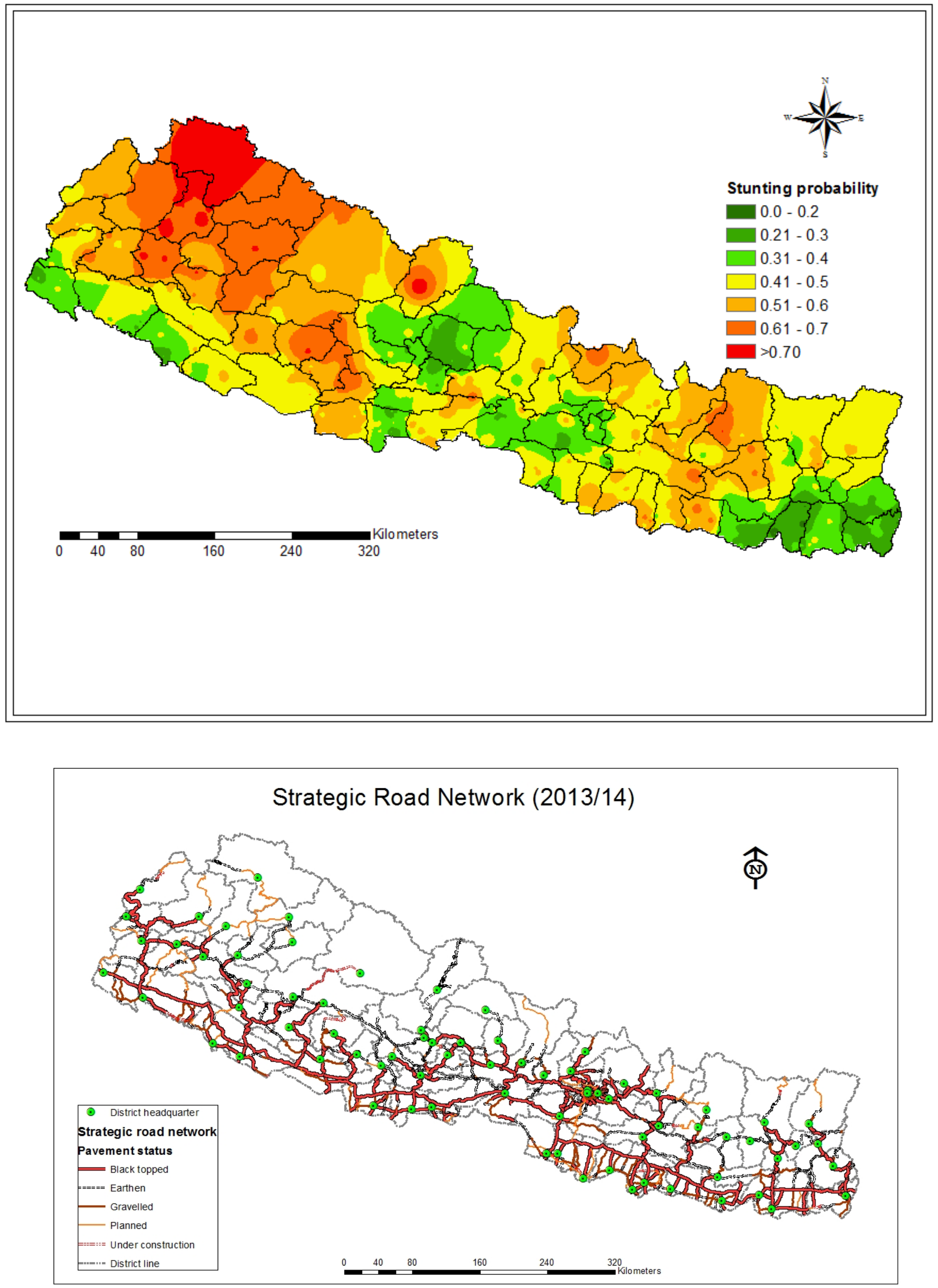
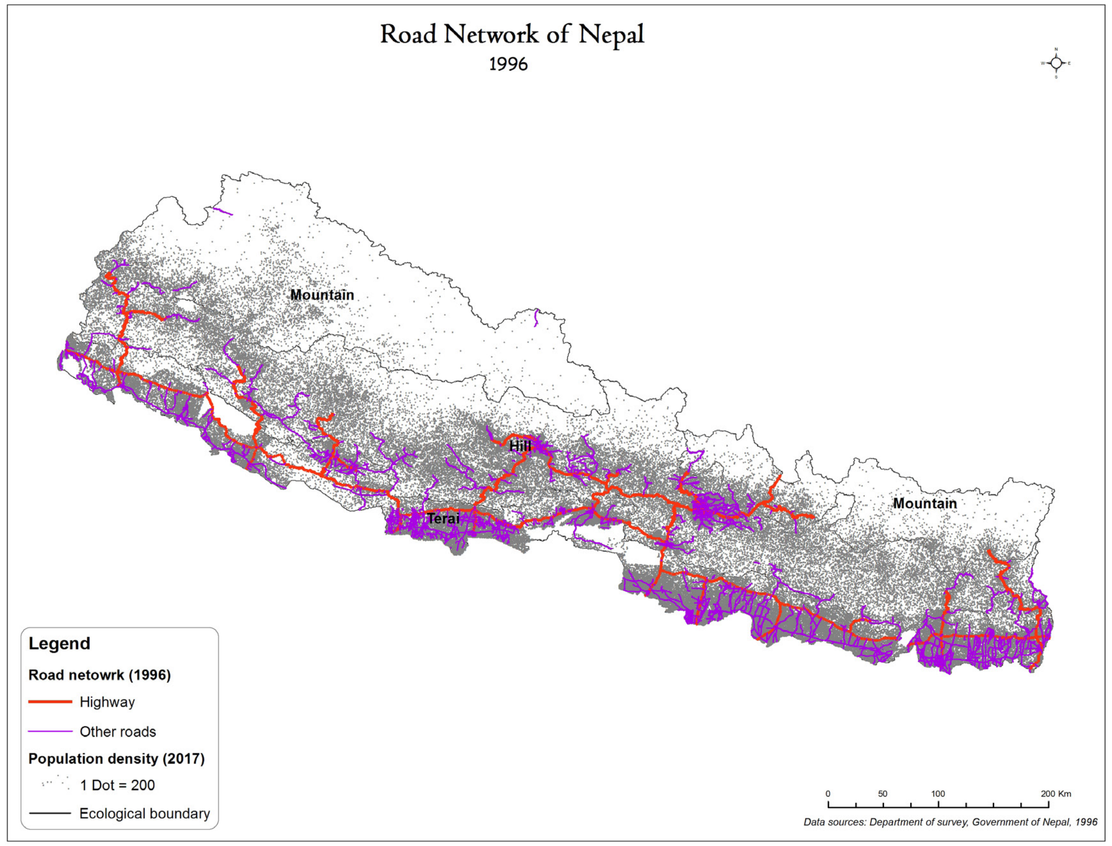


Figure 2 Maps of Nepal indicating stunting probability rates and strategic road network and pavement status in 2014.
Source: Stunting rates computed by the authors based on 2006 and 2011 Demographic and Health Survey (DHS) data. Road data from Department of Roads, Nepal.



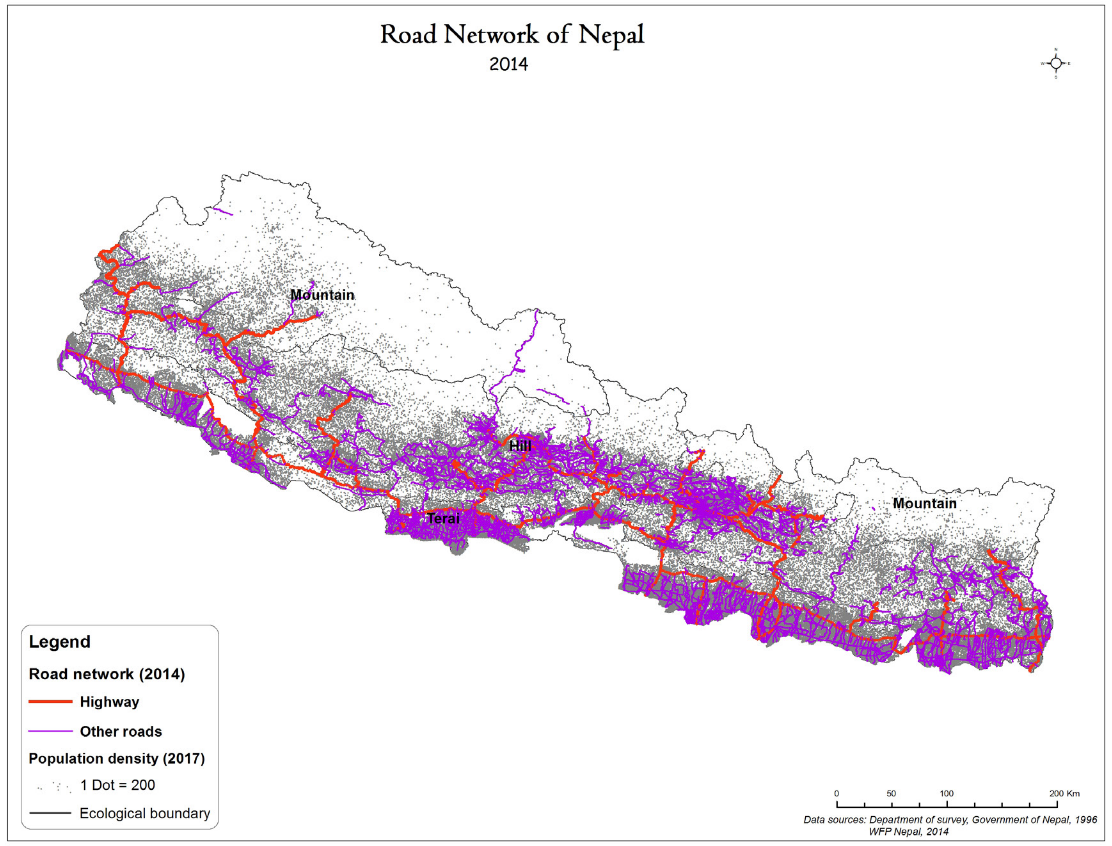


Figure 3 Nepal's complete road network in 1996 and 2014.
Source: Constructed by World Food Program (Kathmandu) using road data from Department of Roads, Nepal.

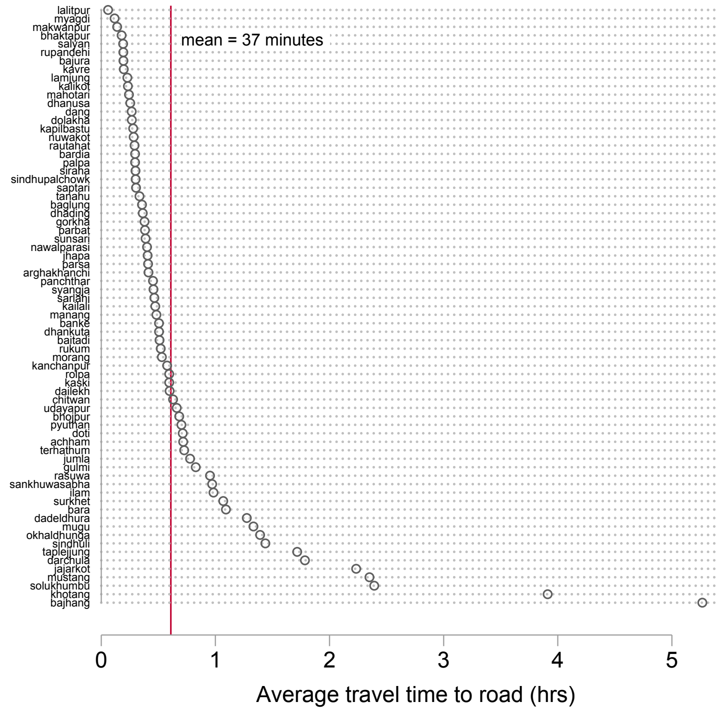


Figure 4 Average travel time to a well-paved road (in hours), by district.
Source: NLSS 2011, agricultural households only, n=401 villages

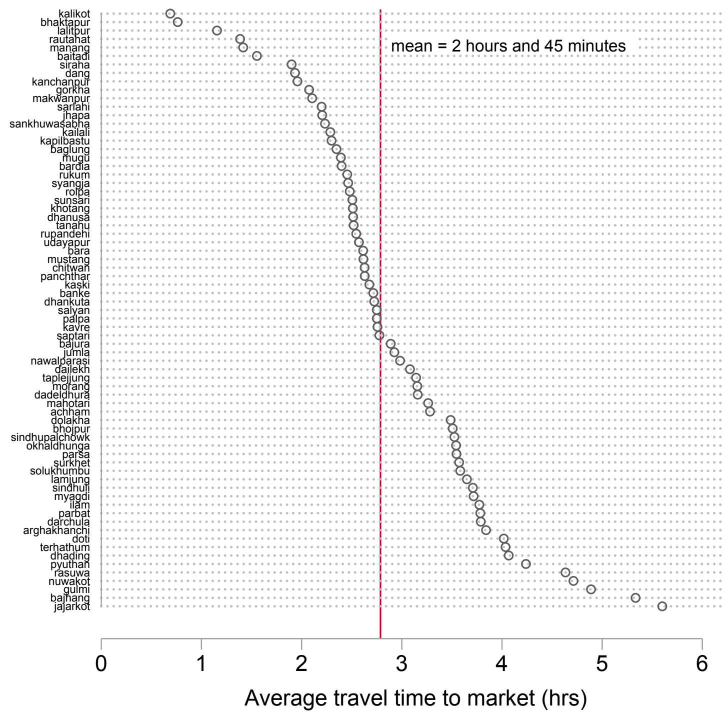


Figure 5 Average travel time to a market center (in hours), by district.
Source: NLSS 2011, agricultural households only, n=401 villages.

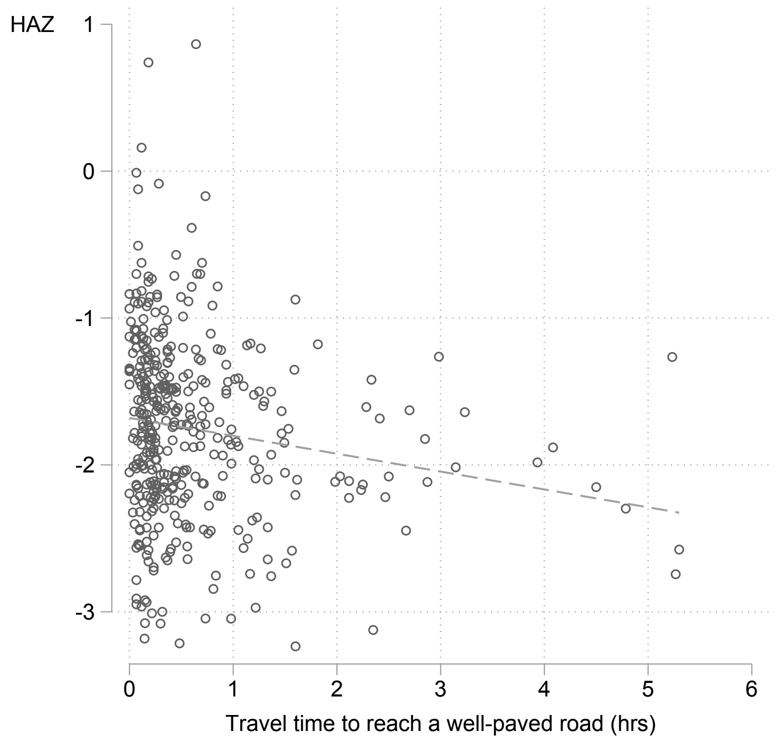


Figure 6 Village average HAZ for children below age 5 and access time to a well-paved road.
Source: NLSS 2011, all children.

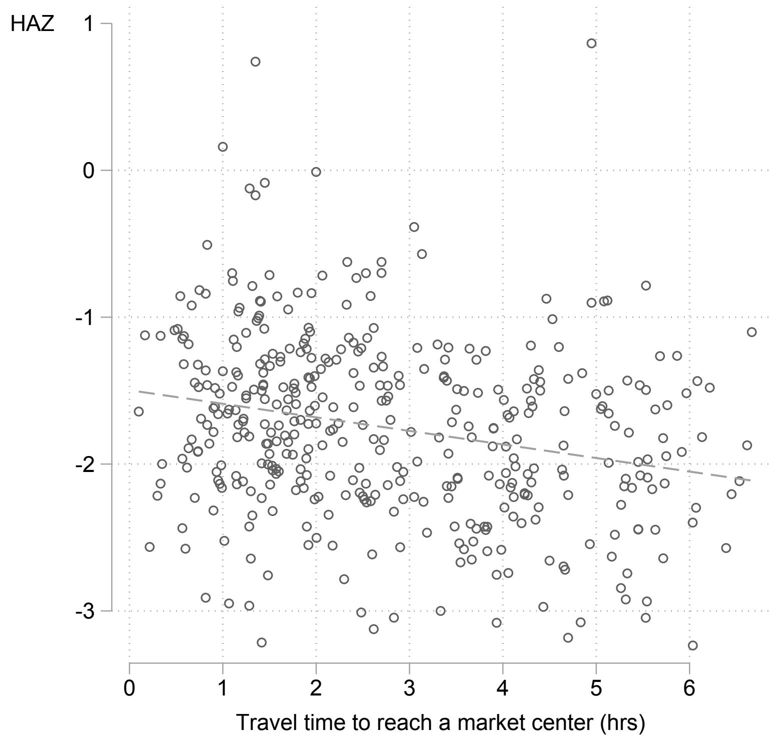


Figure 7 Village average HAZ for children below age 5 and access time to a market center.
Source: NLSS 2011, all children.

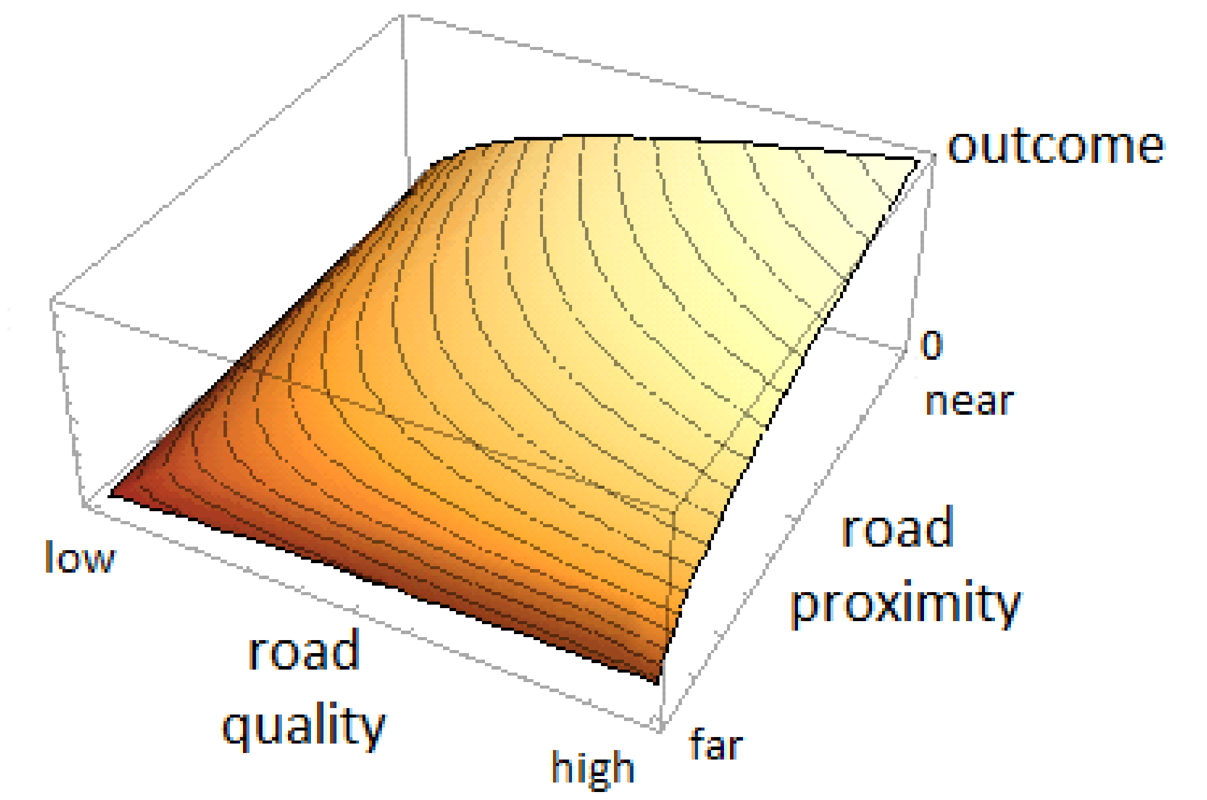


Figure 8 Stylized view of synergies between road quality, road proximity and outcome.
Source: Graph generated by the authors using software at www.wolframalpha.com.

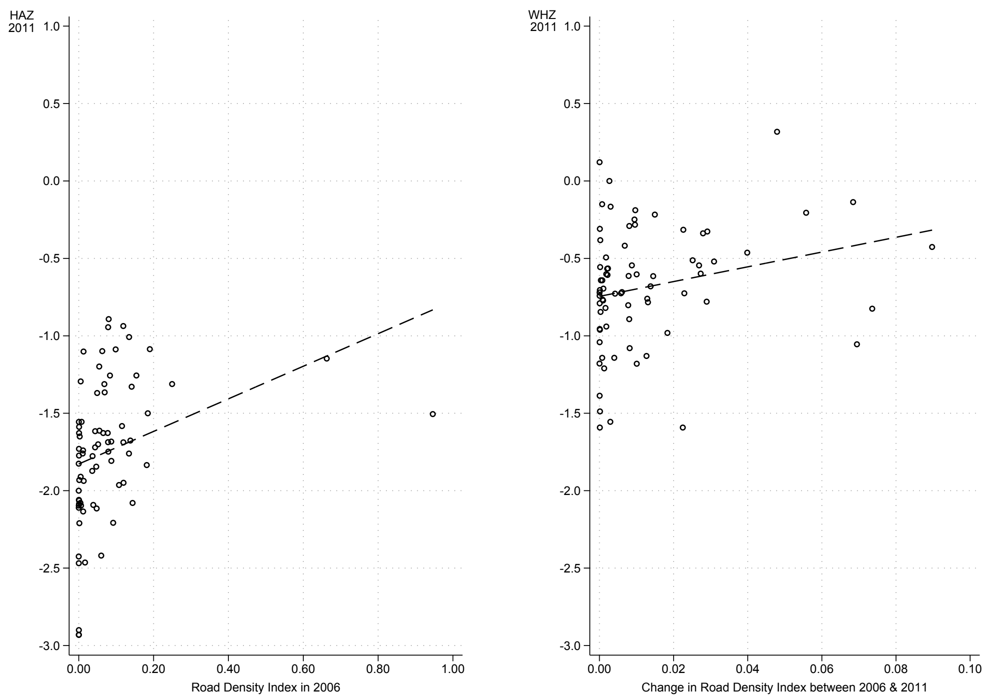


Figure 9 District-level road index and district-average child growth in Nepal, 2011.
Source: Nepal DHS 2006 and 2011, reproduced from Shively and Thapa (2017).

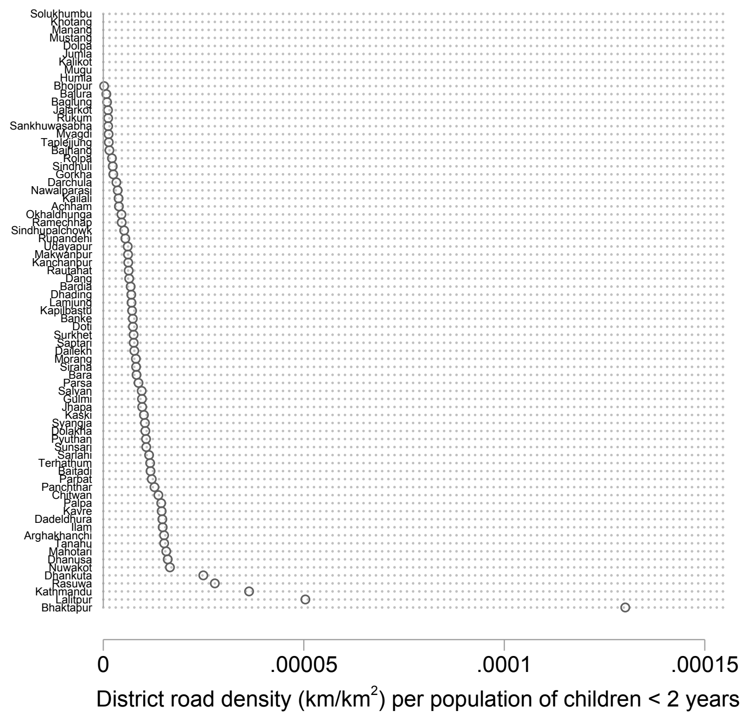


Figure 10 District average road density per population of children below 2 years.
Source: Nepal Census 2010.

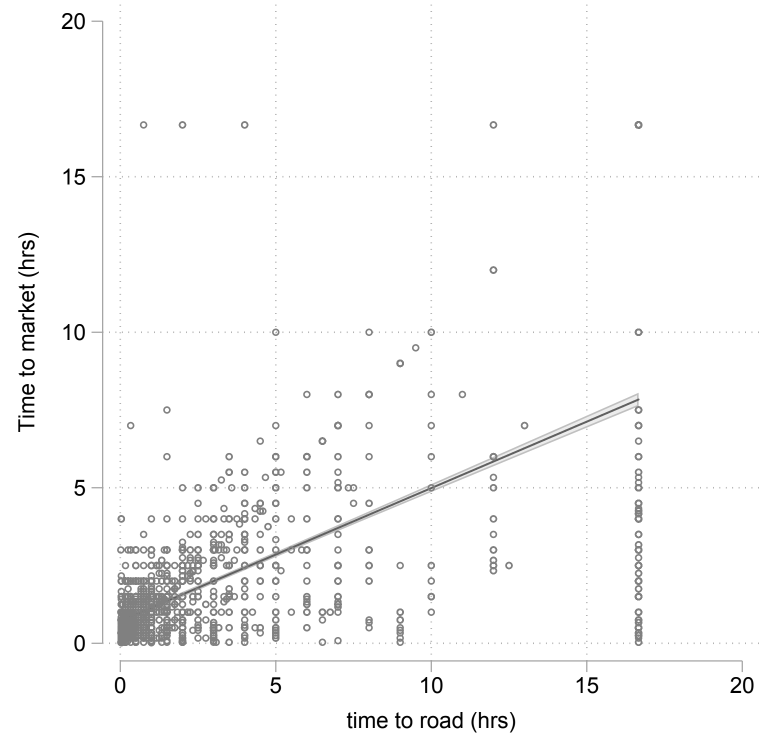


Figure 11 Reported travel time to well-paved road and market center, in hours.
Source: NLSS 2011, agricultural households only; Black line indicates linear fit; gray band indicates 95% confidence interval.

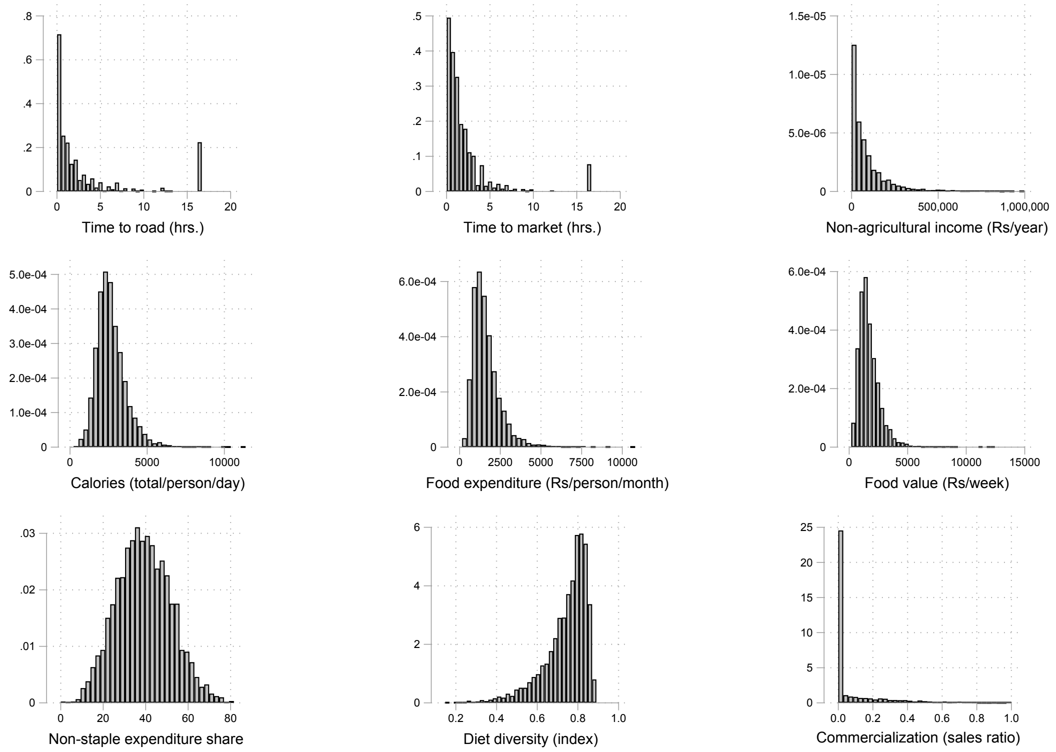


Figure 12 Frequency densities of continuous treatment and household indicator variables. Source: NLSS 2011, agricultural households only.

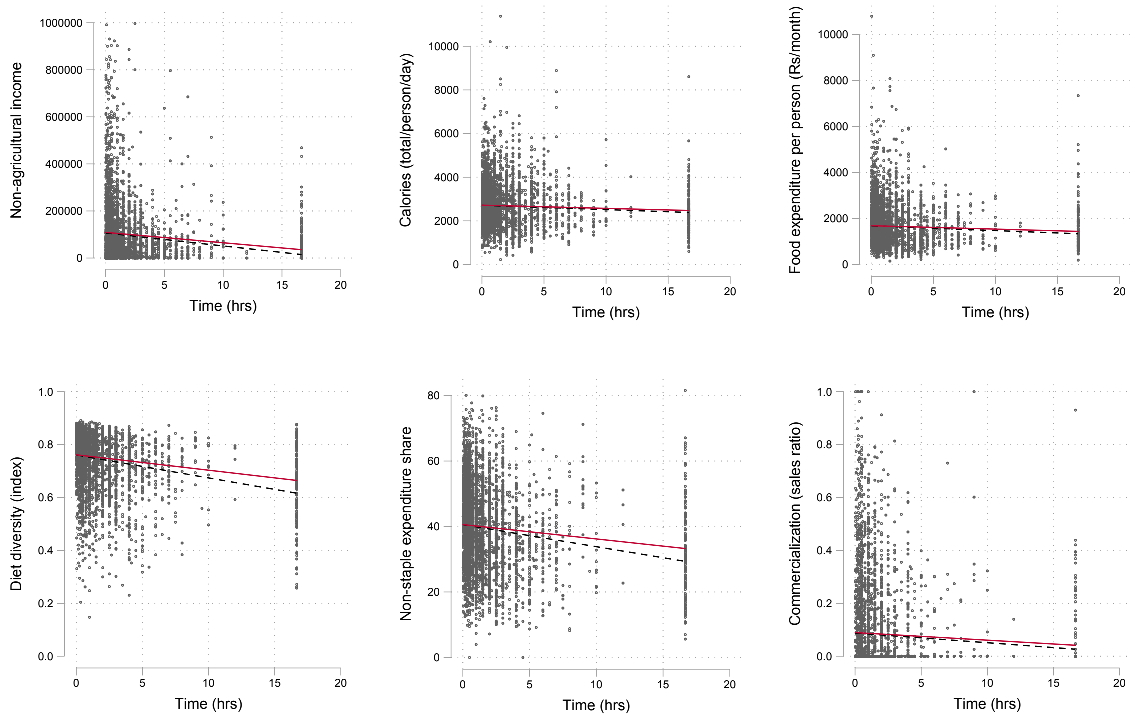


Figure 12 Frequency densities of continuous treatment and household indicator variables. Source: NLSS 2011, agricultural households only.

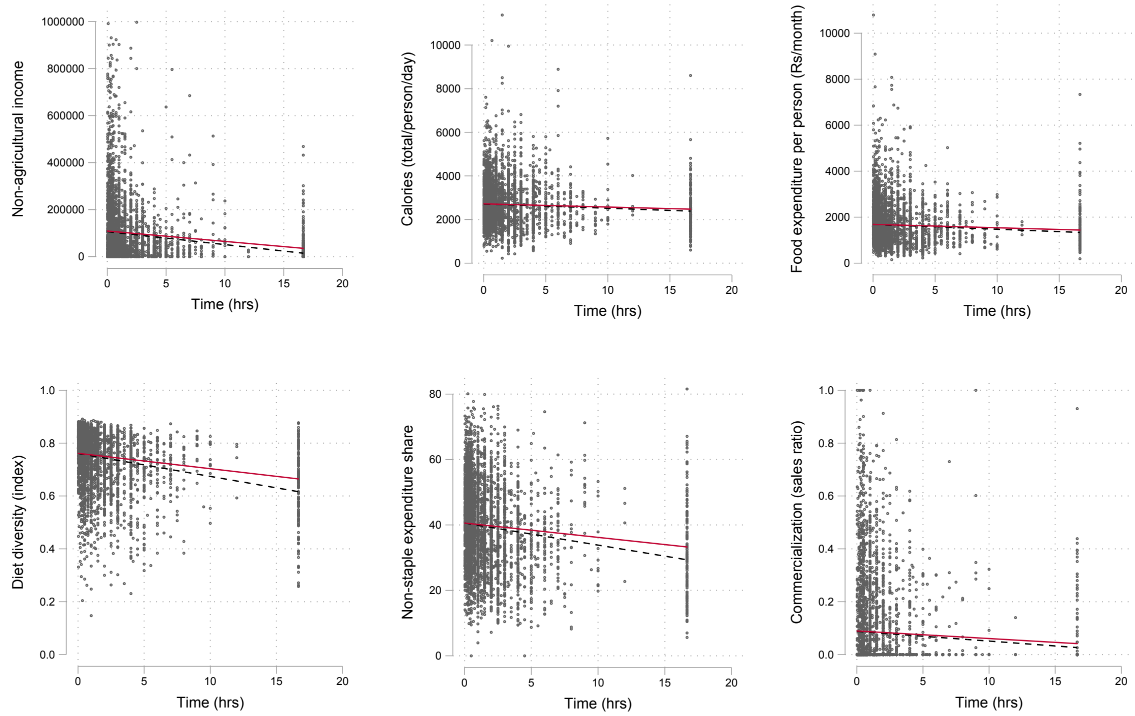


Figure 12 Frequency densities of continuous treatment and household indicator variables. Source: NLSS 2011, agricultural households only.

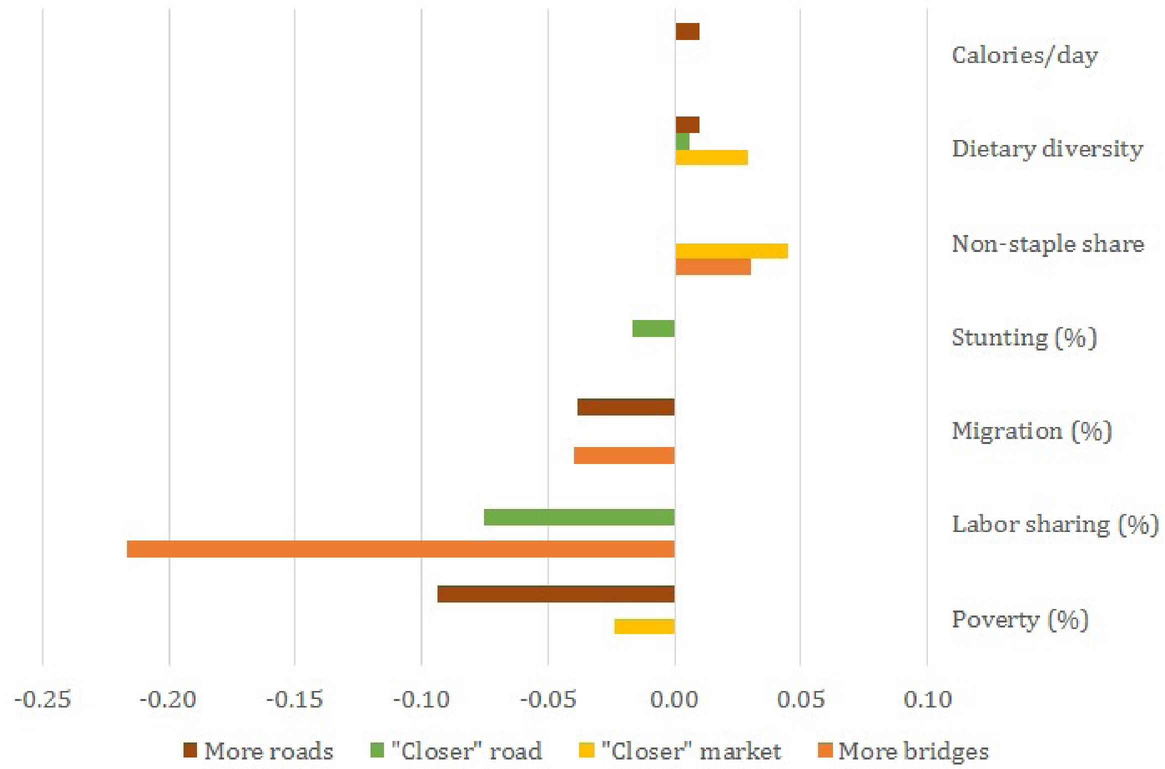


Figure 14 Elasticities (% change in outcome associated with 1% change in treatment) computed at sample mean values. Source: Calculated by the authors using NLSS 2011.

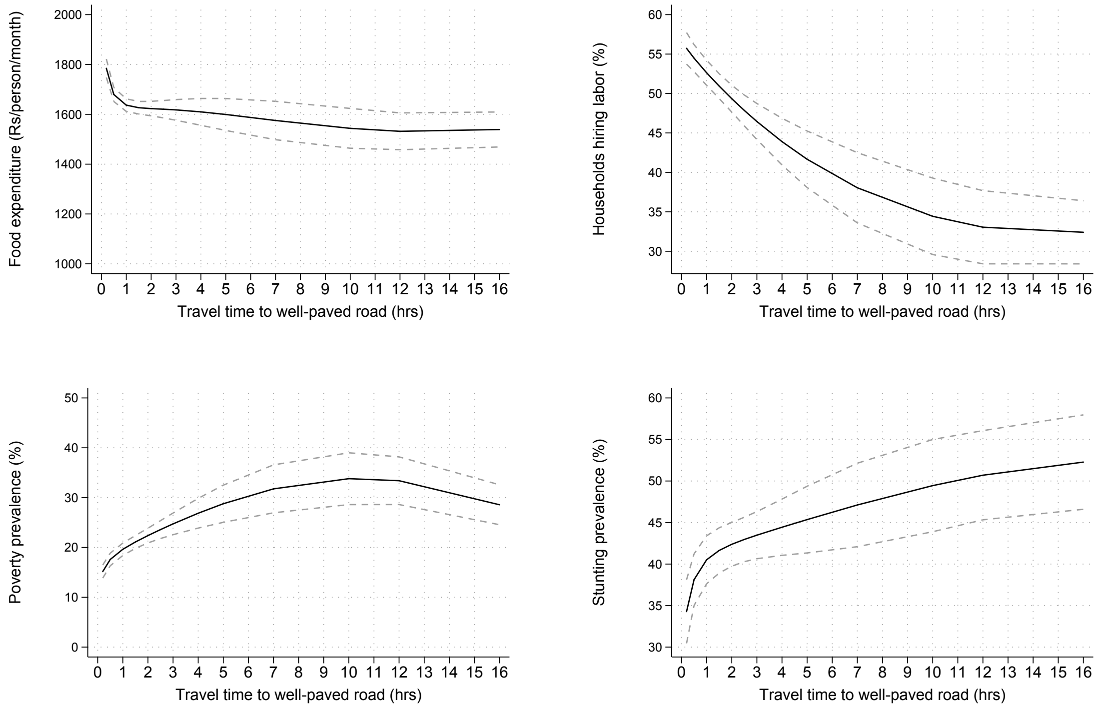


Figure 15 Dose-response predictions for access time to a well-paved road (in hours).
Source: NLSS 2011, agricultural households only except for stunting prevalence; dashed lines indicate 90% confidence bands

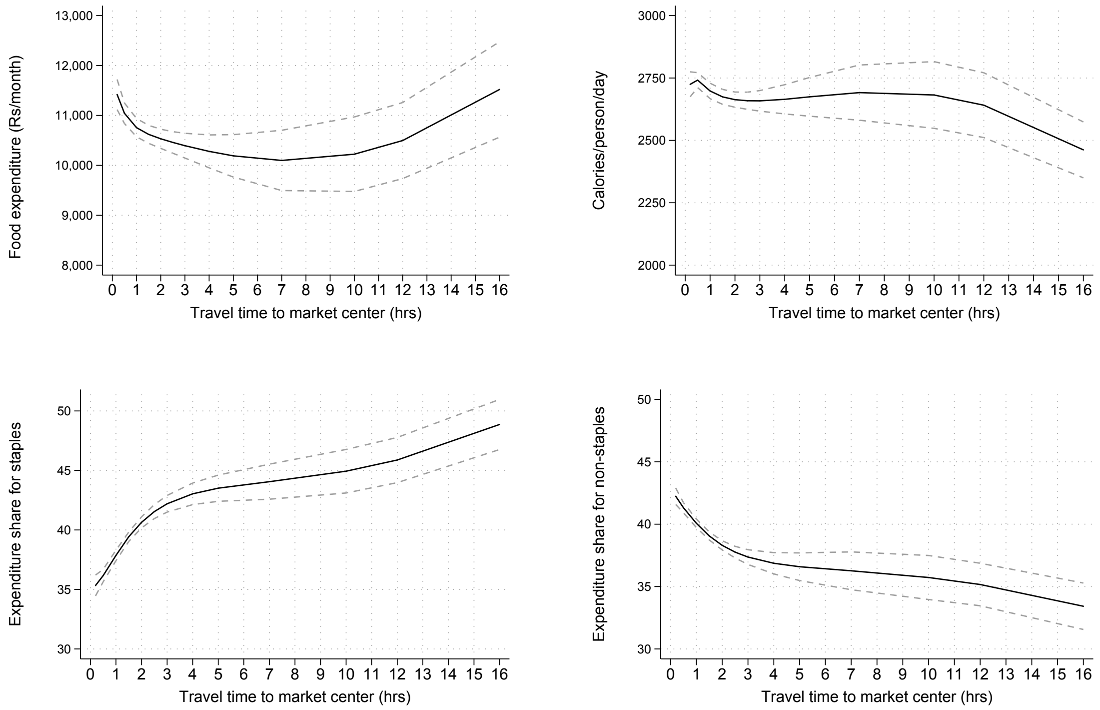


Figure 16 Dose-response predictions for access time to a market center (in hours).
Source: NLSS 2011, agricultural households only; dashed lines indicate 90% confidence bands.

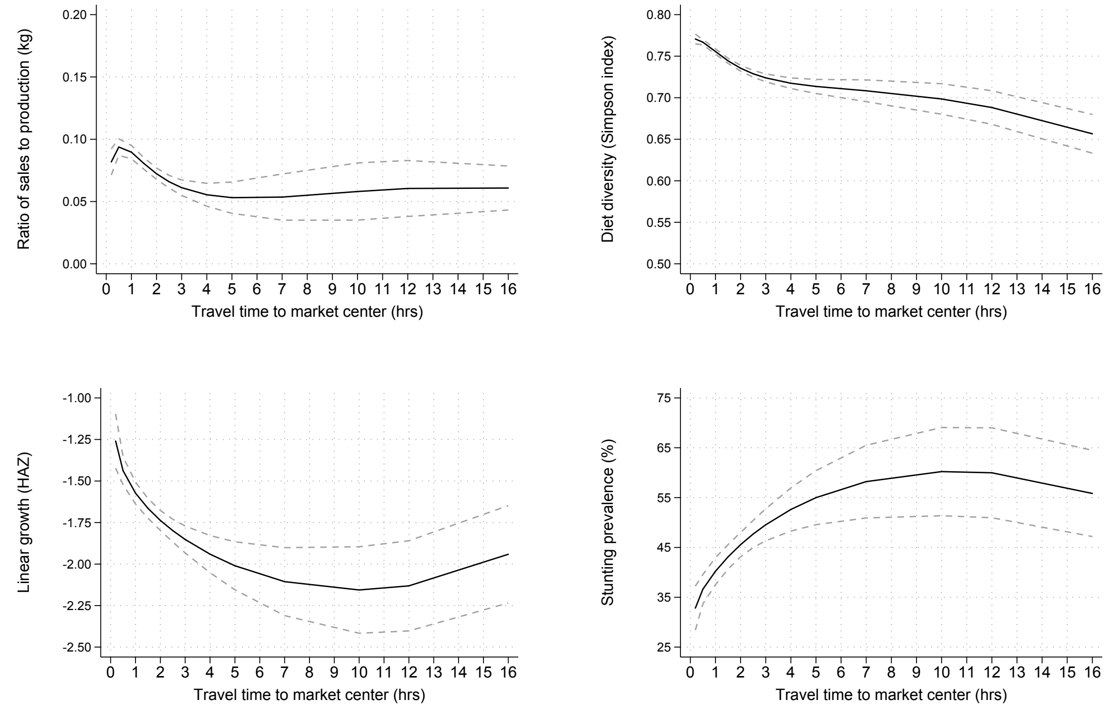


Figure 17 Dose-response predictions for access time to a market center (in hours).
Source: NLSS 2011, agricultural households only except for linear growth (HAZ) and stunting prevalence; dashed lines indicate 90% confidence bands.

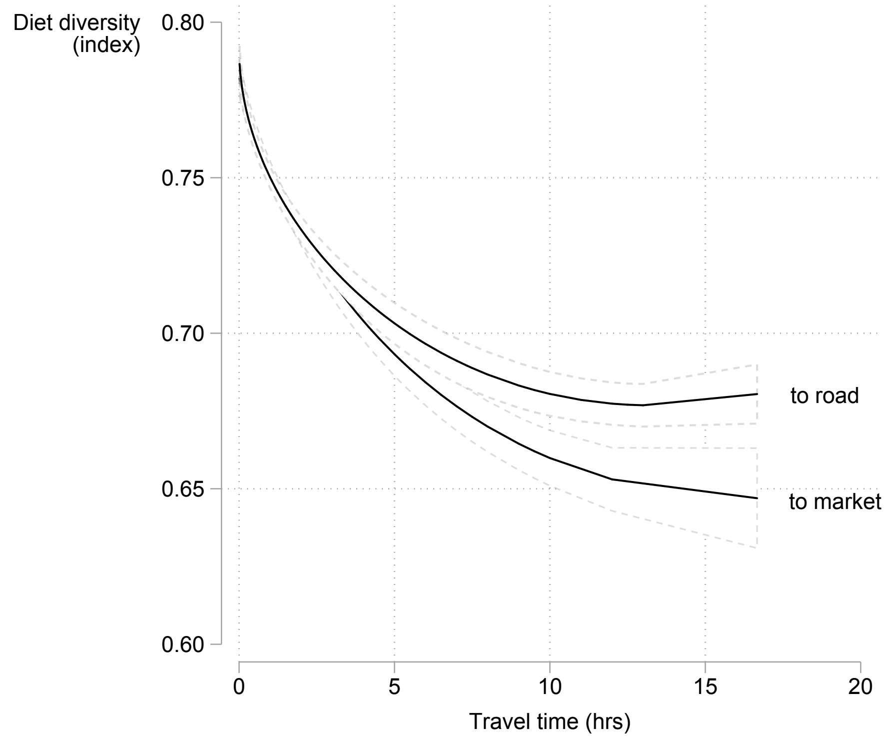


Figure 18 Dietary diversity and travel time to well-paved road and market center.
Source: NLSS 2011, agricultural households only; dashed lines indicate 90% confidence bands.

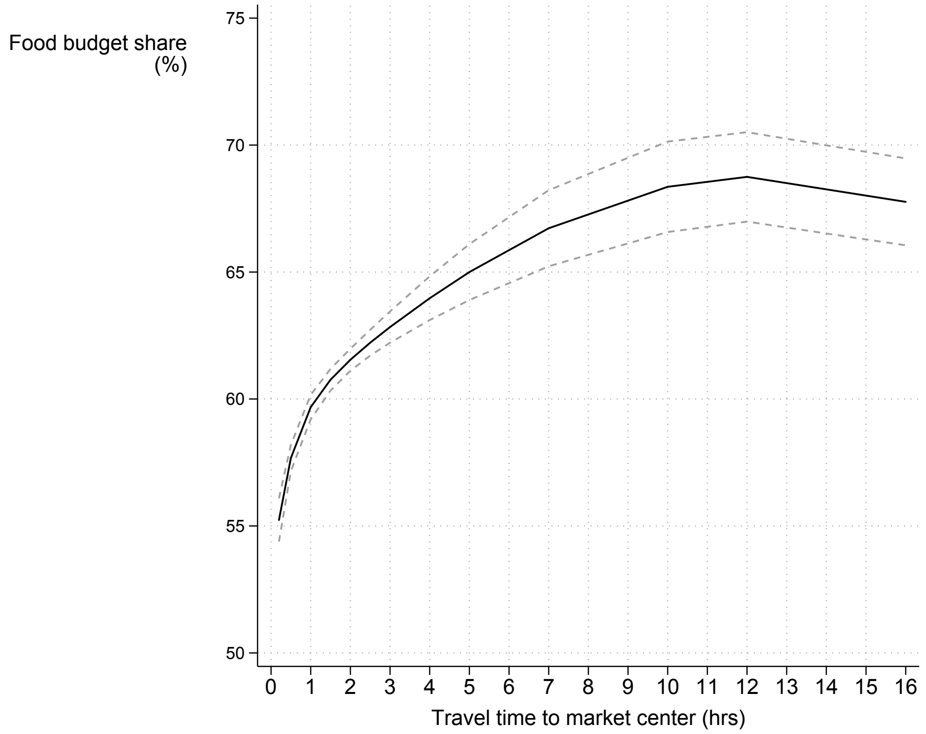


Figure 19 Dose-response prediction for food budget share and access time to a market center.
Source: NLSS 2011, agricultural households only; dashed lines indicate 90% confidence band.

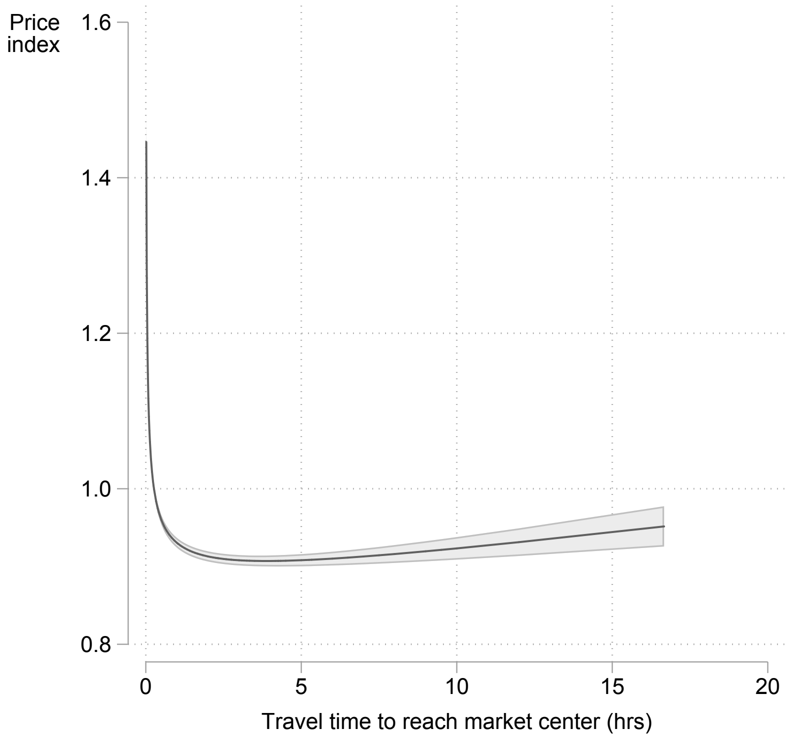


Figure 20 Basic needs price index and travel time to market center.
Source: NLSS 2011, agricultural households only; solid line indicates predicted relationship based on fractal polynomial regression; dashed lines indicate 95% confidence band.

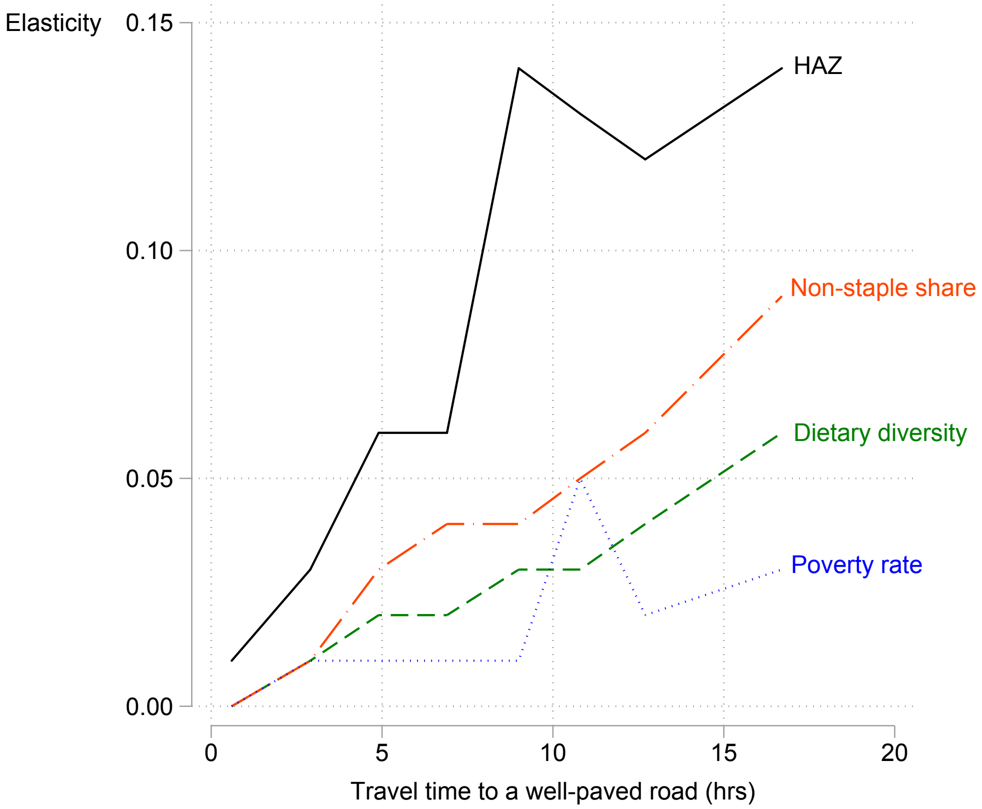


Figure 21 Elasticity estimates (% change in outcome resulting from 1% change in travel time; absolute value) for four indicators.
Source: Calculated by the authors using data from NLSS 2011.

APPENDIX

Table A1 Average household-reported access time (in hours) to a well-paved road and market center, within VDC, for sub-sample of agricultural households in 2011 NLSS (n=3,937)

District	VDC	Well-paved road	Market center
Achham	Bannatoli	4.41	2.97
	Darna	3.42	1.47
	Kalagau	4.73	0.76
	Mastamandau	0.57	0.09
	Siddheswor	0.17	0.71
Arghakhanchi	Arghatos	1.64	0.34
	Dharapani	1.61	0.32
	Nuwakot	2.26	0.22
	Thada	0.22	0.12
Baglung	Amalachaur	1.39	0.22
	Dhudhilabhati	3.46	0.23
	Kalika N.P.	0.93	0.03
	Khunga	12.1	0.28
	Tara	6.79	0.10
Baitadi	Bumiraj	2.00	2.79
	Dasharathchanda N.P.	0.40	1.88
	Gwallek	2.09	16.7
	Nagarjun	3.75	9.85
	Shikharpur	1.48	1.58
Bajhang	Byasi	3.90	1.09
	Kaphalaseri	8.42	2.83
	Parakatne	4.20	3.00
Bajura	Bramhatola	8.21	1.50
	Kotila	16.7	0.32
Banke	Bageswari	0.36	0.55
	Bhawaniyapur	0.15	0.79
	Kalaphanta	4.00	3.43
	Kohalpur	0.03	0.03
	Naubasta	0.23	0.27
	Nepalgunj N.P.	0.09	0.31
	Rajhena	0.10	0.23
	Sonapur	0.09	0.56
Bara	Benauli	16.7	2.08
	Dahiyar	0.56	0.41
	Jitpur Bhawanipur	0.03	0.03
	Lipanimal	0.23	0.56
	Piparpati Parchrouwa	2.29	2.06
Bardia	Belawa	0.11	0.29
	Dhadhawar	1.27	0.83
	Gulariya N.P.	0.24	0.79
	Magaragadi	1.08	0.29
	Motipur	0.22	0.35
	Rajapur	2.94	0.27
	Suryapatawa	1.62	1.36
Bhaktapur	Bhaktapur N.P.	0.05	0.07
	Changunarayan	0.10	0.76
	Kautunje	0.06	0.37
	Madhyapur Thimi N.P.	0.03	0.32
Bhojpur	Basikhola	15.7	4.51
	Chhinamakhu	16.7	5.17
	Keemalung	16.7	4.10
	Pangcha	16.7	3.93
	Tunggechha	4.58	0.39
Chitwan	Bharatpur N.P.	0.07	0.34
	Chainpur	0.47	0.52
	Jutpani	0.17	0.66
	Kumroj	0.41	0.67
	Pithuwa	0.15	0.35
	Ratnanagar N.P.	0.14	0.19
Dadeldhura	Amargadhi N.P.	0.87	1.06
	Belapur	2.92	3.83
	Manilek	1.14	2.20
Dailekh	Chamunda	8.63	2.50
	Khadkawada	1.65	2.42
	Narayan N.P.	0.53	0.66
	Odhari	6.73	2.77
	Tilepata	3.21	3.33
Dang	Chaulahi	0.06	0.06
	Duruwa	0.88	1.47
	Hansipur	6.71	7.50
	Laxmipur	0.60	0.85
	Pawan Nagar	0.70	0.70
	Rampur	1.22	1.47
	Sisahaniya	0.80	1.27
	Tribhuwan Nagar N.P.	0.29	0.46
	Tulsipur N.P.	0.19	0.50
Darchula	Khalanga	16.7	0.03
	Sunsera	16.7	16.7

Dhading	Baseri	5.56	2.32
	Dhola	1.29	1.64
	Jogimara	3.36	4.22
	Nalang	2.74	2.28
	Pida	1.03	1.31
	Sunaula Bazar	1.75	0.84
Dhankuta	Bhirgaun	2.02	2.54
	Dhankuta N.P.	0.19	0.60
	Hathikharka	2.00	2.47
	Parewadin	2.68	2.68
Dhanusa	Bharatpur	0.37	0.37
	Debadiha	0.86	1.30
	Gopalpur	1.00	1.00
	Janakpur N.P.	0.03	0.05
	Laxmipurbagewa	0.25	0.58
	Mukhiyapattimushargiya	1.00	1.00
	Siddha	0.96	1.07
Dolakha	Bhimeswor N.P.	0.55	0.76
	Dudhpokhari	4.06	3.10
	Jugu	3.17	2.56
	Mali	1.96	1.90
	Suri	16.7	2.16
Doti	Banlek	1.38	1.46
	Dipayal Silgadhi N.P.	0.35	0.33
	Gaihragau	1.43	1.41
	Lana Kedareswor	15.2	6.53
	Simchaur	16.7	1.50
Gorkha	Aanppipal	2.25	1.65
	Fujel	2.81	3.17
	Kerauja	16.7	13.0
	Prithbinarayan N.P.	0.17	0.22
	Takukot	6.73	6.73
Gulmi	Badagaun	1.85	1.85
	Darbar Devisthan	1.04	1.93
	Jayakhani	4.79	2.85
	Pallikot	0.81	1.21
	Tamghas	0.03	0.03
Ilam	Barbote	0.33	0.58
	Danabari	1.55	1.61
	Ilam N.P.	0.33	1.03
	Jitpur	3.58	4.50
	Maipokhari	0.42	0.97
	Phikal Bazar	0.48	0.92
	Shree Antu	0.96	0.88
Jajarkot	Jagatipur	9.69	2.96
	Paink	16.7	16.7
Jhapa	Arjundhara	0.65	0.65
	Bhadrapur N.P.	0.03	0.12
	Chandragadhi	0.29	0.30
	Damak N.P.	0.43	0.46
	Dharampur	0.21	0.53
	Jalthal	0.81	0.88
	Khudunabari	0.23	0.27
	Mechinagar N.P.	0.73	0.97
	Pathariya	2.56	0.63
	Sanischare	0.03	0.12
	Surunga	0.67	0.75
Jumla	Badki	16.7	8.83
	Lihi (Rara)	16.7	2.10
Kailali	Basauti	2.27	1.80
	Chaumala	0.19	0.84
	Dhangadhi N.P.	0.06	0.49
	Durgauli	1.89	0.91
	Joshipur	1.67	0.65
	Malakheti	0.14	0.26
	Pahalmanpur	0.28	0.36
	Phulwari	1.24	2.33
	Sreepur	0.51	0.55
	Tikapur N.P.	0.91	0.85
Kalikot	Dholagohe	16.7	16.7
	Odanku	16.7	16.7
Kanchanpur	Baisi Bichawa	0.86	0.52
	Daijee	0.39	0.75
	Jhalari	0.30	0.45
	Mahendranagar N.P.	0.57	0.82
	Parasan	1.98	0.92
	Tribhuwanbast	1.30	0.56
Kapilbastu	Bahadurganj	0.17	0.70
	Bijuwa	0.16	1.43
	Dumara	0.50	1.27
	Hathausa	0.34	0.73
	Kapilbastu N.P.	0.09	0.18
	Krishna Nagar	0.37	0.40
	Motipur	0.14	1.18
	Pipara	0.67	1.28
	Thunhiya	0.67	1.47
Kaski	Kaskikot	0.74	1.57
	Lekhnath N.P.	0.23	0.39
	Namarjung	5.24	5.56
	Pokhara N.P.	0.03	0.24

Kathmandu	Bajrayogini (Sankhu)	0.82	0.77
	Gokarneswor	0.03	0.17
	Ichang Narayan	0.03	0.03
	Jorpati	0.03	0.03
	Kathmandu N.P.	0.04	0.19
	Khadka Bhadrakali	0.03	0.20
	Kirtipur N.P.	0.06	0.15
	Satungal	0.06	0.10
Kavre	Banepa N.P.	0.03	0.03
	Chandeni Mandan	1.38	1.38
	Dhulikhel N.P	0.48	0.82
	Gairi Bisouna Deupur	0.63	0.89
	Mahendra Jyoti	0.19	0.65
	Panauti N.P.	0.15	0.29
	Panchkhal	0.03	0.20
	Saping	1.59	1.54
Khotang	Bamrang	9.08	1.67
	Dhitung	16.7	1.79
	Kharmi	12.2	6.00
	Nunthala	15.8	2.67
	Suntale	7.00	6.73
Lalitpur	Bhattedanda	2.48	3.23
	Gimdi	11.0	6.88
	Lalitpur N.P.	0.05	0.24
	Siddhipur	0.08	0.78
Lamjung	Balungpani	1.41	1.41
	Chakratirtha	2.32	2.62
	Puranokot	2.23	1.55
Mahotari	Aurahi	0.12	0.12
	Basabitti	4.75	0.69
	Fulakaha	1.42	0.79
	Hathilet	0.03	0.63
	Jaleshwor N.P.	0.03	0.03
	Manara	0.65	0.81
	Sahasaula	0.08	0.43
	Sisawakataiya	1.07	1.33
Makwanpur	Bajrabarahi	0.29	1.63
	Churiyamai	0.27	0.60
	Hetauda N.P.	0.07	0.42
	Kankada	3.08	3.21
	Namtar	16.7	6.89
	Sarikhet Palase	1.50	2.33

Morang	Amahibariyati	0.71	0.83
	Bayarban	0.80	0.84
	Biratnagar N.P.	0.09	0.33
	Dadarbairiya	0.62	0.60
	Drabesh	0.47	0.60
	Itahara	0.21	0.82
	Katahari	0.14	0.44
	Madhumalla	1.07	1.04
	Necha	1.00	1.33
	Sijuwa	0.33	0.93
	Sundarpur	0.15	0.27
Mugu	Karkibada	16.7	0.31
Myagdi	Bhakilmi	2.07	2.07
	Muna	7.11	5.01
	Singa	1.26	1.26
Nawalparasi	Agryouli	0.50	0.91
	Bhujhawa	0.88	1.93
	Dhaubadi	1.46	1.49
	Gairami	0.36	0.93
	Kawaswoti	0.03	0.16
	Makar	0.03	1.06
	Naya Belhani	0.96	0.96
	Pragatinagar	0.03	0.30
	Ramgram N.P.	0.12	0.22
	Rampurkha	0.22	0.44
	Sukrauli	0.29	0.70
	Thulo Khairatawa	2.33	1.80
Nuwakot	Bidur N.P.	0.09	0.42
	Chaturale	1.83	1.43
	Ghyangphedi	16.7	9.03
	Kholegaun Khanigaun	0.08	0.50
	Taruka	1.33	1.28
Okhaldhunga	Fediguth	16.7	16.7
	Mulkharka	6.58	6.35
	Singhadevi	6.50	1.44
Palpa	Darchha	3.98	0.50
	Humin	0.53	1.32
	Ringneraha	2.92	0.44
	Tansen N.P.	0.08	0.39
Panchthar	Amarpur	6.05	1.41
	Lungrupa	3.31	5.10
	Pauwa Sartap	2.21	2.46
	Sarang Danda	4.12	1.59
Parbat	Lekhfant	2.52	2.00
	Shankar Pokhari	1.69	1.33

Parsa	Amarpatti	0.42	0.84
	Beriya Birta	0.30	1.00
	Birgunj N.P.	0.05	0.26
	Jhouwa Guthi	0.88	2.29
	Ramgadhawa	0.03	0.35
	Sugauli Partewa	16.7	12.2
Pyuthan	Bijaya Nagar	0.61	0.53
	Dhuwang	2.57	3.00
	Maranthana	1.42	0.82
	Ramdi	1.00	1.19
Ramechhap	Bhatauli	7.09	3.36
	Gelu	3.31	1.70
	Pritee	16.7	16.7
	Tilpung	3.46	1.50
Rasuwa	Chilime	5.39	3.83
Rautahat	Basantapatti	1.67	1.67
	Chandranigahapur	0.08	0.21
	Gaur N.P.	0.47	0.42
	Jhunkhunwa	0.21	0.42
	Pacharukhi	7.62	7.53
	Pratappur Paltuwa	1.15	1.67
	Saruatha	0.42	1.06
Rolpa	Budagaun	11.9	6.59
	Harjang	2.97	2.86
	Kotgaun	4.51	4.40
	Rangsi	16.7	6.85
	Wot	16.7	4.08
Rukum	Garayala	15.4	3.75
	Magma	16.7	3.97
	Ranmamaikot	16.7	16.7
Rupandehi	Asurena	1.04	2.51
	Bodabar	0.55	1.33
	Butawal N.P.	0.03	0.17
	Devadaha	0.23	0.65
	Gangoliya	0.19	0.62
	Karahiya	0.04	0.74
	Madhbaliya	0.05	0.38
	Masina	0.08	0.82
	Pokharvindi	0.39	1.03
	Samera Marchwar	2.17	1.99
	Siddharth Nagar N.P.	0.03	0.28
	Souraha Pharsatikar	0.07	0.31
Salyan	Bame	15.7	4.00
	Dhanwang	2.04	2.25
	Korbang Jhimpe	1.94	2.49
	Phalawang	1.11	1.77

Sankhuwasabha	Ankhibhui	2.57	2.61
	Khandbari N.P.	3.72	0.63
	Madi Mulkharka	3.27	1.17
	Siddhakali	2.15	1.19
Saptari	Bakdhauwa	0.30	1.04
	Belhichapena	3.43	4.95
	Fakira	0.88	1.29
	Inarwa	0.44	0.44
	Kushaha	0.35	0.68
	Malhanama	0.81	1.04
	Pato	1.46	1.65
	Rajbiraj N.P.	0.03	0.03
	Theliya	0.50	0.55
Sarlahi	Barahathawa	0.96	0.39
	Dhungrekhola	0.60	0.90
	Gourishankar	0.80	1.27
	Jabdi	0.57	0.57
	Madhubani	2.64	1.75
	Malangawa N.P.	0.06	0.17
	Netraganj	0.08	0.12
	Sankarpur	1.00	0.70
Sindhuli	Amale	6.42	6.58
	Kamalami N.P.	0.61	0.67
	Kapilakot	16.7	12.1
	Mahendrajhayadi	9.00	9.00
	Sirthouli	2.44	1.79
Sindhupalchowk	Bhimtar	1.67	1.43
	Jethal	0.72	0.91
	Maneswor	1.35	1.42
	Ramche	0.16	0.19
	Tauthali	2.00	0.14
Siraha	Ayodhyanagar	0.21	0.40
	Chandrodayapur	0.61	0.47
	Fulkaha Kati	0.69	0.54
	Karjanha	0.17	0.42
	Lahan N.P.	0.09	0.31
	Mahanaur	1.39	1.02
	Sakhuwanankarkatti	0.48	1.07
	Siraha N.P.	0.09	0.28
	Sukhipur	1.13	1.38
Solukhumbu	Bung	16.7	8.72
	Loding Tamakhani	16.7	2.02

Sunsari	Aekamba	0.65	0.68
	Barahachhetra	1.39	0.25
	Bharaul	1.01	0.48
	Dharan N.P.	0.12	0.33
	Hanshposha	0.14	0.20
	Inaruwa N.P.	0.03	0.23
	Itahari N.P.	0.06	0.24
	Khanar	0.11	0.33
	Panchakanya	0.72	0.34
Surkhet	Awalching	9.64	0.60
	Birendranagar N.P.	0.20	0.81
	Dharapani	5.27	4.91
	Kalyan	2.97	2.94
	Lekhparajul	1.47	2.56
	Ramghat	0.76	0.51
	Uttarganga	0.09	0.36
Syangja	Biruwa Archale	0.71	1.84
	Faparthum	0.34	1.80
	Pauwegaude	0.32	1.02
	Putalibazar N.P.	0.22	0.69
	Shreekrishna Gandaki	0.12	0.87
	Wangsing Deurali	0.22	0.73
Tanahu	Anbukhaireni	0.23	0.50
	Bhanu	0.03	0.11
	Byas N.P.	0.28	0.60
	Ghansikuwa	0.10	0.35
	Kotdarbar	2.79	3.03
	Virlung	1.88	1.93
Taplejjung	Lelep	16.7	14.2
Terhathum	Eseebu	9.85	6.55
	Phulek	1.58	1.85
Udayapur	Beltar	1.09	0.86
	Katari	2.83	0.14
	Rauta	3.00	1.63
	Tapeswori	1.50	0.40
	Triyuga N.P.	0.32	1.04

*Note:*indicates binary variable.*

Table A2 Population-weighted descriptive statistics for variables used in the analysis

	Well-paved road				Full sample	
Variable	**Mean**	**Std. dev.**	**Mean**	**Std. dev.**	**Mean**	**Std. dev.**
Child level (n= 2,394)						
Height-for-age (z score)	-1.36	1.58	-1.83	1.51	-1.61	1.56
Child stunted (=1 if HAZ < -2; else 0)	0.35	0.48	0.48	0.50	0.42	0.49
Received immunization (=1 if yes; else 0)	0.97	0.17	0.96	0.19	0.97	0.18
Diarrhea in past two weeks (=1 if yes; else 0)	0.09	0.28	0.06	0.24	0.07	0.26
Fever in past two weeks (=1 if yes; else 0)	0.22	0.41	0.14	0.35	0.18	0.38
Child is male (=1 if yes; else 0)	0.48	0.50	0.49	0.50	0.48	0.50
Child age (in months)	29.55	16.94	30.11	16.87	29.85	16.90
Monsoon season birth (=1 if yes; else 0)	0.30	0.46	0.32	0.47	0.31	0.46
Household level (n= 3,937)						
Travel time to market center (hrs.)					2.21	3.45
Travel time to well-paved road (hrs.)					3.41	5.25
Proximity to road (=1 if < 1 hr. to road; else 0)					0.45	0.50
Proximity to market (=1 if < 1 hr. to road; else 0)					0.41	0.49
Calorie consumption (Kcal/person/day)	2607.73	832.77	2472.73	954.75	2532.96	904.75
Dietary diversity (Simpson's index)	0.76	0.09	0.71	0.12	0.74	0.11
Non-staple expenditure share (%)	40.61	11.45	36.49	12.86	38.33	12.42
Food budget (Rs/week/household)	2089.00	1179.28	1821.82	1051.26	1941.03	1117.98
Commercialization (ratio kg sold to kg produced)	0.11	0.20	0.06	0.14	0.08	0.17
Non-agricultural income (Rs/household/year)	17.30	88.37	11.71	126.92	14.21	111.40
Food expenditure (Rs/person/month)	1574.86	810.64	1393.11	728.15	1474.20	771.26
Poor household (=1 if yes; else 0)	0.19	0.39	0.35	0.48	0.28	0.45
Exchanged (shared) labor (=1 if yes; else 0)	0.22	0.42	0.42	0.49	0.33	0.47
Sales labor (=1 if yes; else 0)	0.59	0.49	0.42	0.49	0.49	0.50
Migrant (=1 if any member migrated; else 0)	0.53	0.50	0.56	0.50	0.55	0.50

Food for work participant (=1 if yes; else 0)	0.01	0.09	0.06	0.24	0.04	0.19
Male head (=1 if yes; else 0)	0.80	0.40	0.79	0.41	0.80	0.40
Age of household head (years)	48.04	12.94	47.16	13.59	47.55	13.31
Family size (# persons)	6.23	2.93	6.10	2.68	6.16	2.80
Dependency ratio (# < 15 + # > 65 / # persons)	0.40	0.21	0.47	0.21	0.44	0.21
Brahmin (=1 if yes; else 0)	0.15	0.35	0.10	0.30	0.12	0.33
Mongolian (=1 if yes; else 0)	0.19	0.39	0.31	0.46	0.25	0.44
Madheshi (=1 if yes; else 0)	0.18	0.38	0.09	0.28	0.13	0.33
Unprivileged group (=1 if yes; else 0)	0.33	0.47	0.28	0.45	0.30	0.46
Car (=1 if own; else 0)	0.01	0.09	0.00	0.05	0.01	0.07
TV (=1 if own; else 0)	0.59	0.49	0.21	0.41	0.38	0.49
Telephone (=1 if own; else 0)	0.74	0.44	0.48	0.50	0.60	0.49
Total annual remittance (lakhs Rs)	0.49	1.48	0.64	12.43	0.57	9.30
Chemical fertilizer (=1 if used; else 0)	0.86	0.34	0.62	0.49	0.73	0.44
Improved fertilizer (=1 if used; else 0)	0.56	0.50	0.33	0.47	0.43	0.50
Irrigation (=1 if used; else 0)	0.62	0.48	0.57	0.50	0.59	0.49
Agricultural advice (=1 if received; else 0)	0.13	0.34	0.08	0.27	0.10	0.30
Livestock (=1 if owned; else 0)	0.89	0.31	0.98	0.13	0.94	0.24
Mother literate (=1 if yes; else 0)	0.32	0.47	0.36	0.48	0.34	0.47
Kitchen garden (=1 if yes; else 0)	0.66	0.47	0.72	0.45	0.69	0.46
Small farm (=1 if 0.33 ≤ farm size ≤ 0.66; else 0)	0.22	0.42	0.27	0.44	0.25	0.43
Medium farm (=1 if 0.66 ≤farm size ≤2; else 0)	0.27	0.44	0.34	0.47	0.31	0.46
Large farm (=1 if farm size >2 ha; else 0)	0.13	0.34	0.08	0.27	0.10	0.30
Farm size (hectares)	0.73	0.96	0.72	0.80	0.73	0.87
Crop diversity (# of crops grown)	11.18	5.85	13.48	5.68	12.45	5.87
Urban region (=1 if yes; else 0)	0.19	0.39	0.02	0.13	0.09	0.29
Community (n=447)						
Crop diversity (# of crops grown in village)	17.02	5.46	19.32	5.00	18.29	5.33
Irrigation (% of households with access)	65.50	26.97	58.10	31.46	61.40	29.76

Price (index)	0.95	0.18	0.92	0.07	0.93	0.13
District (n=71)						
Road density (km/km2 × 100, quality weighted)	17.93	26.91	7.65	12.13	12.23	20.75
Spatial lag road index (quality weighted)	183.03	72.22	128.42	78.21	152.79	80.31
Bridge density (#/km2 × 100)	0.03	0.03	0.01	0.02	0.02	0.02
Cereal deficit (=1 if yes; else 0)	0.37	0.48	0.43	0.49	0.40	0.49
Grain storage capacity (kg/person)	3.90	4.30	2.82	3.88	3.30	4.11
Hill (=1 if yes; else 0)	0.29	0.45	0.59	0.49	0.46	0.50
Mountain (=1 if yes; else 0)	0.01	0.09	0.15	0.35	0.08	0.28
Terai (=1 if yes; else 0)	0.70	0.46	0.26	0.44	0.46	0.50

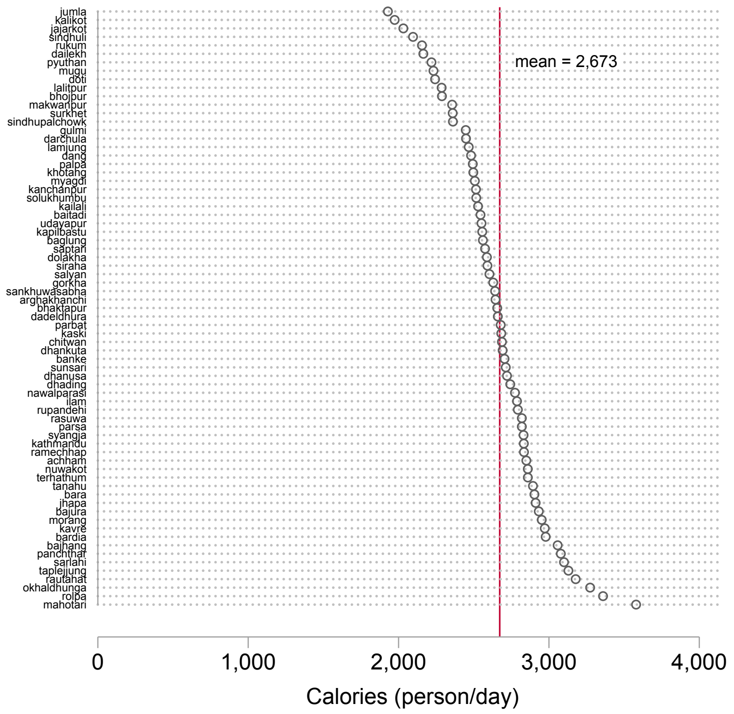


Figure A1 Calories (per person, per day), by district.
Source: NLSS 2011, agricultural households only; overall sample mean shown.

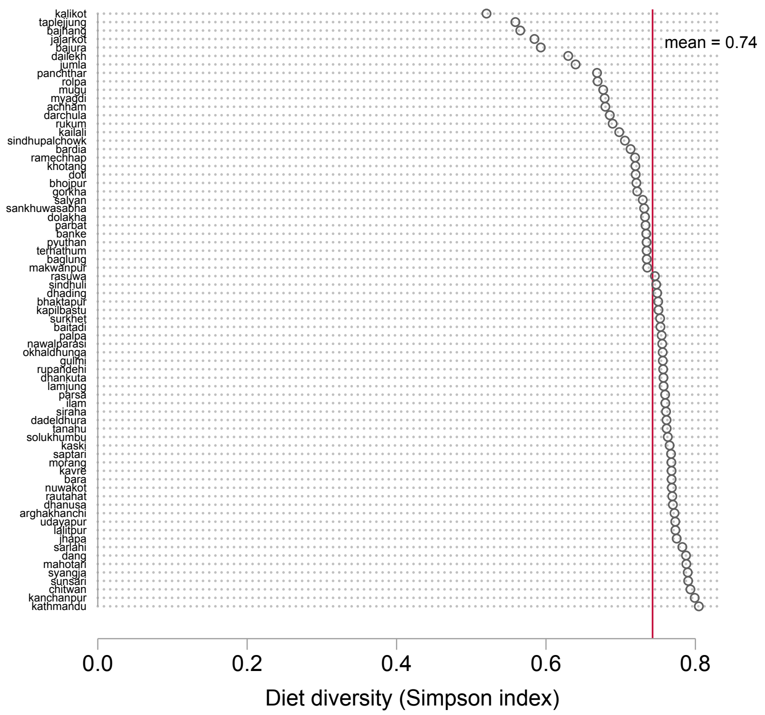


Figure A2 Dietary diversity (Simpson's index), by district.
Source: NLSS 2011, agricultural households only; overall sample mean shown.

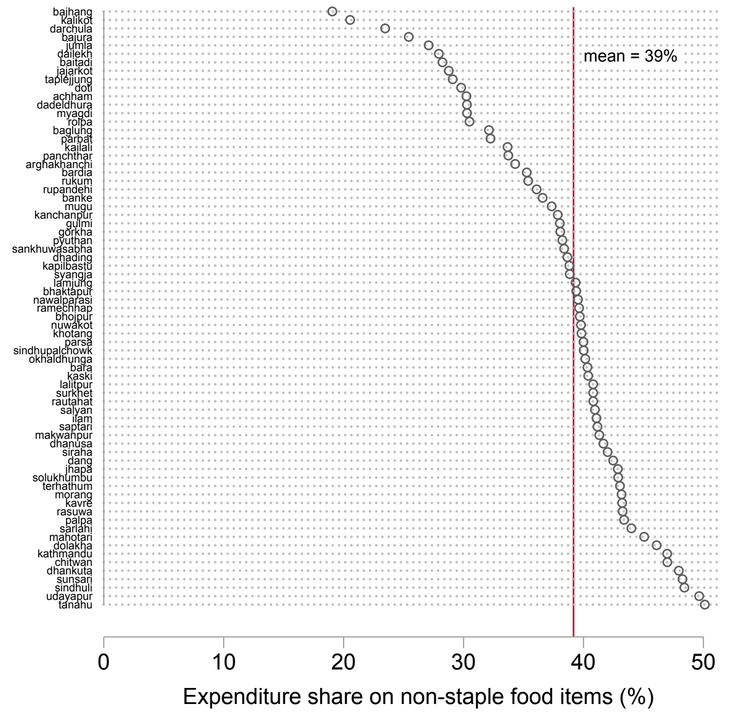


Figure A3 Non-staple food expenditure share (%), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

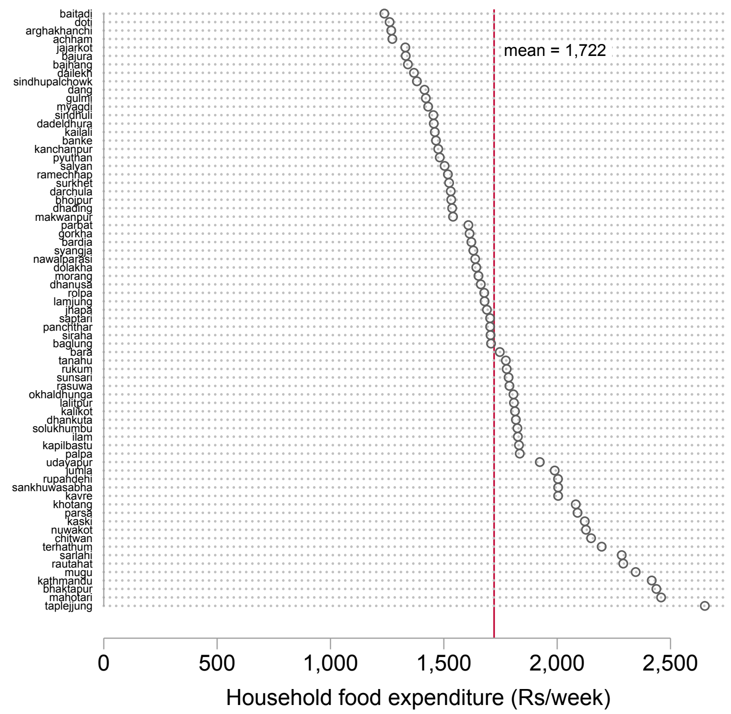


Figure A4 Household food expenditure (Rs/week), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

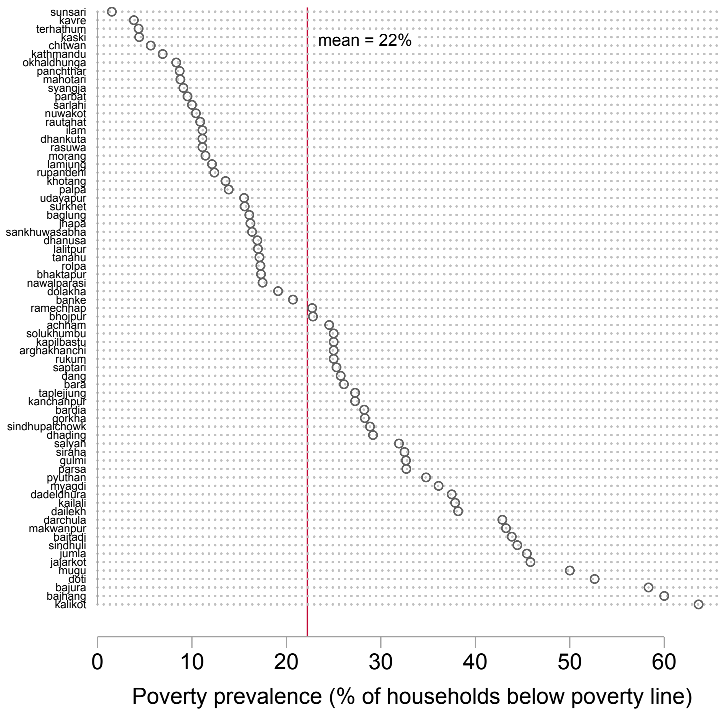


Figure A5 Poverty prevalence, by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

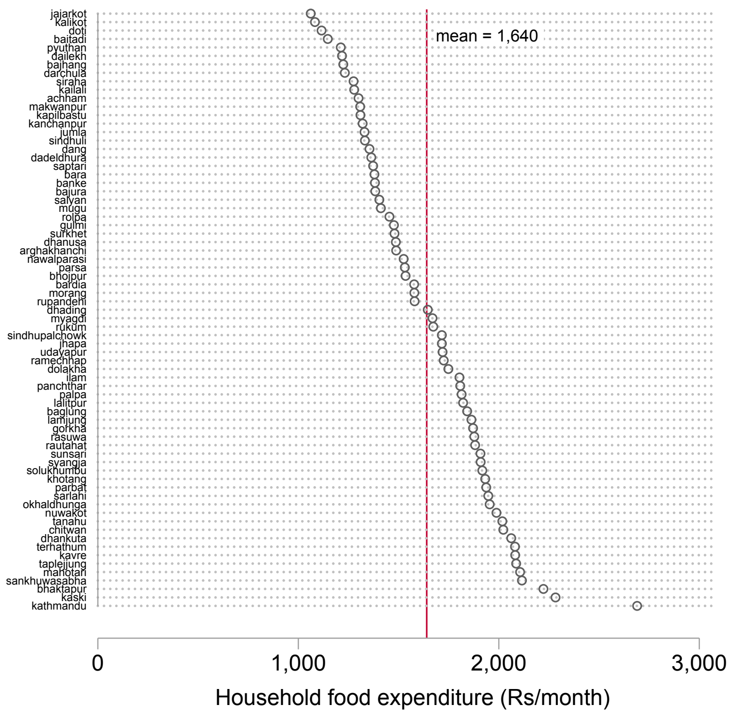


Figure A6 Household food expenditure (Rs/month), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

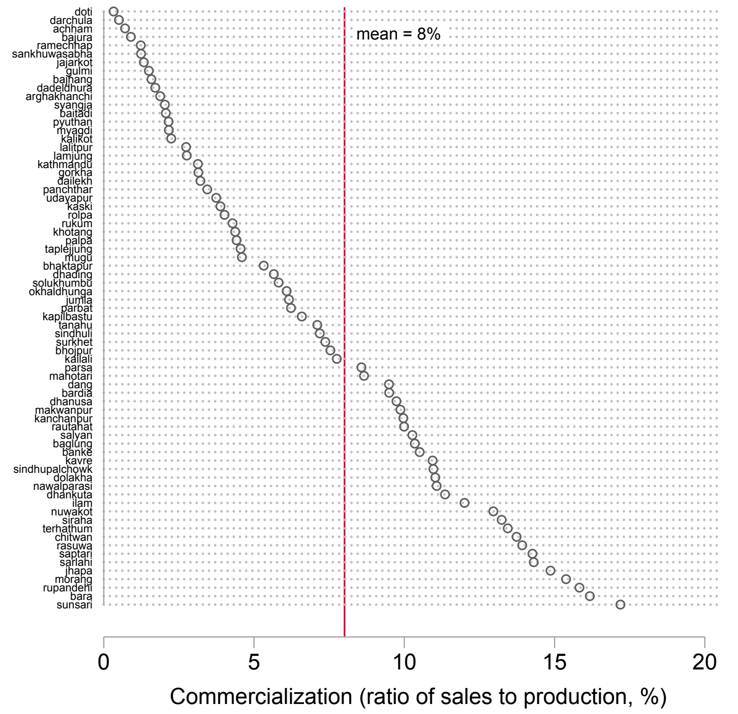


Figure A7 Agricultural commercialization (kg sold/kg produced), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

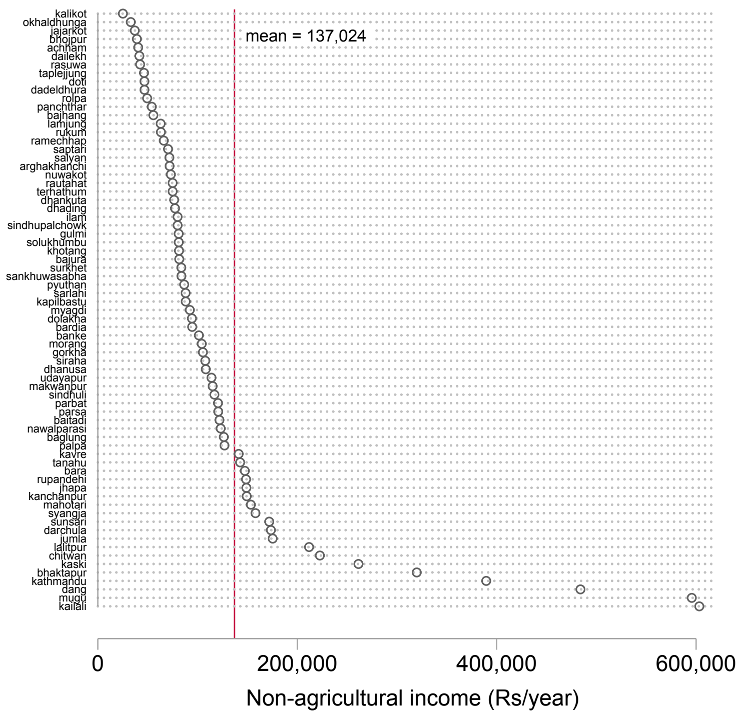


Figure A8 Non-agricultural income (Rs/year), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

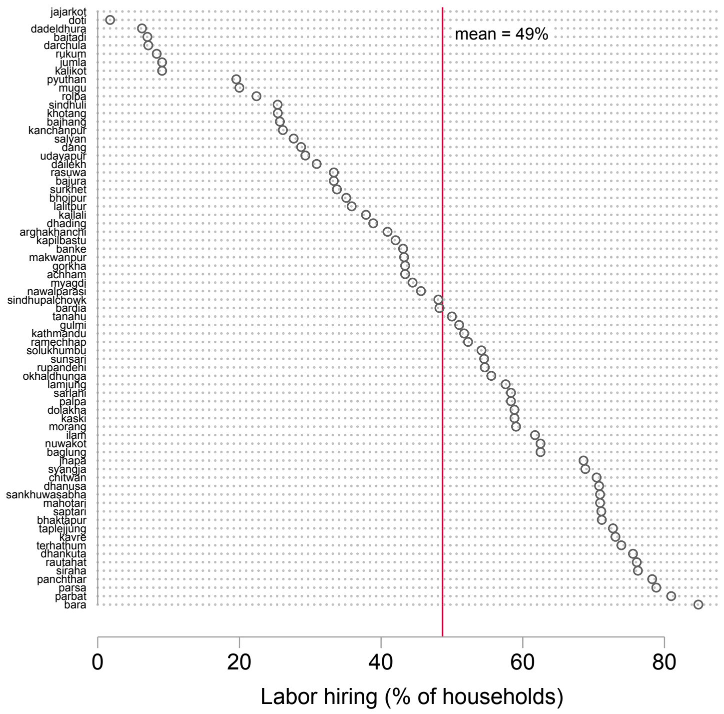


Figure A9 Labor hiring (% of households), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

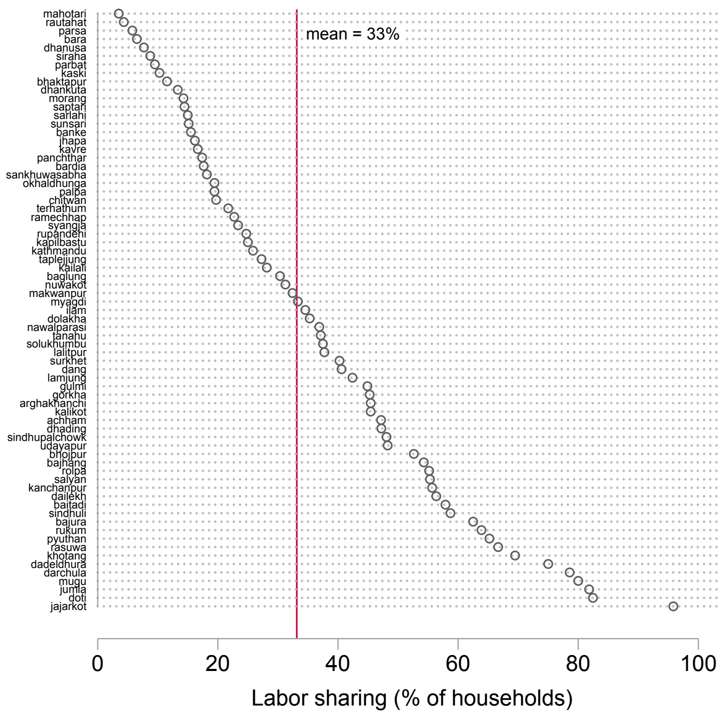


Figure A10 Labor sharing (% of households), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

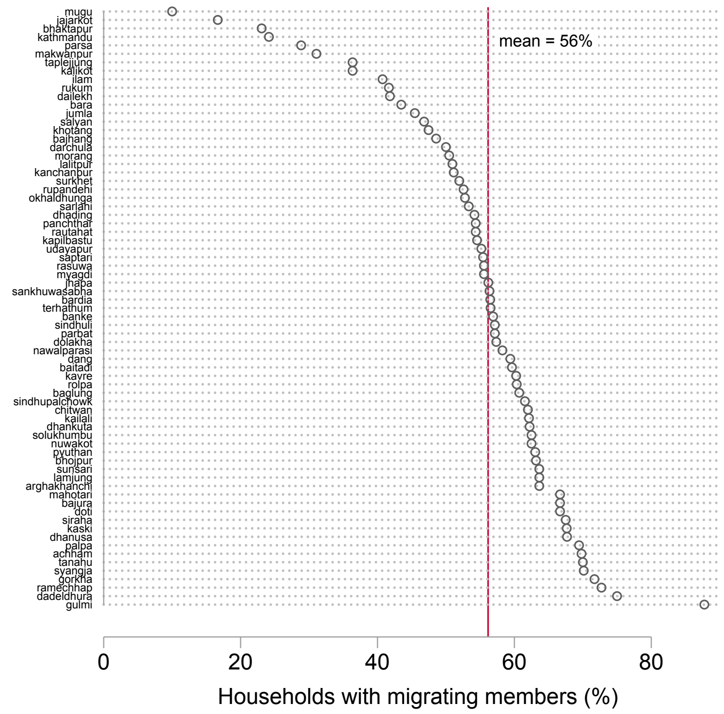


Figure A11 Migration (% of households with members who migrated), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

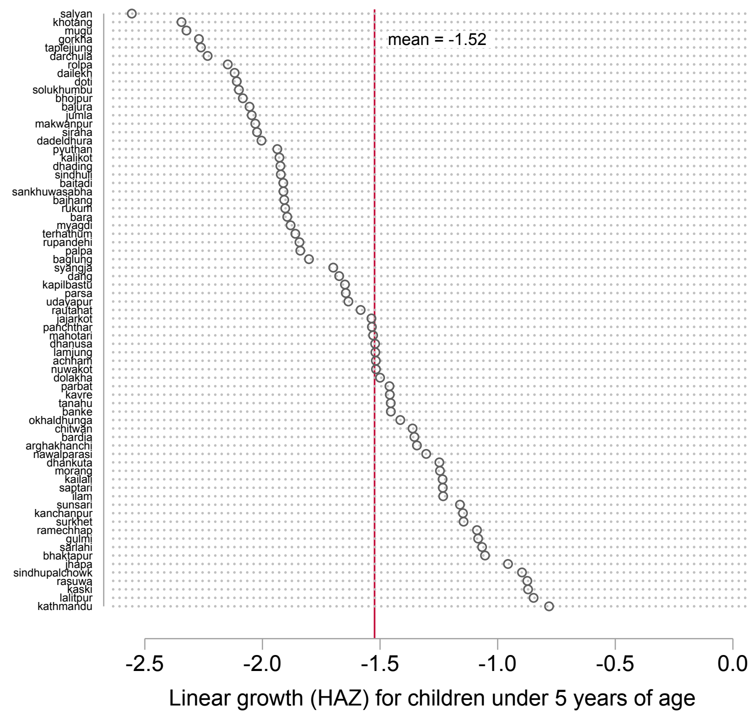


Figure A12 Linear growth (height-for-age z score) for children below 5 years, by district.
Source: NLSS 2011, all households; mean for 71 districts shown in red.

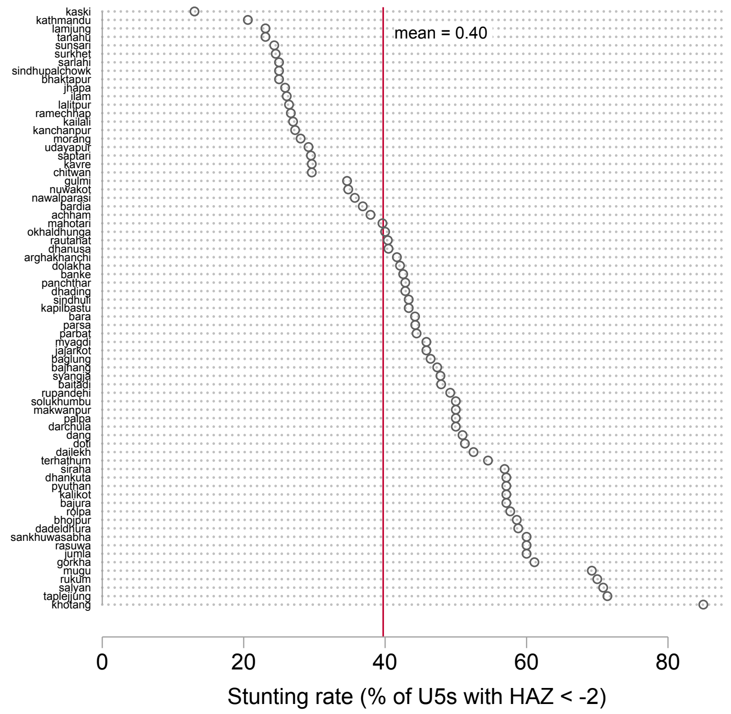


Figure A13 Stunting rate (HAZ < -2.0) for children below 5 years, by district.
Source: NLSS 2011, all households; mean for 71 districts shown in red.

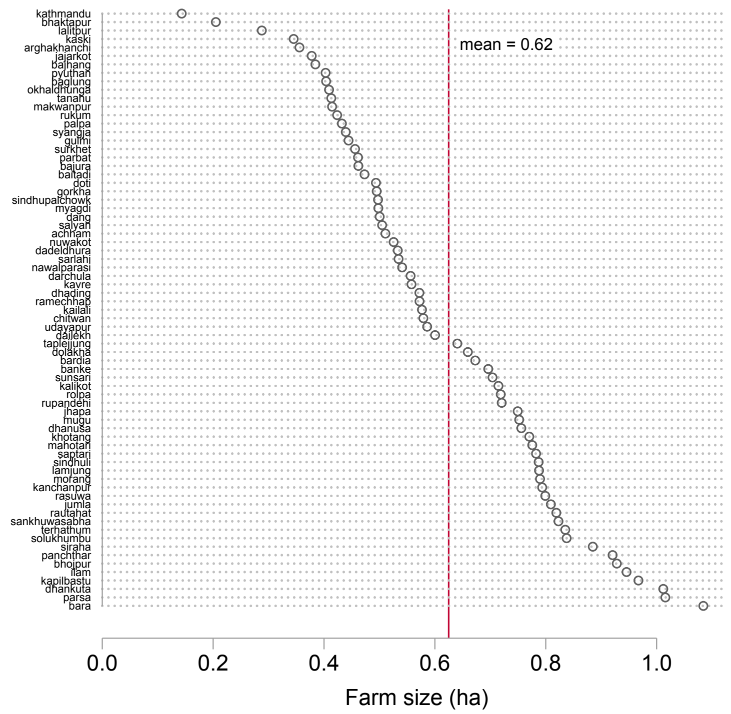


Figure A14 Farm size (in hectares), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

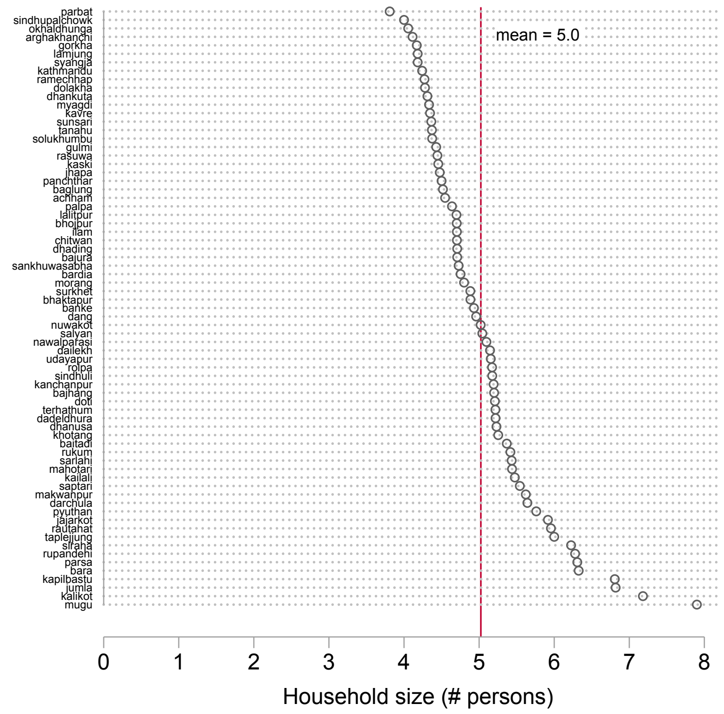


Figure A15 Household size (# persons), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

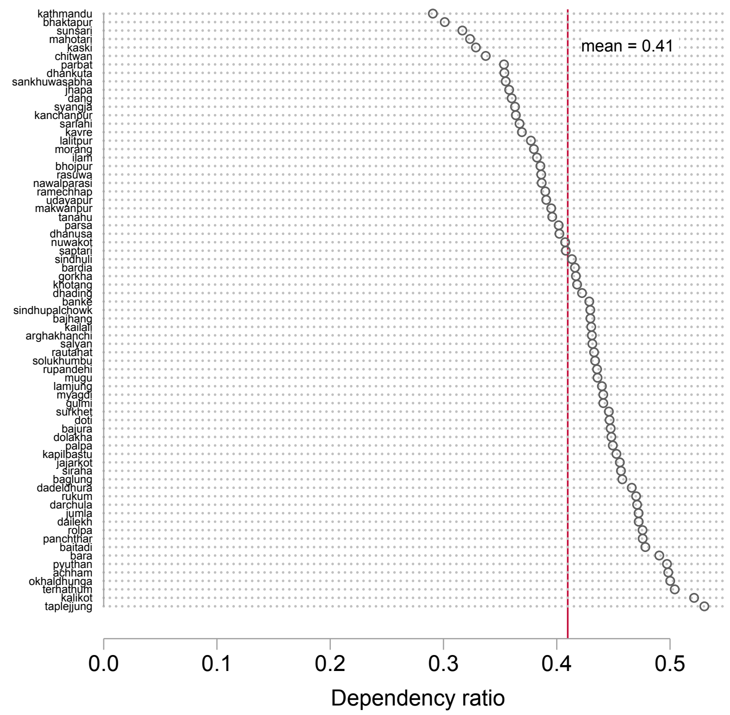


Figure A16 Dependency ratio ((# < 15 + # > 65)/# persons), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

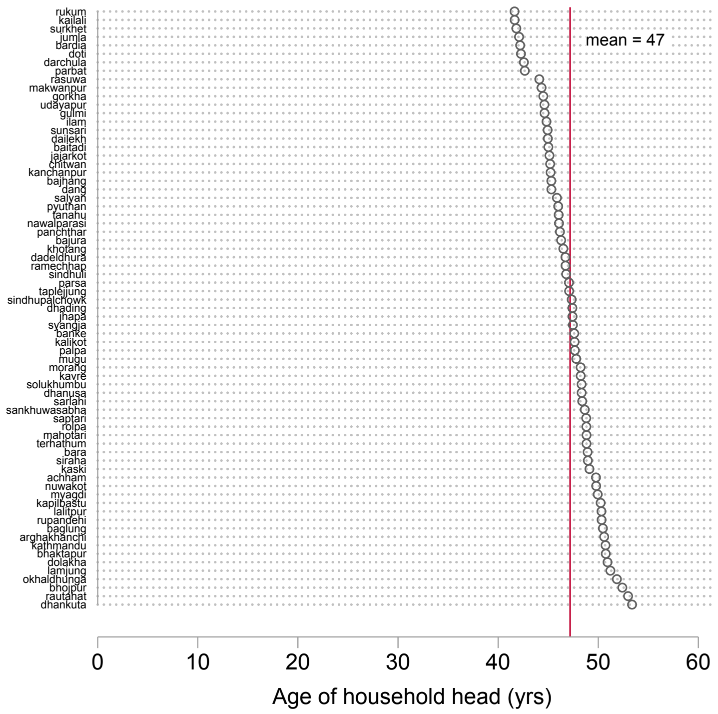


Figure A17 Age of household head (in years), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

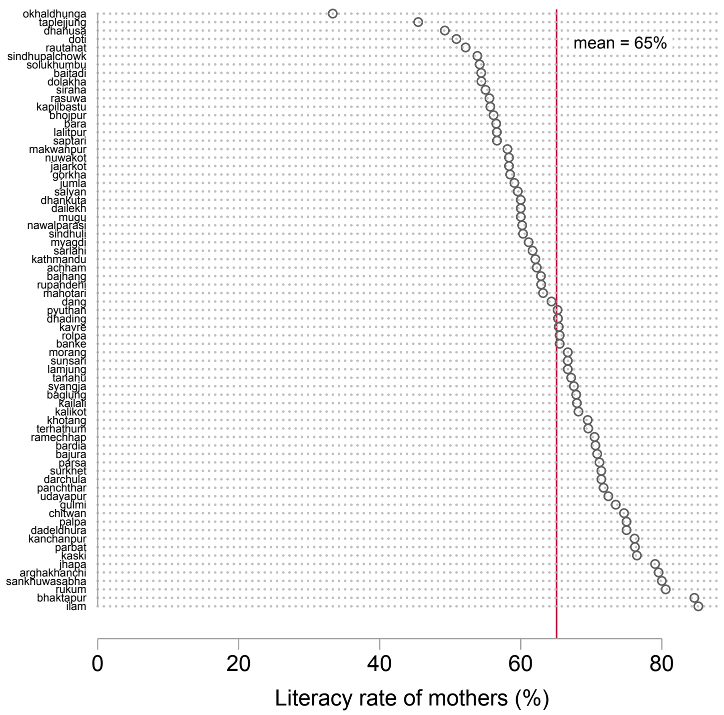


Figure A18 Literacy rate of mothers (% of mothers), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

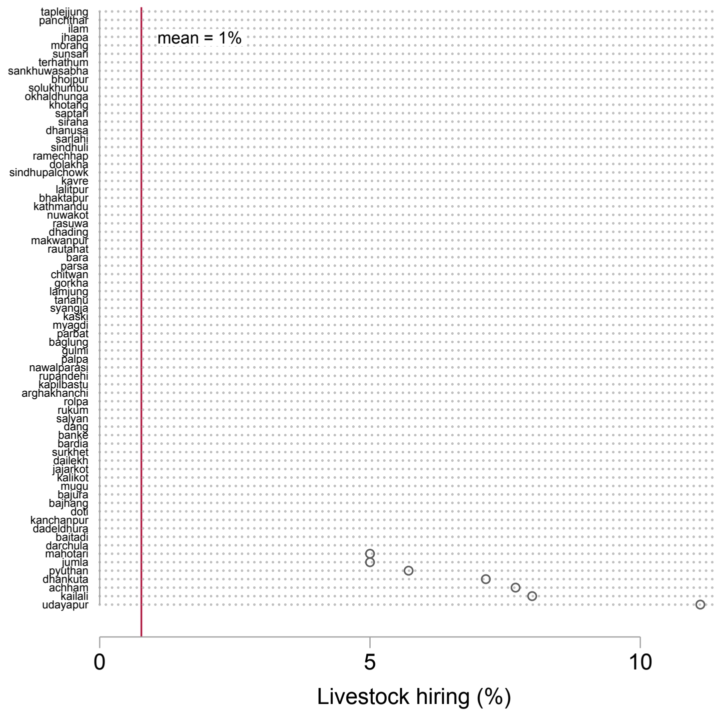


Figure A19 Livestock hiring (% of households), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

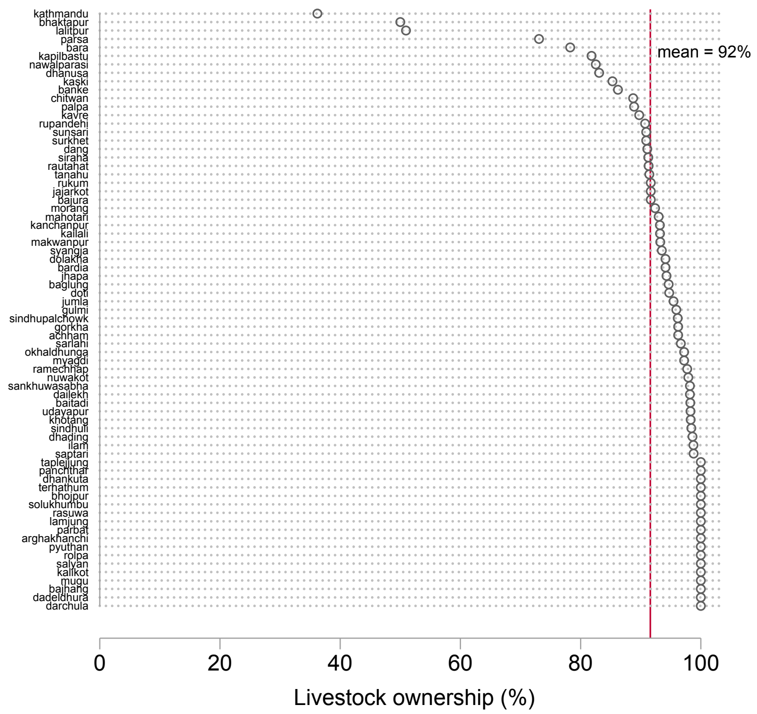


Figure A20 Livestock ownership (% of households), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

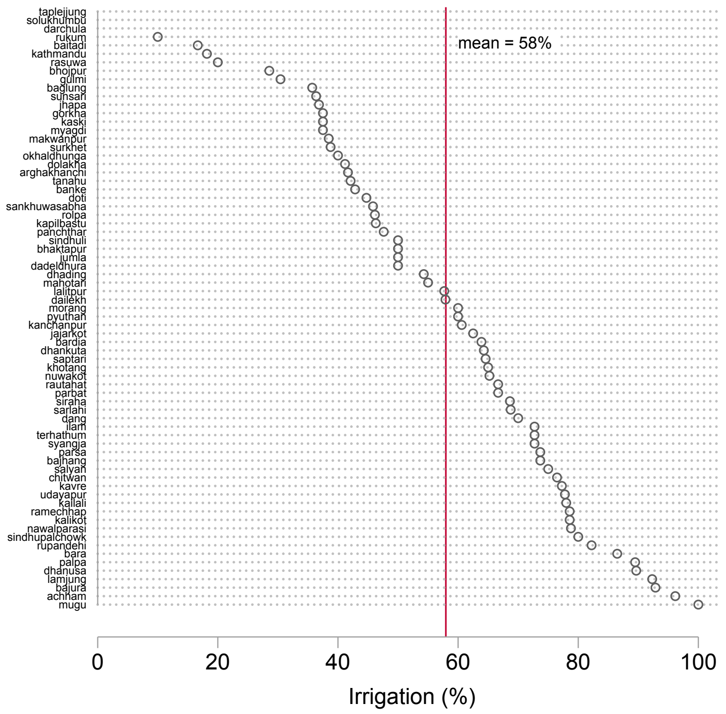


Figure A21 Irrigation (% of farms), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

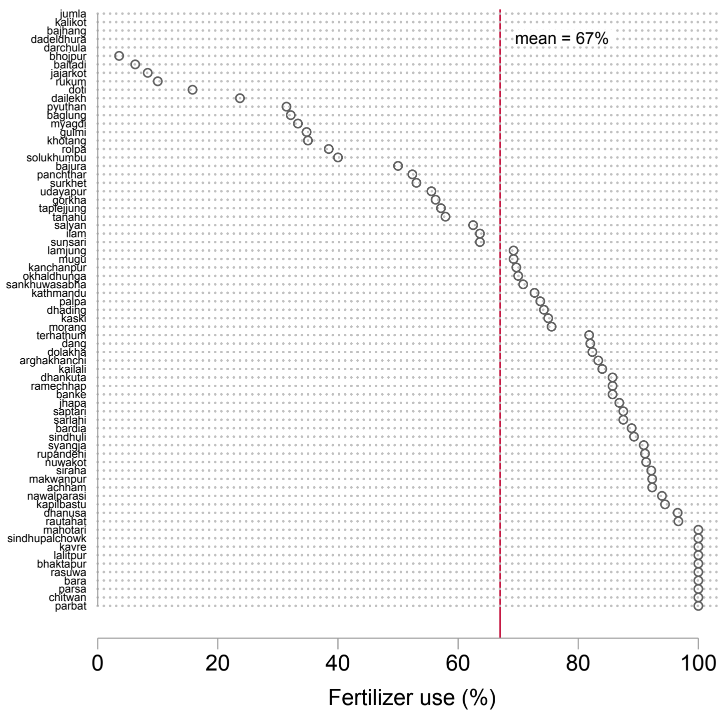


Figure A22 Fertilizer use (% of farms), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

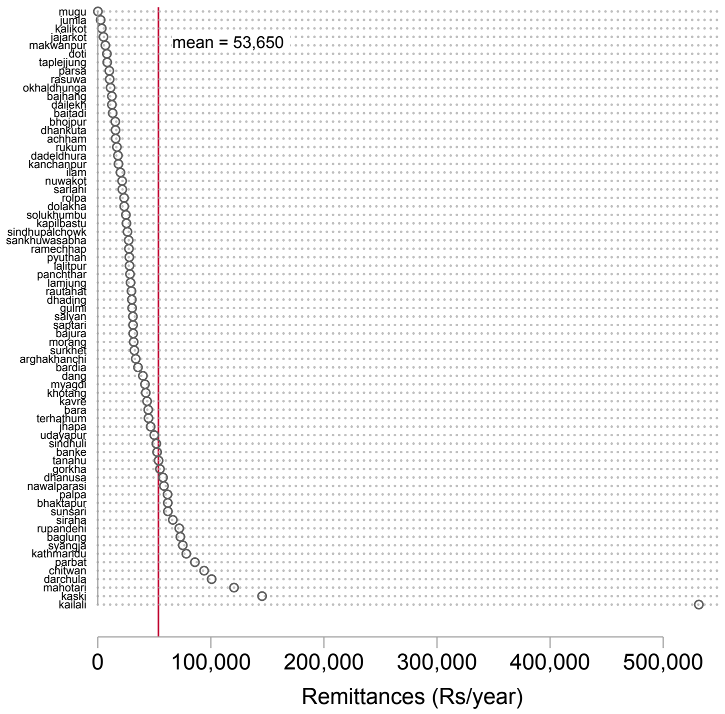


Figure A23 Remittances (Rs/year), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

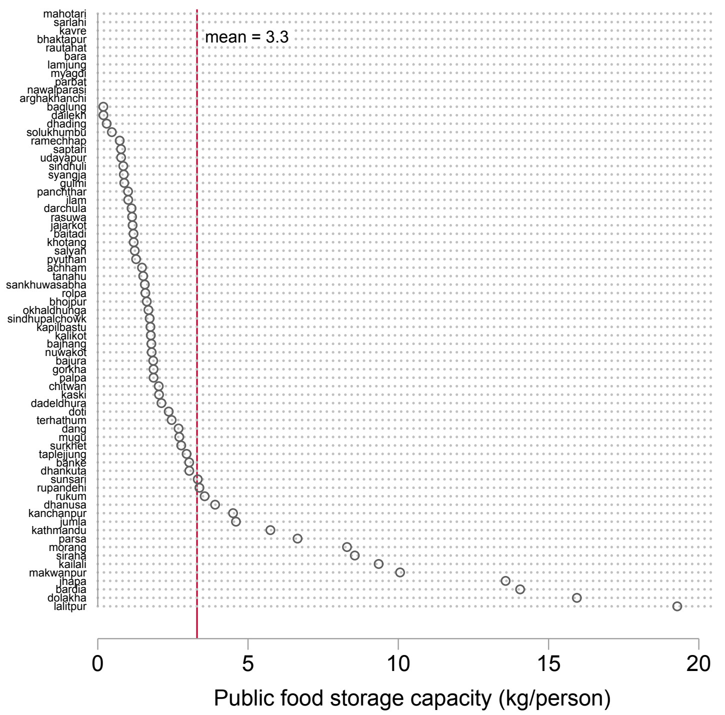


Figure A24 Public food storage capacity (kg/person), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

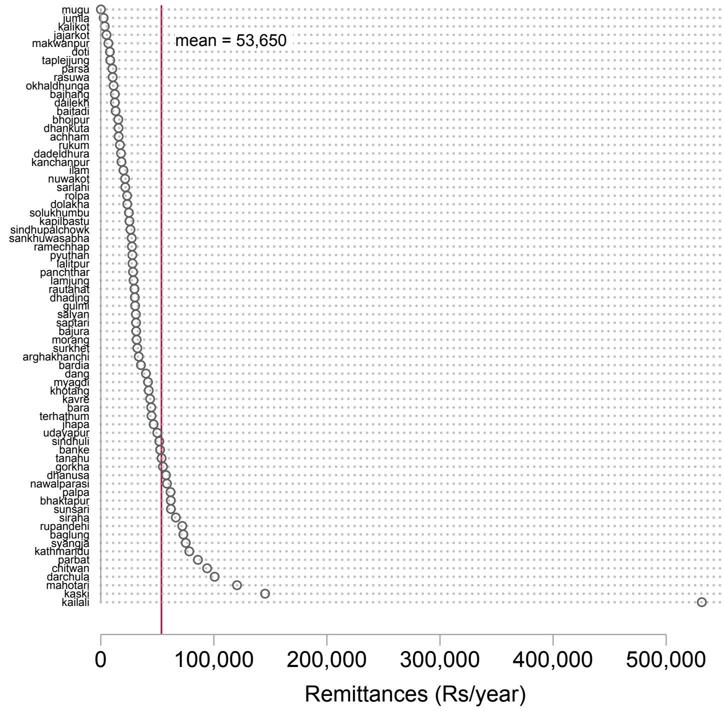


Figure A23 Remittances (Rs/year), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

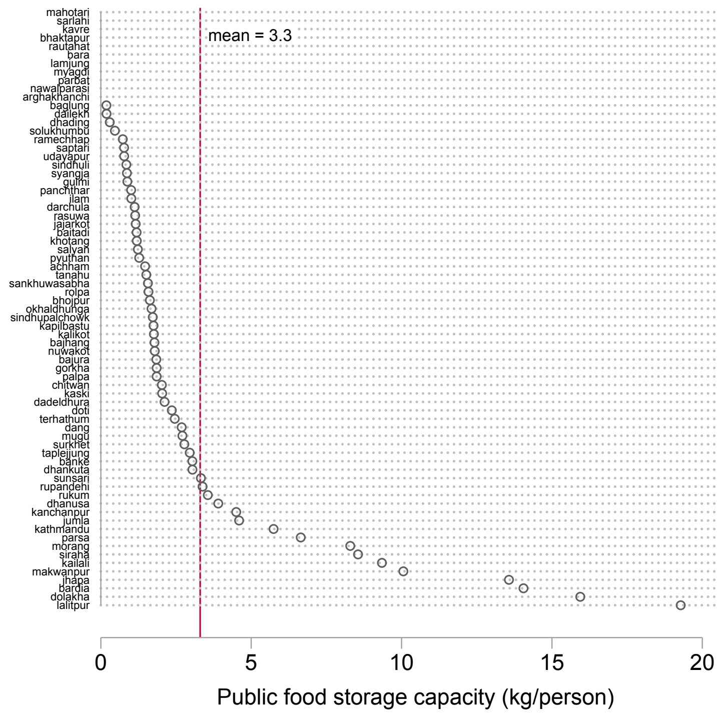


Figure A24 Public food storage capacity (kg/person), by district.
Source: NLSS 2011, agricultural households only; mean for 71 districts shown in red.

Tourists walk on the Philim Ripchet trail towards Tsum valley.

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