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ABSTRACT

The relationship between forests and human nutrition is not yet well understood. A better understanding of this relationship is vital at a time when the majority of new land for agriculture is being cleared from forests. We use Demographic Health Survey data on food consumption for children from 21 African countries and Global Land Cover Facility tree cover data to examine the relationship between tree cover and three key indicators of nutritional quality of children's diets: dietary diversity, fruit and vegetable consumption, and animal source food consumption. Our main findings can be summarized as follows: there is a statistically significant positive relationship between tree cover and dietary diversity; fruit and vegetable consumption increases with tree cover until a peak of 45% tree cover and then declines; and there is no relationship between animal source food consumption and tree cover. Overall our findings suggest that children in Africa who live in areas with more tree cover have more diverse and nutritious diets.

1. Introduction

The contribution of forests and tree-based agricultural systems to human nutrition remains poorly understood (Colfer et al., 2008; Vinceti et al., 2013). As more and more of the world's forests are cleared in large part with the aim of providing more food to a growing human population (Gibbs et al., 2010; Godfray et al., 2010; Lambin and Meyfroidt, 2011; Phalan et al., 2011; Pretty, 1998), the need to better understand the entire range of the contributions that forest make to human diets takes on increasing urgency. Several recent papers suggest that forests might have beneficial impacts on human nutrition (Arnold et al., 2011; Colfer et al., 2008; Vinceti et al., 2013), but there is as yet scant empirical evidence to support these claims. This paper investigates whether there is a statistical association between tree cover and the nutritional quality of children's diets using data from 21 African countries.

It is increasingly recognized that nutrition is a vital dimension of food security (FAO, 1998; Pinstrup-Andersen, 2009). In 2012, the Food and Agricultural Organization estimated that 868 million people in the world did not consume sufficient food energy (calories), but that micronutrient deficiency affected over 2 billion people (FAO et al., 2012). Micronutrient deficiency is often called the "*hidden hunger*" because it can occur even when diets include an adequate amount of energy (calories). Iron, vitamin A, iodine and zinc are the micronutrients most commonly deficient in diets around the world (WHO, 2000; UN, 2004).

We create a new dataset by combining dietary intake data for over 93,000 children from 21 Demographic Health Surveys from across the African continent with GIS data from the Global Land Cover Facility on tree cover (as well as data from other datasets). We use this dataset to empirically examine whether there is a relationship between tree cover and three key indicators of dietary quality which are known to be associated with micronutrient intake: dietary diversity, consumption of fruits and vegetables, and consumption of animal source foods (Arimond et al., 2010; Neumann et al., 2003; Ruel et al., 2005).

How might tree cover affect the nutritional quality of children's diets? There are at least three possible pathways. First, people living near forests could have greater access to nutritious wild foods than people living in other ecosystems; such foods might include wild fruits, leafy greens, grubs, snails, and bush meat. Second, households that plant or harvest agro-forests on their land may benefit from increased access to fruits and nuts from trees. Third, it is possible that the agricultural techniques used in more forested areas, particularly shifting cultivation, might be more conducive to diversified and nutritious diets since such practices often involve complex mosaics of multiple crops. For any of these possible pathways to result in differences in diets and nutrition, however, there would also have to be some accompanying market imperfection that prevents people in all places from having the same market-mediated access to nutritious foods.

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There are two ways that a household can access nutritious food: either by direct production (or collection) or by purchase. If markets operate perfectly, then there should be little difference in consumption related to vegetation cover unless the vegetation cover affects productivity (and thus income) because people would be able to purchase nutritious food no matter their location. If markets are imperfect, however, then there could be differences in consumption associated with tree cover if any of the three pathways described above hold.

If markets function well and we assume that nutritious foods are 'normal' goods (a normal good is a good whose consumption increases as income increases), then we would expect that people with lower income would be less likely to consume more nutritious foods. There is considerable evidence that people living in forested areas tend to have lower incomes than those in other areas (Fisher and Christopher, 2007; Sunderlin et al., 2008). Therefore, we would expect people living in forested areas to have poorer quality diets, *ceteris paribus*, since they tend to have lower incomes. If markets for nutritious foods are imperfect, however, and people living in more forested areas have better access to nutritious foods unmediated by markets, then it is possible that they could have more diverse and nutritious diets through one, or more, of the three pathways described above.

There is reason to believe that markets for many nutritious foods in the rural areas of developing countries are likely to be imperfect (Ruel et al., 2005). As with many agricultural goods produced in rural areas of developing countries, imperfections in labor, land, insurance, and credit markets all have impacts on the agricultural output produced and sold by small farmers (Key et al., 2000; Singh et al., 1986). In addition to these difficulties, however, fresh meat, fruits, and vegetables are highly perishable, resulting in high transaction costs in getting them to market, thus creating a gap between the buying and selling price of these nutritious foods (Ruel et al., 2005). The larger the gap, the less likely the household is to participate in the market. Many households may therefore only produce/collect such goods for their own consumption. If this is the case, then we would expect to see greater consumption of certain types of nutritious foods in areas where they are more available.

2. Data

Demographic Health Surveys are nationally representative household surveys developed by the United States' Agency for International Development for the collection of data on health and fertility in many developing countries. These surveys use model questionnaires and standardized data formats to ensure that data are comparable across countries. We use the data from 21 country surveys that were completed during the period 2003–2011. Fig. 1 shows the location of the communities included in the analysis.

As a component of these surveys, female respondents are asked detailed questions about the diets of their children born in the last five years. The Demographic Health Survey data (and thus this paper) focus on children under five years because they are the most nutritionally vulnerable members of a community. We focus on children between the ages of 12 and 60 months because before 12 months children are still heavily dependent on breast milk or formula and thus have limited diets. While many African children continue to breastfeed after 12 months, complementary foods take on an increasing importance in their diets (UN, 2004). The most recent rounds of Demographic Health Surveys include questions on whether a child ate foods from various food groups in the previous twenty-four hours. From this information we created two types of indicators of dietary quality: dietary diversity and consumption of nutritionally important foods (fruits and vegetables; and animal source foods).

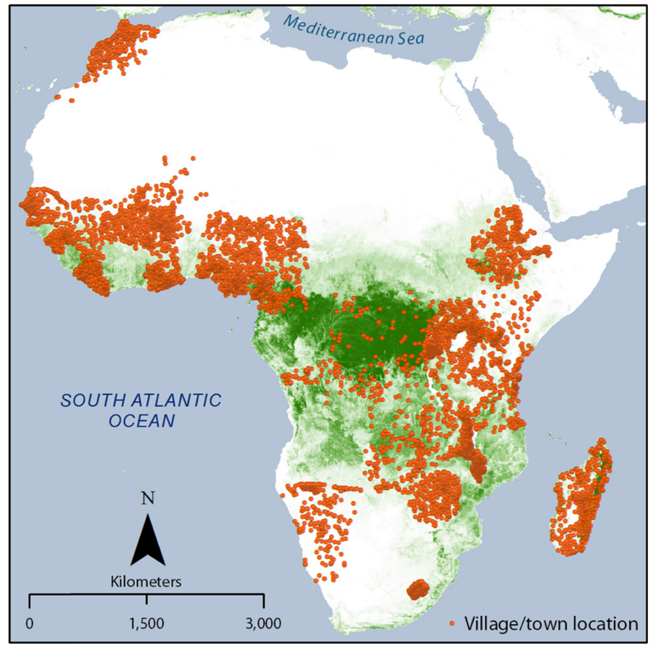

Fig. 1. Locations of communities from the Demographic Health Surveys.

2.1. Dietary diversity

A diverse diet is more likely to contain adequate amounts of all essential nutrients and less likely to contain large amounts of any one potential toxin. Dietary diversity is increasingly accepted as an essential component of healthy diets and is associated with nutrient intake. Adequate nutrient intake has been shown to be closely associated with physical and cognitive growth of children as well as lower morbidity and mortality (Arimond and Ruel, 2004; Arimond et al., 2010; Black et al., 2003; Kant et al., 1993; Kennedy et al., 2007; Ruel, 2003).

We created a dietary diversity score by adding up the number of food groups represented in the child's diet of the previous twenty-four hour period. The Demographic Health Survey data collection follows recent efforts to standardize dietary diversity scores and data collection methodologies (FAO et al., 2012; Kennedy et al., 2011). Despite these efforts, there remain different opinions on the number and types of food groups that should be included in dietary diversity scores in part due to data availability (Ruel, 2003) and to differing local contexts (Kennedy et al., 2011).

The Food and Agricultural Organization (FAO) and the Food and Nutrition Technical Assistance Project (FANTA) guidelines for creating an individual dietary diversity score recommend using the following 14 food groups: cereals; vitamin A rich vegetables and tubers; white roots and tubers; green leafy vegetables; other vegetables; vitamin A rich fruits; other fruits; organ meat; flesh meat; eggs; fish; legumes, nuts and seeds; milk and milk products; oils and fats. We create a dietary diversity score based on these guidelines, but only include ten of the fourteen food groups. About half of the countries from the Demographic Health Surveys that we use do not disaggregate the animal source foods, so we combine 'flesh meat', 'organ meat', 'fish', and 'eggs' into one category: animal source foods. In addition, the Demographic Health Surveys combine 'other fruits' and 'other vegetables' into one group.

2.2. Intake of fruit, vegetables and animal source foods

Since the dietary diversity score gives each food group equal weight and all food groups are not equally important for nutrition (especially for intake of micronutrients which are most commonly deficient in African diets), we also look at fruit and vegetable and animal source food consumption separately. Fruits and vegetables are important sources of vitamin A, vitamin C, folate, iron, and phytochemicals. Adequate consumption of a diverse range of fruits and vegetables is widely accepted as one of the most important aspects of diet associated with health and nutrition (FAO et al., 2012; WHO, 2004). The World Health Organization ranks inadequate consumption of fruits and vegetables as one of the top ten global health problems (Ruel et al., 2005). Although minerals are less bio-available in plant foods than in animal foods, vegetables provide a large proportion of minerals such as iron and calcium consumed by rural populations in developing countries.

Many animal source foods are good sources of highly bio-available iron, zinc, vitamin A and vitamin B_{12}; their low consumption results not only in low intake of protein but also in inadequate intake and low bioavailability of many micronutrients (Neumann et al., 2003). Limited consumption of animal source foods in Africa diets is considered to be an important constraining factor for meeting nutritional requirements.

2.3. Spatial data

The Demographic Health Surveys use a 'cluster' as the geographical sampling unit. This corresponds to a village, a part of a village, or a small group of villages (depending on population size) in rural areas and usually a city block in urban areas (ICF, 2012). Thus we think of the term 'cluster' as roughly representing a community and we use the two terms interchangeably. Since the Demographic Health Surveys include longitude and latitude information for all clusters, it is possible to spatially link this data to other sources of available geographic information. Several other sources of data were thus integrated with the Demographic Health Survey data. Data on percentage tree cover based on MODIS (250 m resolution) were obtained from the Global Land Cover Facility (DiMiceli et al., 2013) for the years 2003 and 2010. The Demographic Health Survey does not report exact coordinates for the clusters included in the survey, but displaces 99% of clusters up to 5 km (and displaces 1% by up to 10%) to protect anonymity of respondents. We, therefore, aggregate the tree cover data pixels to create new pixels with average percentage tree cover for a 5 km area. The aggregated data are then spatially joined with the Demographic Health Survey data to extract the percentage of tree cover in the 5 km pixel in which the cluster is located.

Information on road location was obtained from the *National Imagery and Mapping Agency's Vector Map* (National Imagery and Mapping Agency, 1997). Data on urban populations come from the Gridded Population of the World Center for International Earth Science Information Network (CIESIN et al., 2004). The Consultative Group on International Agricultural Research's global aridity index at a resolution of 1 km was used to control for differences in climate (Trabucco and Zomer, 2009).

3. Methods

We run three different regressions which all take the following basic form:

$$y_i = \alpha + \beta T + \gamma T^2 + \delta X_1 + \theta X_2 + \mu A + \vartheta A^2 + \pi A^3 + \rho B + \tau F + \varphi M + \omega R + \sigma D + \varepsilon \quad (1)$$

where y_i represents the various nutritional indicators that we examine (dietary diversity, fruit and vegetable consumption, animal source food consumption); T represents percentage of tree cover in 2010 (but we also report results using 2003 in Appendix A); X_1 is a vector of household characteristics; X_2 is a vector of community characteristics; A represents the child's age; B is a dummy equal to one if the child is a boy; F is a dummy equal to one of the child is currently being breastfed; M represents the month that the household was interviewed; R is a vector of geographical characteristics; and D represents a vector of country dummies.

We control for both tree cover and tree cover squared to address potential non-linearities in the relationship between tree cover and our indicators of dietary quality. There are several household level variables which we think may potentially have an impact on diets. Parents' education has been shown to affect child health (Block, 2007; Breierova and Duflo, 2004; Christiansen and Alderman, 2004; Glewwe, 1999; Mosley and Chen, 1984). Although data on income are not available in the DHS, there are data on asset ownership. Sahn and Stifel (2003) find that assets are as good as, or a better predictor of child nutritional outcomes in most cases compared with expenditure data. Following the methodology outlined in a seminal paper by Filmer and Pritchett (2001), we use principal component analysis to create an asset index. Several studies have found that such indices are relatively robust and give similar poverty rankings of households as consumption or income measures (Filmer and Pritchett, 1998; Filmer and Scott, 2008; Wagstaff and Watanabe, 2003). The index is based on whether the household owns the following: radio, television, bicycle, motorcycle, car, refrigerator, toilet, and has access to piped water.

There are also several community characteristics which might affect diets. We control for the following: rural *vs.* urban location (since there are likely to be differences in market access and infrastructure between the two types of locations); distance to the nearest city with a minimum of 10,000 inhabitants as a proxy for access to markets and distance to the nearest road since this will likely affect transactions costs for purchasing food, for selling output, and for the household's access to health and nutrition information. This is especially important for our analysis since it is likely that areas with more tree cover are also further from roads.

In addition, we control for the child's age, but also include a squared and cubic term to allow for the possibility of a non-linear relationship. We include a dummy equal to one if the child is a boy to address possible gender differences in diets. Since children who are currently being breastfed may eat less solid food, we include a dummy equal to one if the child is currently being breastfed. We use an ordered variable to represent the month that the interview was conducted in order to address potential seasonal constraints on food availability. In order to control for possible differences in crop production driven by geographical differences, we include an aridity index and elevation. Finally, we include country dummies to control for unobserved national characteristics which might affect nutritional quality of diets. These should capture some broad geographical differences as well as differences in national levels of development. Descriptive statistics for all variables used in the regression are presented in Table 1.

Our model of choice for the dietary diversity regression is a zero inflated negative binomial regression model. Because the dietary diversity score is actually a count of the number of food groups consumed and is bounded between zero and ten, a simple ordinary least squares regression is inappropriate since the dependent variable does not follow a normal distribution. In a negative binomial regression, the dependent variable is assumed to follow a discrete probability distribution, as is the case here. However, there are also a substantial number of children who report having consumed from zero food groups in the last twenty four hours; a zero-inflated negative binomial regression model allows us to model those children who consume zero food groups differently from the rest of the group (the model for predicting consumption of zero food groups includes the following independent variables: mother's education, father's education, sex dummy, breastfeeding

Table 1
Summary statistics – means with standard deviations.

Dietary diversity score	3.08 (2.23)
Fruit and vegetable consumption	0.57 (0.49)
Vitamin A rich fruit and vegetable consumption	0.28 (0.45)
Green leafy vegetable consumption	0.41 (0.49)
'Other' fruits and vegetables	0.24(0.43)
Animal source food consumption	0.46 (0.50)
Tree cover 2010	10.18 (11.99)
Tree cover 2003	10.87 (13.45)
Mother's education (highest level)	0.735 (0.776)
Father's education (highest level)	0.938 (0.883)
Wealth score	−0.389 (1.309)
Rural dummy	0.779 (0.415)
Distance to road in km	5.616 (9.117)
Distance to city in km	33.50 (37.59)
Age (in months)	33.61 (13.75)
Boy	0.502 (0.500)
Currently breastfeeding	0.20 (0.398)
Month of survey	6.955 (3.088)
Aridity index	6549 (3958)
Elevation	740.4 (627.0)

status, month of survey, rural dummy, and wealth index). We also run an ordinary least squares regression as a robustness check.

For the fruit and vegetable regression, the dependent variable is a dummy equal to one for children who reported having consumed any of the following in the last twenty-four hours: green vegetables, vitamin A rich fruits and vegetables, or 'other' fruits and vegetables. Since each of these groups may offer differ nutritional benefits, we also look at each group individually. The animal source food regression uses a dummy equal to one if the child was reported to have consumed meat, eggs, or fish in the last twenty-four hours. Since these models have a dummy as the dependent variable, we run logit regressions for these models.

4. Results

The main set of results reported is from regressions using the 2010 percent tree cover data, but since the Demographic Health Survey data spans the years 2003–2011, we also run the regressions using 2003 percent tree cover data. Results for the latter regressions are reported in Appendix A. We find that there is a statistically significant positive linear relationship between tree cover and the dietary diversity score using both the zero inflated negative binomial model and the ordinary least squares models using both years of tree cover data. Table 2 presents the results of the regressions for the different nutrition indicators with standard errors clustered at the community level.

These results imply that a one standard deviation higher percentage of tree cover is associated with between a 0.11 (using the zero inflated negative binomial model results with all other variables held constant at their means) and 0.16 (using the ordinary least squares estimates) higher dietary diversity score.

The relationship between fruit and vegetable consumption and tree cover is more complex; fruit and vegetable consumption first increases with tree cover up to a peak of 45% tree cover and then declines. Since this category consists of several different components, we also run regressions for each of its components. A table with results for the individual components can be found in Appendix A. To summarize: we find that there is a statistically significant positive relationship between tree cover and consumption of vitamin A rich fruits and vegetables; a similar linear relationship between tree cover and consumption of 'other' fruits and vegetables, and an inverted U shaped relationship between tree cover and consumption of green leafy vegetables peaking at about 43% tree cover. Since only 3% of the children in our sample live in communities with more than 43% tree cover, the relationship is effectively linear for the majority of the sample. And finally, there is no statistically significant association between tree cover and animal source food consumption.

Most of the independent variables have similar qualitative impacts across indicators of the nutritional quality of children's diets. Both mother's and father's education are positively and significantly related to each of the indicators, although mother's education has 2–3 times stronger impact depending on the regression. Children from wealthier households enjoy greater dietary diversity, eat more fruits and vegetables, as well as animal source foods. Children in rural households have significantly lower diversity in their diets and are less likely to consume fruits and vegetables and animal source foods. While distance to road has a significantly negative impact on dietary diversity and fruit and vegetable consumption, it does not have a statistically significant effect on animal source food consumption. Distance to the nearest city does not have a statistically significant association with any of the dietary indicators.

All of the indicators of dietary quality have a statistically significant non-linear relationship with child's age; first increasing with a child's age, then decreasing, and then increasing again (we chose this functional form because it best fit the data). There are no statistically significant differences between boys and girls in dietary diversity or in the consumption of fruits and vegetables or animal source foods. Children who are currently being breastfed have lower dietary diversity according to the zero inflated negative binomial model. This relationship appears positive in the ordinary least squares regression and in the individual logit regressions, but this is because these regressions include children for whom zero food groups were reported. When these regressions are restricted to children who report dietary diversity scores greater than zero (not reported here, available from authors upon request), the sign becomes negative. The aridity index has a positive statistically significant effect on all three dietary quality indicators (a higher number indicates more humidity) indicating that climatic differences independent of tree cover have an impact on nutrition. Higher elevation is associated with higher dietary diversity and higher consumption of fruits and vegetables, but lower consumption of animal source foods.

5. Discussion

There have been a few case studies from around the world that find a positive association between forests and different aspects of nutrition (Dounias et al., 2007; Powell et al., 2011; Johnston et al., 2013). The current study adds to this literature by using data for multiple countries and a very large sample of children to empirically examine the relationship between tree cover and the nutritional quality of children's diets. Our results are supportive of a wider literature that posits why forests are likely to play a positive role in food security (Colfer et al., 2008; Vinceti et al., 2008; Arnold et al., 2011). But while we have found clear evidence linking tree cover and indicators of diet quality, we are not able to determine the drivers of this relationship. Our data do not allow us to distinguish between natural forests, old fallows, and agro-forests; thus we cannot ascertain if people living near forests are collecting more nutritious foods from the forest or if they are cultivating them on farms and in agroforests, or a combination.

The results of our analysis are likely to understate the benefits of forests and trees for nutritious diets since they only capture the higher quality of diets for the children who live in the communities in which the trees are found. They do not capture the indirect benefits that trees provide to food production outside their immediate vicinity; such benefits might include a variety of ecosystem services including soil, nutrient regulation, hydrological services, pollination services, and the conservation of genetic

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Table 2
Results from nutrition regressions with standard errors clustered at community level.

	(1) Dietary diversity score (ZINB)	(2) Dietary diversity score (OLS)	(3) Fruit and vegetable (logit)	(4) Animal source foods (logit)
Tree cover 2010	0.00406***	0.0137***	0.0230***	0.00141
	(4.168)	(3.898)	(6.722)	(0.374)
(Tree cover 2010)^2	−2.06e−05	−0.000100	−0.000255***	3.14e−05
	(−1.150)	(−1.516)	(−4.097)	(0.465)
Mother's education	0.0747***	0.302***	0.161***	0.253***
	(15.01)	(16.43)	(8.901)	(13.19)
Father's education	0.0349***	0.101***	0.0470***	0.0980***
	(7.947)	(6.500)	(3.057)	(5.934)
Wealth score	0.0384***	0.170***	0.0915***	0.175***
	(13.39)	(13.47)	(7.655)	(11.69)
Rural dummy	−0.0807***	−0.296***	−0.155***	−0.298***
	(−7.974)	(−8.100)	(−4.438)	(−8.179)
Distance to road	−0.000911**	−0.00294**	−0.00373**	0.00125
	(−2.158)	(−2.292)	(−2.522)	(0.859)
Distance to city	−8.65e−05	−0.000357	−0.000395	−0.000253
	(−0.730)	(−0.940)	(−1.094)	(−0.606)
Age (in months)	0.0460***	0.169***	0.130***	0.111***
	(12.44)	(13.29)	(9.223)	(7.588)
Age^2	−0.00150***	−0.00594***	−0.00451***	−0.00417***
	(−13.60)	(−15.62)	(−10.80)	(−9.603)
Age^3	1.43e−05***	5.95e−05***	4.50e−05***	4.31e−05***
	(13.90)	(16.67)	(11.56)	(10.63)
Boy	−0.00229	−0.00548	−0.0102	−0.0133
	(−0.582)	(−0.402)	(−0.685)	(−0.860)
Currently breastfeeding	−0.0191***	0.282***	0.356***	0.0997***
	(−2.905)	(12.04)	(13.67)	(3.644)
Month of survey	0.000357	−6.90e−05	0.000724	0.00966*
	(0.293)	(−0.0153)	(0.153)	(1.878)
Aridity index	3.04e−06**	1.51e−05***	1.96e−05***	5.54e−05***
	(1.995)	(2.815)	(3.920)	(10.32)
Elevation	0.000112***	0.000315***	0.000248***	−0.000167***
	(11.61)	(9.821)	(7.395)	(−3.966)
Country dummies	*Yes*	*Yes*	*Yes*	*Yes*
Constant	0.428***	0.512***	−1.873***	−1.77***
	(8.922)	(3.22)	(−10.62)	(−9.60)
R^2 (Pseudo R^2)	0.20	0.16	0.11	0.15
Wald chi^2	7506.57		4788.39	5186.75
Observations	93,527	93,527	88,614	84,128

Robust *z*-statistics in parentheses.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

resources (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005; Sunderland, 2011; ten Kate and Laird, 1990). Also, our results do not capture the benefits to households who purchase nutritious food that originates in forested areas, but is consumed outside the community in which it is produced. These might be quite substantial.

6. Conclusions

Until quite recently, there has been extensive focus on the quantity of food produced and consumed in food security rhetoric and in policy and decision making arenas and much less attention given to the nutritional quality of foods and diets (Pinstrup-Andersen, 2009). Discussions centered on food security have often implied that increased food production will need to come either at the expense of forests or from intensification of land located on ecosystems other than forest (Godfray et al., 2010; Green et al., 2005; Phalan et al., 2011; Tilman et al., 2011). The definition of food security adopted at the 1996 World Food Summit, however, recognizes that food security involves more than calorie consumption: ‘‘food security exists when all people, at all times, have physical and economic access to sufficient safe and *nutritious food* [emphasis added] to meet their dietary needs and food preferences for a healthy and active life'' (FAO, 1998).

When the importance of micronutrient consumption and dietary diversity is recognized, the need to move beyond merely increasing production area or yield of staple crops to achieve food security becomes clear. If improving nutrition is viewed as central to achieving food security, then the results presented here suggest that landscapes that incorporate substantial tree cover may themselves be important for food security. While much of the concern voiced by scientists decrying the expansion of agriculture into forests centers around loss of biodiversity (Foley et al., 2011; Gibbs et al., 2010; Green et al., 2005; Phalan et al., 2011), our study suggests that deforestation might also have a long-term negative impact on nutrition. Recent evidence that between 1980 and 2000, 95% of new land cleared for agriculture in Africa came from land that had previously been covered by forests (Gibbs et al., 2010) suggests that further research into better understanding the reasons for the association that we find between tree cover and nutrition is imperative.

Acknowledgments

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Appendix A

See Tables A1 and A2.

Table A1
Results from nutrition regressions using 2003 tree cover data with standard errors clustered at the community level.

	(1) Dietary diversity score (ZINB)	(2) Dietary diversity score (OLS)	(3) Fruit and vegetable (logit)	(4) Animal source foods (logit)
Tree cover 2003	0.00222**	0.00868**	0.0162***	0.00368
	(2.335)	(2.542)	(5.006)	(1.059)
(Tree cover 2003)^2	2.46e−06	−3.01e−05	−0.000132**	−7.92e−06
	(0.152)	(−0.509)	(−2.497)	(−0.144)
Mother's education	0.0747***	0.302***	0.161***	0.251***
	(15.07)	(16.42)	(8.853)	(13.09)
Father's education	0.0351***	0.102***	0.0471***	0.0975***
	(7.997)	(6.531)	(3.067)	(5.895)
Wealth score	0.0380***	0.170***	0.0904***	0.176***
	(13.23)	(13.42)	(7.588)	(11.70)
Rural dummy	−0.0771***	−0.287***	−0.148***	−0.301***
	(−7.625)	(−7.878)	(−4.247)	(−8.254)
Distance to road	−0.000898**	−0.00287**	−0.00372**	0.00123
	(−2.108)	(−2.216)	(−2.432)	(0.832)
Distance to city	−7.40e−05	−0.000334	−0.000390	−0.000225
	(−0.624)	(−0.876)	(−1.079)	(−0.541)
Age (in months)	0.0462***	0.170***	0.131***	0.111***
	(12.45)	(13.34)	(9.278)	(7.593)
Age^2	−0.00150***	−0.00596***	−0.00453***	−0.00417***
	(−13.62)	(−15.67)	(−10.85)	(−9.610)
Age^3	1.44e−05***	5.96e−05***	4.52e−05***	4.31e−05***
	(13.92)	(16.72)	(11.61)	(10.64)
Boy	−0.00232	−0.00558	−0.0103	−0.0135
	(−0.588)	(−0.408)	(−0.690)	(−0.871)
Currently breastfeeding	−0.0189***	0.283***	0.358***	0.0993***
	(−2.863)	(12.07)	(13.73)	(3.629)
Month of survey	0.000358	−0.000169	0.000394	0.00964*
	(0.294)	(−0.0375)	(0.0825)	(1.875)
Aridity index	4.55e−06***	1.91e−05***	2.37e−05***	5.48e−05***
	(2.999)	(3.571)	(4.716)	(10.22)
Elevation	0.000112***	0.000316***	0.000254***	−0.000167***
	(11.63)	(9.880)	(7.531)	(−3.952)
Country dummies				
Constant	0.427***	0.516***	−1.86***	−1.77***
	(8.885)	(3.227)	(−10.56)	(−9.62)
R^2 (Pseudo R^2)	0.20	0.16	0.11	0.15
Wald chi^2	7671		4787	5195
Observations	93,527	93,527	88,614	84,128

Robust z-statistics in parentheses.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

Table A2
Results from logit regressions for components of fruit and vegetables with standard errors clustered at community level.

	(1) Vitamin A rich fruit and vegetables	(2) Green leafy vegetables	(3) 'Other' fruits and vegetables
Tree cover 2010	0.0101**	0.0198***	0.0213***
	(2.521)	(5.783)	(5.472)
(Tree cover 2010)^2	−6.60e−05	−0.000229***	−0.000113
	(−0.906)	(−3.741)	(−1.596)
Mother's education	0.169***	0.0747***	0.243***
	(8.112)	(4.105)	(11.64)
Father's education	0.0541***	0.0359**	0.0993***
	(3.024)	(2.244)	(5.516)
Wealth score	0.102***	0.0378***	0.112***
	(8.995)	(3.841)	(9.434)
Rural dummy	−0.141***	−0.00216	−0.275***
	(−3.346)	(−0.0619)	(−7.121)
Distance to road	−0.00323*	−0.000903	−0.00688***
	(−1.869)	(−0.615)	(−3.886)
Distance to city	0.000467	−6.85e−05	−0.00131***
	(1.010)	(−0.182)	(−2.670)
Age (in months)	0.0785***	0.121***	0.0988***
	(4.932)	(8.507)	(5.864)
Age^2	−0.00287***	−0.00391***	−0.00354***
	(−6.078)	(−9.263)	(−7.131)

Table A2 (*Continued*)

	(1) Vitamin A rich fruit and vegetables	(2) Green leafy vegetables	(3) 'Other' fruits and vegetables
Age^3	2.94e−05***	3.76e−05***	3.58e−05***
	(6.681)	(9.569)	(7.770)
Boy	−0.00873	0.00286	0.0122
	(−0.521)	(0.189)	(0.702)
Currently breastfeeding	0.134***	0.391***	0.101***
	(4.588)	(14.70)	(3.304)
Month of survey	−0.0239***	0.00137	0.00818
	(−4.286)	(0.287)	(1.616)
Aridity index	1.73e−05***	2.06e−06	2.38e−05***
	(3.027)	(0.391)	(4.240)
Elevation	0.000196***	0.000281***	0.000252***
	(5.099)	(8.150)	(6.733)
Country dummies	*Yes*	*Yes*	*Yes*
Constant	−2.11***	−2.87***	−3.69***
	(−10.70)	(−15.88)	(−17.29)
Pseudo R^2	0.14	0.08	0.14
Wald chi^2	4096.79	3428.19	4249.74
Observations	85390	83519	83710

Robust *z*-statistics in parentheses.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

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