Electrification and Deforestation

Maimouna BARRO[1], Johanna CHOUMERT[2], Pascale COMBES MOTEL[3]

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Abstract

In this article, we explore the electrification-deforestation nexus in Tanzania, a low-income country. In 1990 only 5% of the population had access to electricity, compared to 16% today with significant differences between rural and urban areas. Most households rely on traditional fuels, especially charcoal and firewood, which adds pressure on forest resources. Significant efforts must thus be devoted to mass electrification to reach the sustainable development goals objectives and ensure access to affordable and reliable electricity to all Tanzanians. Electrification will have a wide range of positive externalities on various dimensions of welfare, notably in terms of human capital outcomes. These externalities have been widely studied and identified in the literature. However, the impacts of electrification on deforestation are less known despite the existing linkages between fuel use and forest degradation. In order to investigate the electrification-deforestation nexus, we use pixel data sets both for electrification and deforestation between 2001 and 2013. These detailed data allow us to test whether electrification slows down deforestation as households are less dependent on biomass. Our results will bring insights into cost-benefit analysis of electrification programmes and into the underlying causes of deforestation.

Keywords

Forest; grid electricity; energy; Sub-Saharan African; pixel data; nighttime light data

JEL codes

Q23, Q40, Q56, N57

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[1] School of Economics & CERDI - UMR CNRS 6587, Université Clermont Auvergne, 65, bd François Mitterrand, 63 009 Clermont-Ferrand Cedex 1, France

[2] *CORRESPONDING AUTHOR.* Economic Development Initiatives (EDI) Limited, 38 Crendon Street, High Wycombe, Buckinghamshire HP13 6LA, United Kingdom
j.choumert.nkolo@surveybe.com

[3] School of Economics & CERDI - UMR CNRS 6587, Université Clermont Auvergne, 65, bd François Mitterrand, 63 009 Clermont-Ferrand Cedex 1, France

1. Introduction

The household energy landscape in Tanzania is characterised by a very high prevalence of traditional fuel use, especially charcoal and firewood. Linkages between fuel use, forest degradation and pollution have been highlighted in the literature (Baland et al., 2010; Heltberg et al., 2000; Hofstad, 1997). But according to The United Republic of Tanzania (2017), only 16.9% of rural and 65.3% of urban inhabitants of mainland Tanzania are connected to some form of electricity.

The 2015 Tanzania National Energy Policy sets the framework to implement the new energy policy, accounting for the United Nations' global initiative of providing sustainable energy for all, the need for energy conservation and efficiency and the recent gas discoveries in the south-east coast of the country. To achieve Sustainable Development Goal no 7, that is ensuring universal access to affordable electricity by 2030, Tanzania must implement ambitious policies to ensure its energy transition, which is key to drive and shape the economic transformation of the country.

While mass electrification is a national priority and is slowly progressing (See Figure 1), research should also investigate externalities associated with mass access to electricity. Indeed, moving-up the energy ladder (Hosier and Dowd,1987; Leach, 1992; van der Kroon et al., 2013) has a wide range of impacts on individuals' and households' well-being, such as improved health outcomes (reduced indoor air pollution, improved nutrition), better opportunities to build human capital (lighting for studying), improved business opportunities, more voice and accountability (via access to information), and less pressure on environmental systems.

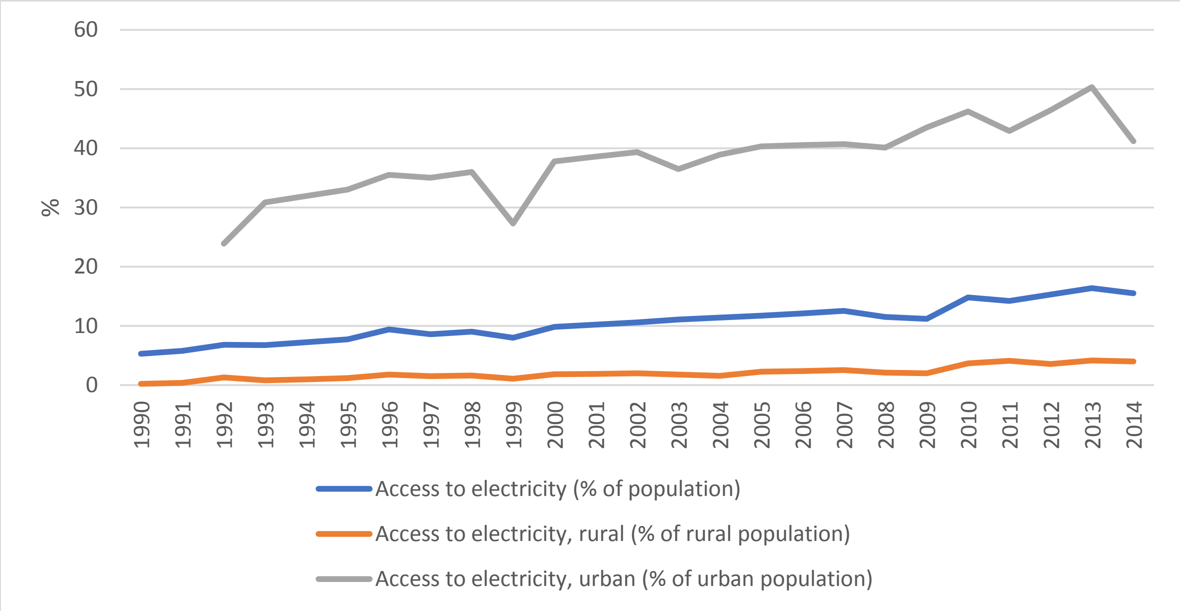
Several studies have stressed that reliance on biomass leads to deforestation. Forests play a crucial role in climate and ecological processes. They are also central to human livelihoods. Therefore, understanding the causes of forest depletion and processes slowing it down is key both in the context of global climate change mitigation and local livelihood protection (See Angelsen and Kaimowitz, 1999; Leblois et al., 2017; Rudel, 2013). The fuel-deforestation nexus has drawn attention from scholars for several years. Yet, existing studies either rely on case studies, or on macroeconomic data, for both access to electricity and forest cover whose accuracy can be contested.

In this paper, we look at the impact of electrification on deforestation in Tanzania using pixel data from 2001 to 2013. Our hypothesis is the following: if households are less reliant on biomass, forest degradation will decline. Therefore, electrification policies in low-income countries, should not only account for effects on the national economy and on households' welfare, but also for environmental impacts, be they positive or negative.

The contribution of this paper is thus twofold. Firstly, we use satellite imagery for both electrification and forest cover allowing us to have precise information at the pixel level. Secondly, we focus on Tanzania, which is a typical country where electrification has speeded up and will even more so in the next years and decades. This paper will bring additional insights into the causes of deforestation.

The rest of the paper is organised as follows. Section 2 presents the debates in the literature on the electrification-deforestation nexus. Section 3 is devoted to the construction of the database. Section 4 develops on the empirical strategy and the econometric results. Section 5 discusses the results.

Figure 1. Access to electricity in Tanzania



Source: Authors using data from World Bank, Sustainable Energy for All (SE4ALL) database from the SE4ALL Global Tracking Framework led jointly by the World Bank, International Energy Agency, and the Energy Sector Management Assistance Program.

2. The electrification-deforestation nexus

The fuel-deforestation nexus has drawn attention from scholars for several years with several levels of analysis. Firstly, macroeconomic studies typically use a large panel of countries and aggregate data for energy access and deforestation. Looking at a panel of 158 countries, for 1990, 2000 and 2010, Tanner and Johnston (2017) investigate the impact of rural electricity access (measured as the percentage of rural population with access to electricity, World Bank data) on the deforestation rate (measured as the forest area in percentage of land area, FAO data). Access to electricity is due to reduce dependence on biomass and they indeed find that rural electrification slows down deforestation. Sulaiman et al. (2017), in their study of 45 sub-Saharan African countries between 2005 and 2013, using wood fuel consumption measured in cubic meters (African Development Indicators) and forest degradation measured by change in forest cover per 1000 ha (African Development Indicators), find evidence that an increase in wood fuel consumption results in more cutting down of trees, which leads to deforestation. Assunção et al. (2013), in their analysis of 2184 Brazilian countries, between 1960 and 2000, find that electrification improves agricultural productivity strategies, which leads a decrease in deforestation, with the underlying idea that access to electricity allows investments in irrigation which reduces pressure on forests. Electricity access is defined as the proportion of electrified grid points within a county and deforestation is measured as the fraction of county area in farmland, pastures, native vegetation and cropland (Source: Brazilian Census of Agriculture). Using the percentage change in fuelwood and charcoal production and the average annual deforestation rate (natural forest percentage, FAO), in least developed countries, Mainardi

(1998) find that domestic consumption of fuelwood and charcoal induces a depletion of forest resources, which contributes to a high rate of deforestation.

Secondly, time series studies focus on a single country. Khalid et al. (2015), using time series data from 1980 to 2013 in Pakistan, find that wood use to meet energy demand leads deforestation, stressing that use of wood as a fuel and for house construction contribute to environmental degradation. More precisely, a 1% increase in energy consumption leads to a 2.80% increase in deforestation in the short run, and 0.039 in the long run. In Ghana, Yiridoe and Nanang (2001), using time series data 1961-1999, annual change in consumption of firewood and charcoal in cubic meters, and average annual change in forest area and woodland in ha (deforestation FAO), test whether use of fuelwood and charcoal energy for cooking, heating and also in small-scale industries increases dependence on biomass. Their results suggest that when total population pressure increases, this leads to an increase in the amount of fuelwood consumed, and increases deforestation, with “a change in fuelwood consumption by one cubic meter leads to a 2.6 ha loss of forest or woodland area”.

Thirdly, microeconomic articles rely on household survey data. In their field study with 62 households, Gang et al. (2008) look at the relation between domestic energy consumption per capita (obtained from the questionnaire) and forest area (satellite data) as use of firewood and crop residues cause environmental degradation. They find that when households use traditional biomass energies as the main source of energy, they consume more firewood, which leads to deforestation. Using data from 180 Indian households for 1996-1997, Heltberg et al. (2000) look into how fuelwood collection for cooking, heating and selling leads to forest degradation. Their findings suggest that when households spend more time gathering fuelwood from the forests for use in their own households, this contributes to substantial forest degradation and loss of biodiversity. Reyes et al. (2018), in their study in Chile with 275 households in 2012-2013, find that when the proportion of off-farm income of households changes, the decision to produce commercial firewood becomes important, which leads to forest degradation. In their study in Zimbabwe, Dube et al. (2014) find that when they face electric power cuts, the urban poor use firewood as the major energy alternative, which requires a high rate of increase in supply of fuelwood and leads to forest degradation. In Sudan, Hassan et al. (2009), using data for 1984-2000 on per capita fuelwood consumption (Ministry of Energy and Mining) and the rate of deforestation (The forestry National Corporation), find that overexploitation of forest resources and wood consumption due to population growth contribute to the rapid depletion of natural woodland and forest resources, which causes of deforestation. Using data from 902 Ugandan households, in 2003 and 2011, Jagger and Kittner (2017) look into reliance on biomass fuel and deforestation. Using the percentage share of household energy from different biomass fuels in kg and land use cover change in hectares, they find that fuelwood consumption, agriculture expansion and timber harvesting are the principal factors which contribute to an increase in the deforestation rate.

Fourthly, other papers investigate other dimensions of the fuel-deforestation next. Andrade de Sá et al. (2013), in their study of Brazil between 1970 and 2006, using the number of hectares allocated to sugarcane production (IBGE—Agricultural Census) and total land cleared in hectares (IBGE—Agricultural Census), find that biofuel production more especially bioethanol production results in an expansion of the amount of land allocated to sugarcane, which provokes indirect land use changes leading to deforestation. In their study of 112 countries between 2001 and 2012, Keles et al. (2017) find that biofuels production, especially bioethanol leads to direct land-use change, which has an impact on forest cover loss. To this end they use ethanol and biodiesel production data from the United States Energy Information Administration and the percentage of forest loss taken from the Hansen et al. (2013) dataset. Using satellite images, Gao et al. (2011) investigate the spatial relations between biofuel production and deforestation at the global level between 2001 and 2006 and find that biofuel feedstock production requires a large supply of land, which leads forest destruction with land use change.

Conversely, other papers investigate the impact of deforestation of power generation. In Malawi, Kaunda and Mtalo (2013) stress that environmental degradation leads to a difficult production of electricity and that hydropower generation is impacted negatively by environmental degradation, when an area is highly environmentally degraded this affects hydropower energy production. Jagger and Shively (2014)'s results suggest that deforestation influences the types and source of biomass fuels used by households and also leads to a reduction of the supply of high quality biomass. It has a negative impact on total fuel consumed. To this end, they use Uganda panel data, fuel use per households by type and source in kg (NASA's Land Processes Distributed Active Archive Center) and land use change from forest in 1000 ha (NASA's Land Processes Distributed Active Archive Center) to investigate the influence of Land use change on the availability of high quality fuelwood.

The literature review reveals that the fuel-deforestation nexus has drawn attention from scholars for several years. But looking at the electrification-deforestation nexus at a pixel level within a country may offer an interesting case to better understand the nexus.

3. Data and methods

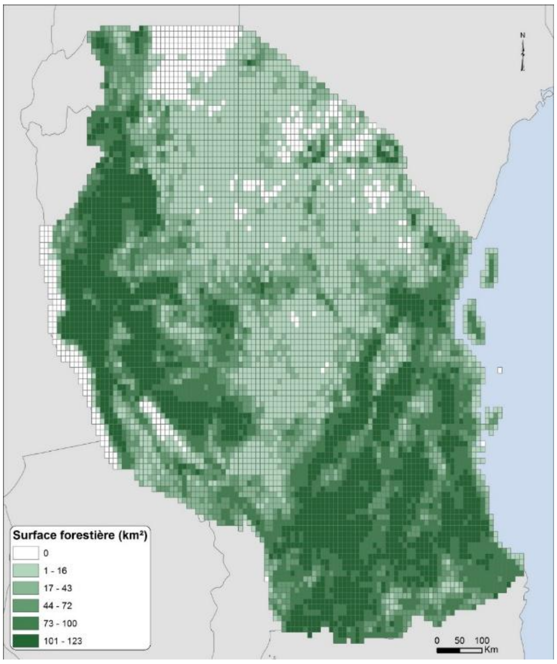
For our study, we cover the period 2001-2013. In the following sections we present the deforestation data, the electrification data and other control variables

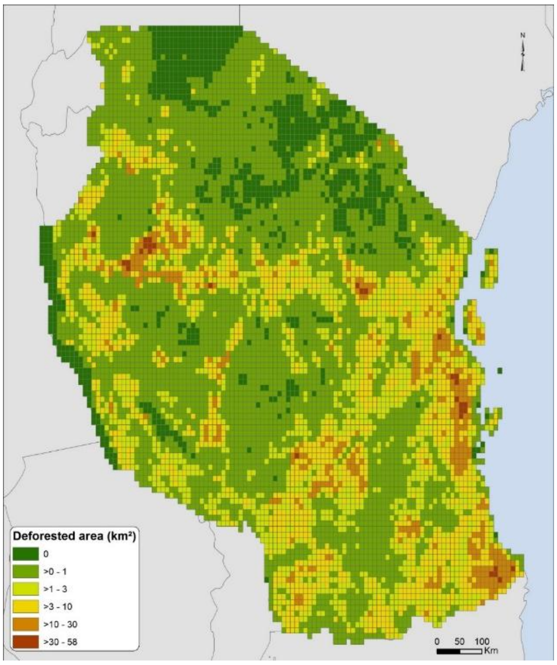
3.1. Forest cover data

Aggregate data as from the FAO Forest Resource Assessments or national data from existing censuses are no longer appropriate to analyse deforestation patterns. Satellite imagery now provides high resolution data on forest cover and thus enables micro level empirical analyses of deforestation. We thus use the Hansen et al. (2013) dataset.

Figure 2. Forest cover 2000

Figure 3. Deforested areas 2001-2013

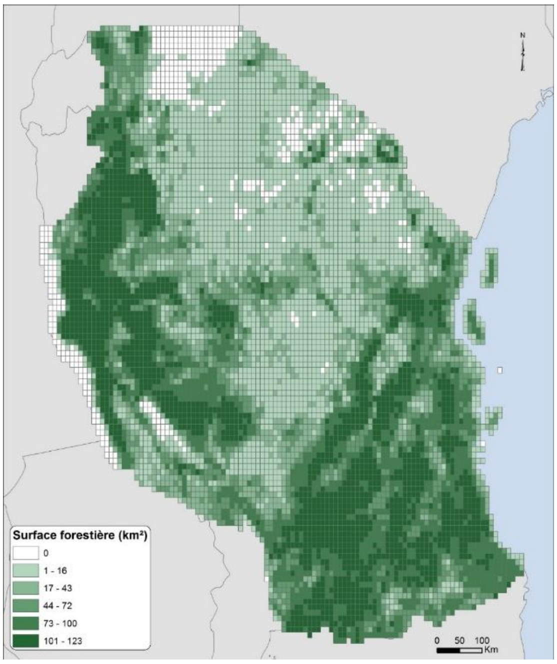


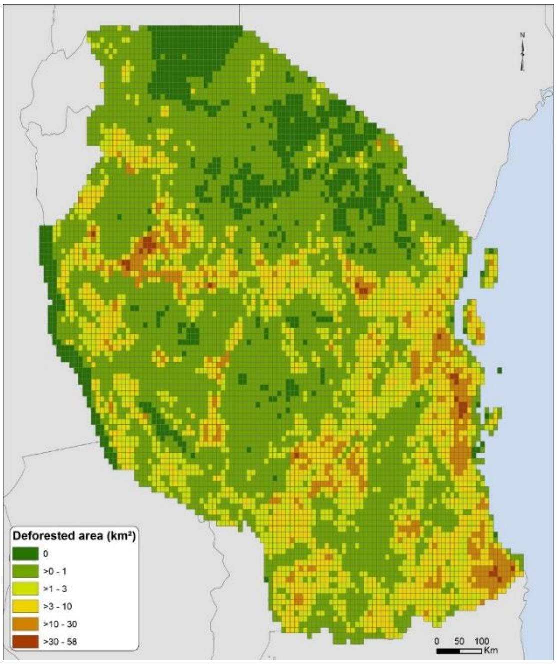


portrays the forest cover over in Tanzania in 2000. We made squares with sides of 10.1km. Forests are defined according to a minimum threshold of percentage of tree cover (10%, 15%, 20%, 25%, 30%, 50%, 75%). Here, we consider 20%. Figure 3 depicts the deforested pixels between 2001 and 2013.

Figure 2. Forest cover 2000

Figure 3. Deforested areas 2001-2013





3.2. Electrification data

In the absence of a map on the national grid, we use the DMSP-OLS Nighttime Lights data published by the U.S. National Oceanic and Atmospheric Administration (NOAA, 2008-2013). There are several convincing arguments in favour of using this data set as a proxy for electrification (Amaral et al., 2005; Chand et al., 2009). Indeed, the light captured by the satellites is mainly the result of electricity-powered illumination. For instance, in a study conducted in Australia, Townsend and Bruce (2010) find a 0.93 correlation between electricity consumption and nighttime lights between 1997 and 2002. Doll and Pachauri (2010) use nighttime lights data in developing countries from 1992 to 2000 in order to investigate the capability of nighttime lights data to estimate populations without electricity access. They note that the data tends to overestimate the population without access to electricity, as the satellite sensors may not capture low density energy usage or indoor lighting. Moreover, such data would fail to reflect situations in which households do have access to the electricity grid in an infrastructural sense, but do not use electricity.

Figure 4 presents the mean nighttime light intensity in each pixel (10.1km2) over the period 2001-2013. Figure 5 portrays the evolution of luminosity over time.

Figure 4. Luminosity 2001-2013

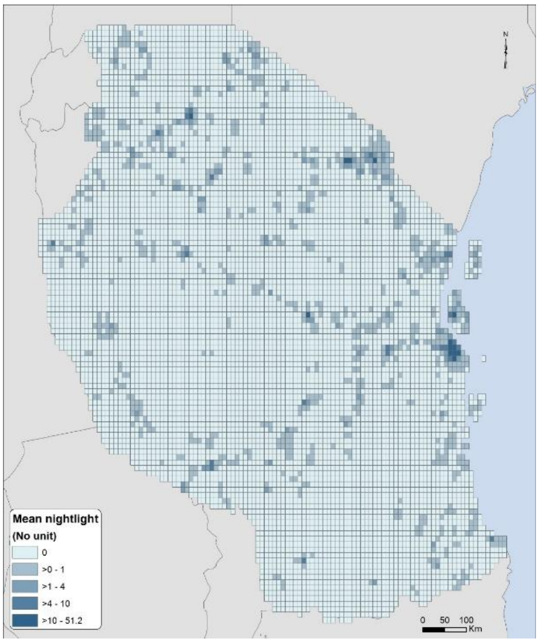
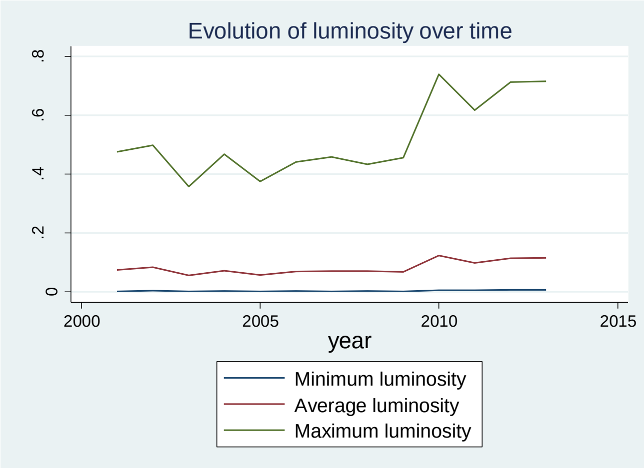


Figure 5. Evolution of luminosity over time



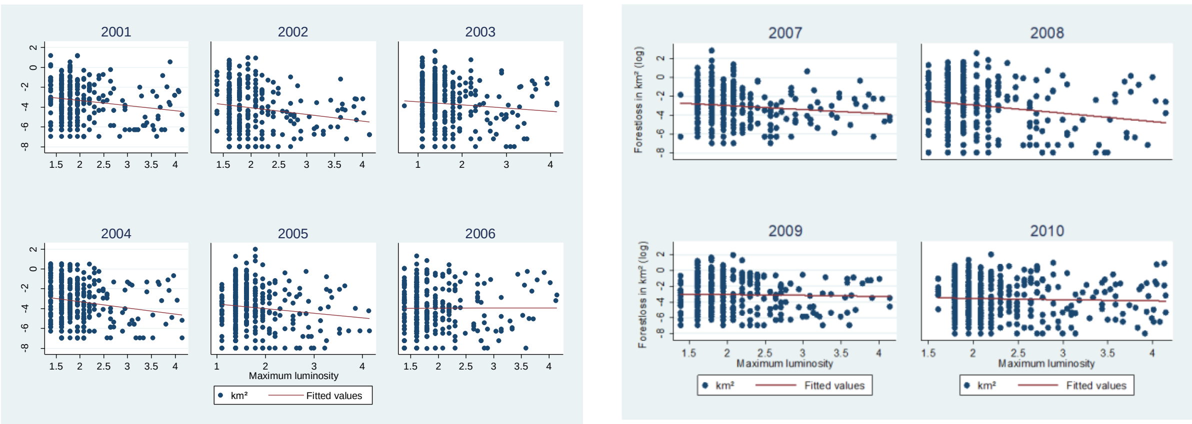
3.3. Control variables

Recent studies have shown that the location of the forest can influence the profit obtained from cleared land. And since the profitability of agricultural land depends on fertility, slope and proximity to the nearest road, river and markets (towns), we introduce additional control variables. These include for each pixel, the slope, altitude, climate conditions, and other physical characteristics.

4. Results (*in progress*)

Preliminary analysis indicates a negative correlation between electrification and forest loss. Put differently, deforestation slows down as electrification increases (See Figure 6).

Figure 6. Relationship between deforestation and maximum luminosity



5. Discussion

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