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***Article***

# Understanding the Relationship Between Livelihood Constraints of Poor Forest-adjacent Residents, and Illegal Forest Use, at Volcanoes National Park, Rwanda

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## Abstract

The relationship between livelihoods and forest use is one of the main challenges facing wildlife and habitat conservation in developing countries. Poor residents in forest-adjacent areas are typically perceived to be the main forest users, with use often deemed illegal. However, there is still a limited understanding of livelihood constraints of the poor, and how such constraints influence illegal forest use, particularly for poor residents in forest-adjacent communities. In this paper, we address this gap. First, the measures for livelihood constraints, including food access constraints and education constraints, and illegal forest use are proposed. Second, the developed measures are used in a structural equation model, to explore the relationship between livelihood constraints and illegal forest use, for poor residents in communities adjacent to Volcanoes National Park, in Rwanda. Food access constraints, a dimension of food security constraints, were found to be the strongest predicator of illegal forest use. However, food insecure residents around the park may not be the main driver of current levels of illegal forest use, supporting previous research questioning the narrative of poverty driven illegal forest use in developing countries.

**Keywords**: livelihood constraints, illegal forest use, local residents, food security, education constraints

## INTRODUCTION

Some of the residents in forest-adjacent communities in developing countries use forests illegally to obtain resources for income and subsistence livelihoods (Fisher 2004; Mackenzie and Hartter 2013; Babigumira et al. 2014). Illegal forest use occurs in multiple forms, including—hunting for bush-meat, forestland encroachment for agriculture, and harvests of timber and non-timber forest products (Overdevest and Green 1995; Sunderlin et al. 2005). In some developing countries, including Rwanda, illegal forest use has been largely attributed to insufficient livelihoods of forest-adjacent communities (Kamanga et al. 2009; Lund et al. 2009; Masozera and Alavalapati 2004; Munanura et al. 2016; Vedeld et al. 2012). Considering the negative impact of illegal forest use on biodiversity in developing countries (Bleher et al. 2006; Kamanga et al. 2009; MacKenzie and Hartter 2013; Masozera and Alavalapati 2004; Yonariza and Webb 2007), and the futility of law enforcement (Mukul et al. 2014), research has called for conservation incentives aimed to improve the livelihoods of forest-adjacent communities (Appiah et al. 2009; Ancrenaz et al. 2007; Blomley et al. 2010; Persha et al. 2011; Stone and Stone 2011).

The majority of conservation incentives programmes in developing countries are aimed at providing forest-adjacent communities with opportunities for alternative livelihoods. Empirical evidence, however, has demonstrated minimal conservation impact of conservation incentives programmes, due to constraints such as, mismanagement and poor linkages between the conservation incentives and illegal forest use indicators (Munanura et al. 2016; Naughton-Treves et al. 2005).

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The failures of conservation incentives programmes could also be attributed to emphasis on addressing only material constraints of forest-adjacent residents. Conservation incentives in developing countries, are typically designed to address material hardships, for example, lack of livestock, lack of income, limited access to financial, natural and infrastructure capital, and other indicators perceived to be responsible for poverty and biodiversity loss (Blomley et al. 2010; Munanura et al. 2016; Naughton-Treves et al. 2005). However, addressing material hardships could be partially addressing the causes of illegal forest use in forest-adjacent communities. It is important to understand broad aspects of livelihood constraints, which could influence illegal forest use, in addition to material hardships. For example, nonmaterial aspects of livelihood constraints, such as—healthcare constraints (Huynen et al. 2004), education constraints (Sachs et al. 2009), and exclusion from active participation in community decisions (Forstner 2004; Pasape et al. 2015; Stone and Stone 2011) have also been identified as constraints to sustainable forest resources management. It has also been suggested that nonmaterial aspects of livelihood constraints have the potential to reduce the capability of a household to acquire and maintain a living (Alkire 2005, 2007; Alkire and Seth 2008).

The need to comprehensively understand the human livelihoods constraints, have led to a 'Sustainable Livelihoods' framework (Chambers and Conway 1992; Scoones 2009). Consequently, the Sustainable Livelihoods framework has been applied to explore the relationship between human wellbeing, and natural resources (Ashley 2000; Ashley and Carney 1999; Munanura et al. 2016; Simpson 2009). In this paper, we use a Sustainable Livelihoods framework to investigate the relationship between various dimensions of livelihood constraints and illegal forest use, for poor residents adjacent to Volcanoes National Park in Rwanda. We focus on poor residents because they are considered to be responsible for illegal forest use at Volcanoes National Park (Bush 2009; Bush et al. 2010; Plumptre et al. 2004; Sabuhoro et al. 2017; Spenceley et al. 2010). A sample of poor residents in communities adjacent to Volcanoes National Park was used to validate the measures of livelihoods constraints, such as food, education and health constraints. In addition, these measures were used evaluate the influence of livelihood constraints of poor residents, on illegal forest use at Volcanoes National Park in Rwanda.

## BACKGROUND

### Sustainable Livelihoods Framework

Chambers and Conway (1992) defined livelihood as a means of making a living, comprised of the capabilities, assets, and resources used in daily activities. Livelihoods are secure when a household is able to use its capabilities, assets and resources to satisfy and maintain a decent living without compromising opportunities for the future (Chambers and Conway 1992; Ellis 2000; Scoones 2009). Scoones (2009) adds that livelihoods are secure when they do not threaten natural resources. The capability of a household to maintain a secure livelihood involves the ability to adequately access basic needs of life (such as education, healthcare, and food), as well as being able take advantage of available opportunities to make a living (Bebbington 1999; Chambers and Conway 1992; Scoones 2009). Limited access to such basic human needs has the potential to erode capabilities of residents in forest-adjacent communities. When the resident's capabilities are eroded, they fail to acquire and maintain desired livelihoods, and are more likely to engage in desperate means of securing livelihoods, including illegal harvest of forest resources (Munanura et al. 2016).

The Sustainable Livelihoods framework has become one of the most applied frameworks to understand the complexities of poverty (Sunderlin et al. 2005). Chambers' work on sustainable livelihoods in the mid-1980s, in particular, has generated debate over the years on its interpretation and application (Chambers 1995; Chambers and Conway 1992; Scoones 2009). This debate has significantly advanced the conceptualisation of poverty in international development, from an income-and-assets-based phenomenon to secure and sustainable livelihoods. Sustainable livelihoods encompass, not only income, but also the opportunities, such as, access to education and healthcare, which enable the household's capabilities to transform and maintain a decent living.

There has been emphasis on understanding livelihoods from the human capabilities perspective. For example, Alkire (2005, 2007), and Sen (2004), have used the capability concept to deconstruct human livelihoods as deprivation of important human freedoms. It is suggested that important human freedoms are challenged when there is limited or no access to basic human needs such as food, education and healthcare (Alkire 2007; Sachs et al. 2004). From a developing country's perspective, access to education, healthcare, and food, are important indicators of basic capabilities (Alkire 2007; Krishna 2015; Sen 2004). Therefore, using basic human capabilities indicators such as access to education, healthcare and food, could reveal critical human livelihood constraints, which may influence illegal forest use for poor residents at Volcanoes National Park.

The application of the Sustainable Livelihoods framework in practice has been extensive, particularly in developing countries. For example, CARE International has used the Sustainable Livelihoods framework to develop a Household Livelihoods Security Index, to measure poverty for humanitarian and development interventions (Frankenberger and McCaston 1998; Lindenberg 2002). CARE's Household Livelihoods Security Index takes into account the basic human capabilities to examine livelihood security, through indicators such as food security, health security, education security, economic security, and empowerment (Frankenberger and McCaston 1998). Oxfam has also operationalised sustainable livelihoods from economic, social, institutional and ecological perspectives (Ashley and Carney 1999). While there are operational variations, the underlying multidimensional

indicators of sustainable livelihoods, such as food, health, education and economic security, are common measures of secure and sustainable livelihoods in international development. In this paper, therefore, we use food security constraints, health security constraints, and education constraints, as the primary indicators of livelihood constraints for poor residents in forest-adjacent communities at Volcanoes National Park.

### *Food Security Constraints*

Food security is commonly perceived as the access to enough food for an active and healthy life (Keenan et al. 2001). From a household livelihoods security perspective, nutrition and food scarcity coping strategies for poor households have become important indicators of food security (Maxwell 1996). Food security constraints are experienced when resources of a household are inadequate to obtain enough food to meet basic needs (Keenan et al. 2001). In addition, a food insecure household is one that is uncertain of having nutritious, adequate and safe food, and unable to acquire such food in a socially acceptable way (Bickel et al. 2000). Therefore, indicators of food security constraints must be viewed within three dimensions of food security, including food access, availability, and utilisation (Barrett 2010). Table 1 summarises some of the indicators of food security constraints.

*Table 1*
*Potential Indicators of Food Security Constraints*

| Food security constraints indicators | Sources |
|---|---|
| High frequency of eating non-preferred food | Maxwell, 1996<br>Bickel et al., 2000<br>Barrett, 2010<br>Bickel et al., 2000<br>Ruel, 2003<br>Maxwell, 1998<br>Frankenberger et al., 2000<br>de Sherbinin et al., 2008<br>Goedhart et al., 1977<br>Bhandari & Grant, 2007<br>Lindenberg, 2002 |
| High frequency of eating inadequate food | |
| No access to credit facilitation | |
| Limited availability of seeds for crop planting | |
| Poor dietary diversity | |
| High frequency of working for food | |
| No availability of food surplus for sell | |
| Frequency of skipping meals | |
| Less household food stored in stock | |
| Land is not available for farming | |
| No family members are employed | |
| Annual agricultural yield not increasing | |
| Limited access to alternative income sources | |
| Limited access to household assets | |
| Land is not productive | |
| Women in the household do not control income | |
| Lack of Jobs | |
| Proportion of active people in a household is low | |
| Proportion of active people employed is low | |

### *Health Security Constraints*

There is no consensus in the literature as to the meaning of health security (Aldis 2008). However, it is believed that the basic requirement for human life is the capability to live a long and healthy life (Aldis 2008; Krishna 2015). Health security is important, because it enables optimal productivity of people. There is evidence of close links between poor health and poverty, especially in developing countries where poor health perpetuates poverty (Diamond et al. 2001; Gupta and Mitra 2004; Krishna 2015). For example, the income of a household is strongly associated with health (Gupta and Mitra 2004). When a household's income earner dies, or is unhealthy, the household's income-earning potential typically diminishes, which reduces the capability to acquire and maintain desired livelihoods (Gupta and Mitra 2004; Krishna 2015). Additionally, a poor household is more likely to be exposed to health risks, such as, high fertility and mortality rates, and infectious diseases (i.e. HIV epidemic), especially in rural areas (Diamond et al. 2001; Krishna 2015). Table 2 summarises some of the indicators for health security constraints.

*Table 2*
*Potential indicators of health security constraints*

| Health security constraints indicators | Sources |
|---|---|
| Home reproductive delivery because delivery services are not available | Gupta & Mitra, 2004<br>Falkingham & Namazie, 2002;<br>Diamond et al., 2001<br>Checkley et al., 2004<br>Lindenberg, 2002<br>Bhandari & Grant, 2007<br>Alkire & Santos, 2011<br>Osberg & Sharpe, 2002<br>Krishna, 2015 |
| Health services are not accessible | |
| Clean piped water is not available | |
| Poor hygiene and sanitation<br>Clean latrines are not available | |
| High mortality rates | |
| Lack of access to government subsidized health insurance | |
| Poor quality of health services | |
| Low life expectancy | |
| High child mortality | |
| Poor nutrition | |

### *Education Constraints*

Poverty is believed to be a function of access to education, among other functioning constraints of a poor household (Osberg and Sharpe 2005). Evidence shows that access and pursuit of education results in social and economic benefits (Alkire and Santos 2011; Osberg and Sharpe 2005). Education empowers individuals and their families to tap into opportunities for improved wellbeing. As Alkire and Santos (2011) suggest, without education, the household's capabilities are compromised. Limitations to education for the poor in developing countries are extensive. For example, it has been suggested that education is lower among poor households in developing countries, due to many physical, social, and economic barriers (Sachs et al. 2004).

In addition, school attendance for children from poor households in developing countries is challenged by high costs for scholastic materials, and opportunity costs, where parents' priority for children is provision of additional labour to produce livelihoods (Sachs et al. 2004). Such costs push poor households in rural areas further into perpetual poverty and deprivation without a chance for recovery. When this occurs, the likelihood for illegal forest

use for income and subsistence use is greater, among the forest-adjacent residents (Babigumira et al. 2014). Table 3 summarises some of the potential indicators of education constraints.

*Table 3*
*Potential Education constraints indicators*

| Education security Indicators | Sources |
|---|---|
| High rate of adult illiteracy | Osberg & Sharpe, 2002 Sachs et al., 2004 Alkire & Santos, 2011 Sachs et al., 2004 |
| Low rate of primary school enrollment | |
| High School life expectancy | |
| Inadequate access to learning facilities | |
| Limited labor for agricultural production | |
| Children do not go to school because of no food | |
| Children do not have scholastic materials | |
| Children do not pursue higher education | |
| Lack of incentives to send children to school | |

## Illegal Forest Use

Forest-adjacent communities in developing countries have historically relied on forest resources for livelihoods, due to population growth and land diminution (Babigumira et al. 2014; Fisher 2004; Lund and Treue 2008; MacKenzie and Hartter 2013; Masozera and Alavalapati 2004). Forested areas, especially those in the tropics, provide multiple benefits, such as exploitation of the resources for commercial purposes, tourism services, harvests of Non-Timber Forest Products (NTFPs), harvests of forest resources for subsistence livelihood needs, and ecological services (Babigumira et al. 2014; Beckley 1998; Hackel 1999; Tumusiime et al. 2011). For most residents in forest-adjacent communities, forests harbour resources from which they derive subsistence livelihoods (Kamanga et al. 2009; Lund et al. 2009; Vedeld et al. 2012). However, the harvest of forest resources from national parks and forest reserves is illegal in most developing countries, particularly in Africa.

Illegal forest use may include encroachment on agricultural land, hunting for bush meat, and harvests for timber and non-timber forest resources for income and subsistence use, as shown in Table 4 (Bleher et al. 2006; Cavendish 2000; Gavin and Anderson 2007; Mackenzie and Hartter 2013; Sommerville et al. 2010). In developing countries like Rwanda, where population density is high, and farmland is limited, households in neighbouring protected areas also commonly rely on forest resources to supplement livelihoods (Kamanga et al. 2009; Masozera and Alavalapati 2004; Munanura et al. 2014; Persha et al. 2009). In some cases, it is the only source of livelihood for those households that do not own farmland (Bush et al. 2010).

While such forest resources are important to the poor and vulnerable, their uncontrolled use is also believed to be among the primary drivers of biodiversity loss in developing countries (Bahuguna 2000; Margolius and Salafsky 2001; Masozera and Alavalapati 2004; Nyaupen and Poudel 2011). In most developing countries, such illegal forest use activities have become a source of conflict between local communities and the government institutions responsible for conservation (Blomley 2003; Tumusiime et al. 2011). For this reason, illegal forest use has become an important aspect of conservation in developing countries. In light of this challenge, several authors have called for a better understanding of livelihoods-based illegal forest use, to ensure wildlife sustainability (Fisher 2004; Sunderlin et al. 2005; Vedeld et al. 2012).

There have been attempts to explore the relationship between livelihood constraints and illegal forest use (Agrawal et al. 2008; Babigumira et al. 2014; Munanura et al. 2014; Nyaupane and Poudel 2011; Persha et al. 2011). This body of research has demonstrated high correlation between livelihood needs and illegal forest use, which can result in biodiversity loss. It is also believed that providing alternative means of livelihoods

*Table 4*
*Indicators of Illegal Forest Use*

| Indicators of forest use | Sources |
|---|---|
| Hunting bush meat for subsistence use | Mittermeier, 1987 |
| Hunting bush meat for income | Hitchcock, 2000 |
| Hunting bush meat for medicinal use | Kwizera per comm |
| Land encroachment for cultivation | Wunder, 2003; |
| Land encroachment for livestock | Overdiverst & Green, 1995 |
| Mining for income | Lewis et al., 2011; Gram, 2001 |
| NTFPs (honey, bean-stakes, fuel wood, bamboo, non-wood materials, medicinal herbs, fruit, mushrooms) | Lewis et al., 2011; Gram, 2001; Janvier Janvier Kwizera, Per. Comm. |
| Collecting water | Janvier Kwizera, Per. Comm. |
| Harvesting grass for livestock feed | Janvier Kwizera, Per. Comm. |

can reduce illegal forest use and degradation of biodiversity (Kamanga et al. 2009; Munanura et al. 2016; Vedeld et al. 2012). Despite substantial efforts made, in both theory and practice, the link between human livelihoods and illegal forest use is still unclear. In this paper, we explore the effect of education constraints, health security constraints and food security constraints, on illegal forest use for poor residents adjacent to Volcanoes National Park.

## The Study Site

Volcanoes National Park is located in the northwestern part of Rwanda, adjacent to Virunga National Park in DR Congo and Mgahinga National Park in Uganda. It presents a unique, high altitude part of the Albertine Rift, which is recognised as one of the most valuable ecosystems for biodiversity conservation globally. The Volcanoes National Park is characterised by open montane forest, bamboo, sub-alpine, and afro-alpine vegetation, at varying altitudinal range (ORTPN 2005). The most striking feature of the park is the high level of endemism and distinctiveness in its flora and fauna (Owinji et al. 2005). The most famous of its endangered taxa are the mountain gorillas (Plumptre et al. 2003).

Volcanoes National Park is also important to the wellbeing of neighbouring communities (Plumptre et al. 2004; Weber

1987). It is surrounded by 12 densely populated administrative sectors, with two of them—Bugeshi and Cyanika, exceeding 900 people per sq.km (NISR 2015b). Most of the residents in proximity to the park are subsistence farmers who live in extreme poverty and often depend on illegal harvests of forest resources to supplement their livelihoods (Bush et al. 2010). Although it is small in size (160 sq. km), the Volcanoes National Park accounts for approximately 10% of the country's rainfall (Plumptre et al. 2004). With its forest cover, it stabilises the infiltration and release of water, which is important for agricultural productivity in neighbouring communities (Weber 1987).

Despite such importance, the biodiversity of the Volcanoes National Park continues to be threatened by the livelihoods of poor residents in neighbouring communities (Munanura et al 2014; Plumptre et al. 2004). The main forest based livelihood activities at the park include—hunting for bush meat, firewood gathering, harvesting bamboo for construction and handicraft making, and gathering non-timber forest products (Musana and Mutuyeyezu 2011). Hunting for bush meat has traditionally targeted ungulates (Musana and Mutuyeyezu 2011; Plumptre et al. 2007).

While poaching may not appear to threaten mountain gorillas because of the local culture that prohibits consumption of gorilla meat, mountain gorillas remain victims of accidental snare entrapment and gorilla trafficking for income (Musana and Mutuyeyezu 2011). Both, accidental snare entrapments, and mountain gorilla trafficking, have led to injuries and death of mountain gorillas at the park. Overall, the forest based livelihood activities at the park, have continued to threaten wildlife, including some of the most critically endangered species, at the Volcanoes National Park (Plumptre et al. 2003). For example, since the 1960s, over 15,000 ha of forest cover have been lost and converted to other land uses, resulting in a 40% decline of the mountain gorilla population (Plumptre et al. 2003).

## METHODS

### Participants

The population of this study is restricted to the poor residents in communities adjacent to the Volcanoes National Park. Poor residents are particularly targeted in this study because they are perceived to be the most active illegal forest users for subsistence livelihoods at Volcanoes National Park (Bush 2009; Bush et al. 2010; Plumptre et al. 2004; Sabuhoro et al. 2017; Spenceley et al. 2010). The selection of participants was limited to the Kinigi sector (see Figure 1). The Kinigi sector was selected, because it is one of the neighbouring administrative sectors of the park, with the highest encounter rates of illegal forest use indicators, in the adjacent forest areas, regardless of being the largest beneficiary of conservation incentives investment.

Within the Kinigi Sector, participants were selected from four administrative cells adjacent to the park, including

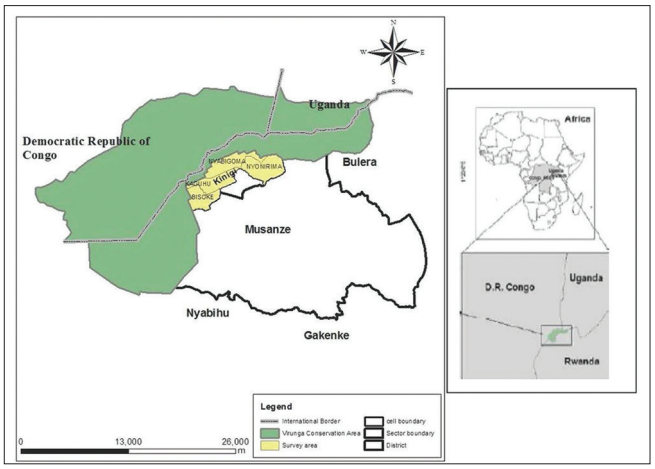



**Figure 1**
***The study site***
***(Source: Abel Musana, Research Warden for VNP)***

the Nyabigoma, Nyonirima, Kaguhu and Bisoke cells (see Figure 1). From each cell, a sampling frame, including a list of extremely poor household heads, was obtained from local leaders. Lower level local leaders in Rwanda particularly at the cell level, keep records of residents classified by the social-economic status. Following the suggestion of Dillman and colleagues, systematic sampling was used to select participants from the sampling frame, using a random interval of 4 (Dillman et al. 2009). A sample of 208 participants was finally selected and invited to participate in this study during the summer of 2013, as part of a graduate research project.

### Survey Instrument Development

The survey instrument used in this study, emerged from a pool of items generated from literature, and refined by local experts. Following DeVellis' guidelines for writing clear and unambiguous indicator statements, measurement indicators were rewritten in the form of a clear and concise belief statement that local residents can understand (DeVellis 2011). For each belief statement representing an indicator of food security constraints (see Table 1), health security constraints (see Table 2), education constraints (see Table 3), and illegal forest use (see Table 4), a response format was created using a seven-point Likert scale, where 1 represented Strongly Disagree and 7 represented Strongly Agree. The developed survey instrument was pre-tested on a group of 10 poor residents.

### Data Analysis

Data were screened using SPSS software to identify missing values and outliers. Twelve cases were found to be outliers, and were subsequently removed (Tabachnick and Fidell 2007). The final sample size was 196 respondents. We performed an Exploratory Factor Analysis (EFA) to identify the patterns and structure of the measures ( Yong and Pearce 2013). Data

was analysed using Principle Axis Factoring and Orthogonal Varimax rotation ( Yong and Pearce 2013). EFA analyses included Kaiser-Mayer-Olkin (KMO) tests for sampling adequacy, rotated Eigen values and scree plot for factor significance determination, factor loading and variance explained ( Yong and Pearce 2013).

The EFA results were examined to identify, and eliminate items preforming poorly before consideration in Confirmatory Factor Analysis (CFA). For example, items with low communities (below 0.3, so that 70% is unique variance) were eliminated (Gie Yong and Pearce 2013). In addition, items with a large number of low correlations (less than + or – 0.3) were also removed, because they may indicate weak relationships between items (Tabachnick and Fidell 2007). In addition, items with correlations greater than 0.9 were also removed, due to the potential for multicolinearity issues (Yong and Pearce 2013).

Structural Equation Modeling in AMOS 24, was used to perform a four-factor Confirmatory Factor Analysis (CFA) model, using a Maximum Likelihood Parameter Estimation (Kline 2011). The baseline model was analysed to determine if the hypothesised model fitted the data. The baseline model revealed only marginally acceptable model fit (CFI=0.913, RAMSEA=0.069) (Bollen 1989; Hu and Bentler 1999). We examined the modification indices to identify the evidence of model misspecifications (Kline 2011). Modification indices were examined, using Lagrange multiplier tests, to improve parsimony (Byrne 1998). The baseline model was re-specified and modified iteratively until it was consistent with the data (Byrne 1998).

Accordingly, the measurement model fit indices showed improved model fit to the data (CFI=0.970, RAMSEA=0.041). Similarly, the structural model revealed a good model fit to the data (CFI =0.953, RAMSEA=0.023), suggesting that relationship between latent variables could be interpreted with confidence (Hu and Bentler 1999).

Finally, the measures were examined for validity and reliability. For example, the convergent validity of each factor, was confirmed by lambda values (λ) for each item exceeding the threshold of 0.4, and the Average Extracted Variance (AVE) exceeding 0.5 (Hu and Bentler 1999, Hair et al. 2006). We used the Fornell-Larcker test to examine discriminant validity of measures (Fornell and Larcker 1981). Fornell-Larcker tests requires the square root of AVE for each latent construct to be greater than any of the inter-latent construct correlations, for discriminant validity to be confirmed (Fornell and Lacker 1981). To establish reliability of the measures, we examined the composite reliability values. Reliability was confirmed when the composite reliability values exceeded the 0.7 threshold (Chin et al. 2003).

## RESULTS

### Sample Description

The sample consisted of men (38%) and women (62%), married (78%) with an average age of 35. Education levels ranged from non-existent (76%), to primary education (24%). The number of household dependents was moderate. For example, 73% of participants had relatively few dependents (ranging between 0-5), while 27% had over 6 and above dependents. Household income comes from agricultural produce and other sources such as casual labour. Income from agricultural produce per month ranged from zero (63.3%), to minimal levels (16.3% earn less than US$2.5, while 20.4% earn over US$2.5 per month). Income from other sources is also low, ranging from zero (57%), to minimal levels (9.8% earn less than US$2.5, while 21.2% earn over US$2.5 per month). Most participants do not own, land (60%), livestock (85%), and do not send children to school (63%).

### Validated Measures for livelihoods constraints, and illegal forest use

The lambda values presented in Table 5, show evidence of convergent validity for measures of all four factors, including, food access constraints, food availability constraints, education constraints and illegal forest use. For example, all lambda values for items within each factor were above the 0.3 lambda value threshold. However, the comparison of the average variance extracted values, and inter-factor correlations presented in Table 6, confirm convergent validity for only three factors, including, food access constraints, illegal forest use, and education constraints. For example, the average variance extracted values for illegal forest use (AVE=0.536), food access constraints (AVE=0.555), and education constraints (AVE=0.464), were higher than all the inter-factor correlations (*see table 6 for inter-factor correlations*). However, as shown in Table 6, the average variance extracted for food availability (AVE =0.398), is less than the correlation between food availability constraints, and food access constraints (r = 0.425). These findings suggest that the measures for food availability are not valid.

Further, the findings presented in Table 6 confirm that the items measuring food access constraints, food availability constraints, education constraints and illegal forest use variables, passed the discriminant validity test. For example, the square root of the average variance extraction for food access constraints (0.745) is greater than the factor correlation between food access constraints, and, illegal forest use (r = -0.529), education constraints (r = -0.121), and food availability constraints (r = 0.425). A similar trend of findings presented in Table 6, confirms discriminant validity of measures (i.e. the square root of average variance extracted was greater than all inter-factor correlations) for the remaining factors, including, food availability constraints, education constraints and illegal forest use. These findings suggest measures for all factors, passed the discriminant validity test.

The composite reliability findings presented in Table 6, confirm the reliability of measures for food access constraints, education constraints, and illegal forest use. For example, the composite reliability values for the education constraints factor (CR=0.722), food access constraints factor (CR=0.831) and illegal forest use (CR=0.908), met the composite reliability

*Table 5*
*Indicators and Factors Emerging from the Exploratory Factor Analysis*

| Measurement Indicators | Mean | SD | Illegal forest use (λ) | Education constraints (λ) | Health security constraints[4] (λ) | Food access constraints (λ) | Food availability constraints (λ) |
|---|---|---|---|---|---|---|---|
| Reliability (RHO) | | | 0.870 | 0.720 | 0.880 | 0.844 | 0.820 |
| Bush meat for subsistence use | 5.14 | 2.478 | 0.793 | | | | |
| Bush meat for income | 4.90 | 2.476 | 0.708 | | | | |
| Bush meat for medicinal use | 4.89 | 2.573 | 0.656 | | | | |
| Harvesting bamboo for subsistence use | 5.38 | 2.316 | 0.745 | | | | |
| Harvesting bamboo for income | 4.92 | 2.474 | 0.745 | | | | |
| Harvesting herbs for medicinal use | 4.81 | 2.602 | 0.730 | | | | |
| Collection of water[1] | 5.28 | 2.425 | 0.540 | | | | 0.432 |
| Harvesting bean-steaks for crop support | 4.71 | 2.576 | 0.676 | | | | |
| Harvesting grass for livestock feed | 4.21 | 2.820 | 0.519 | | | | |
| Harvesting forest honey | 4.96 | 2.488 | 0.776 | | | | |
| Harvesting forest resources for handicraft production | 5.00 | 2.612 | 0.729 | | | | |
| High rate of school dropout among children | 5.02 | 2.295 | | 0.656 | | | |
| Children do not have scholastic materials | 5.30 | 2.086 | | 0.691 | | | |
| Education is not pursued because of no food | 4.56 | 2.358 | | 0.702 | | | |
| Children do not pursue high school[1] education | 4.82 | 2.488 | | 0.326 | | 0.460 | |
| Health care services not available[3] | 3.21 | 2.101 | | | 0.929 | | |
| Health Care services are not accessible | 2.70 | 2.461 | | | 0.580 | | |
| Clean piped water is not available[2] | 3.96 | 2.603 | | | 0.394 | | |
| Home reproductive delivery because delivery services are not available[3] | 3.21 | 2.170 | | | 0.969 | | |
| Clean latrines are not available[2] | 5.55 | 1.699 | | | 0.365 | | |
| Do not have the government subsidized health insurance[2] | 3.32 | 2.787 | | | 0.486 | | |
| High frequency of eating non-preferred food | 4.56 | 2.163 | | | | 0.774 | |
| High frequency of eating inadequate food | 4.83 | 2.289 | | | | 0.819 | |
| No access to credit facilitation | 5.47 | 2.529 | | | | 0.868 | |
| Limited availability of seeds for crop planting | 5.13 | 2.219 | | | | 0.769 | |
| Poor diet food eaten | 6.09 | 1.463 | | | | 0.644 | |
| High frequency of working for food | 5.30 | 2.040 | | | | 0.588 | |
| There is no food surplus for sell[1] | 5.90 | 2.005 | | | | 0.403 | 0.510 |
| Frequency of skipping meals | 4.37 | 2.082 | | | | | 0.542 |
| Less household food stored in stock | 6.13 | 1.500 | | | | | 0.738 |
| Land is not available for farming | 4.39 | 2.004 | | | | | 0.658 |
| No family members are employed[1] | 3.57 | 2.816 | | | | 0.468 | 0.493 |
| Annual agricultural yield not increasing | 5.91 | 1.709 | | | | | 0.769 |

[1]Item removed because of cross-loading (above 0.32) (Gie Yong & Pearce, 2013). [2]Items removed because of low loadings (below 0.5) (Tabachnick & Fidell, 2007). [3]Items removed because of correlations above +/- 0.9 indicated potential for multicolinearity problems (Gie Yong & Pearce, 2013). [4]Health security factor was unidentified because of low number of unique measures and therefore not considered for CFA (Gie Yong & Pearce, 2013)

*Table 6*
*Validity and reliability of illegal forest use and livelihood measures*

| | CR | AVE | MSV | Education Security Constraints | Illegal Forest Use | Food Access Constraints | Food Availability Constraints |
|---|---|---|---|---|---|---|---|
| Education Security Constraints | 0.722 | 0.464 | 0.019 | **0.681** | | | |
| Illegal Forest Use | 0.908 | 0.526 | 0.280 | 0.105 | **0.725** | | |
| Food Access Constraints | 0.831 | 0.555 | 0.280 | -0.121 | -0.529 | **0.745** | |
| Food Availability Constraints | 0.654 | 0.398 | 0.181 | 0.139 | -0.137 | 0.425 | **0.631** |

Convergent Validity: the AVE for education security is <0.50. Reliability: the CR for food availability is <0.70. Convergent Validity: the AVE for Food availability is <0.50

benchmark (CR=0.7). However, the reliability of the food availability constraints variable (CR=0.654), was slightly below the composite reliability benchmark. This implies that the reliability of measures for the food availability constraints factor is unsatisfactory. Therefore, the results associated with food availability constraints factor may be interpreted with caution.

The validity and reliability findings presented, suggest that the measures for food access constraints, education constraints, and illegal forest use are valid, and reliable. Therefore, their use in evaluating the influence of food access constraints, and education constraints, on illegal forest use is plausible. However, the convergent validity findings revealed that

the measures for food availability constraints are not valid. Considering both the reliability and validity findings, it is evident that the measures for food availability constraints are not reliable and valid. Therefore, the influence of food availability on illegal forest use presented in this paper should be interpreted with caution. Table 7 presents the validated measures of illegal forest use, food access constraints, and education constraints, which may be used in evaluating the influence of livelihood constraints on illegal forest use, as demonstrated in the next section.

## Livelihood constraints influencing illegal forest use at Volcanoes National Park

A Structural Equation Model was used to examine the relationship between factors in the hypothesised relationship. In the structural regression models, Beta (β) values indicate the strength of the effect size of the predicting factor. The model fit of the structural model (SB $\chi^2$ = 925.199 (700), p=0.006; CFI=0.953; RMSEA 0.023), indicated that the hypothesised model fit the data (Hu and Bentler 1999).

### *Illegal forest use at Volcanoes National Park*

The structural model predicting illegal forest use at Volcanoes National Park (see Figure 2) accounted for 30% variance.

*Table 7*
*Validated measures of livelihood constraints and forest use constructs*

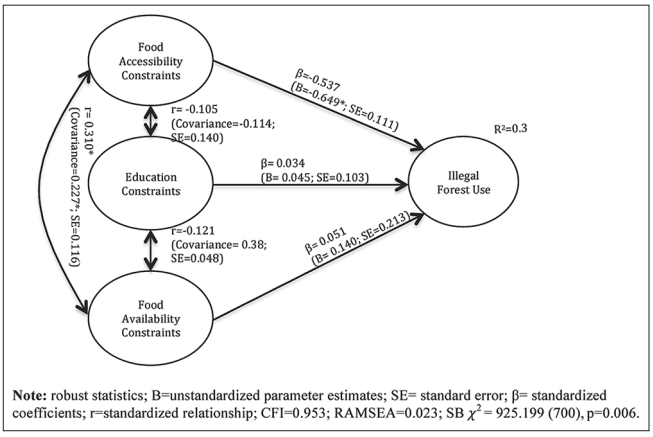
| Latent Construct[2] | Measurement Indicators |
|---|---|
| Illegal forest use | Harvest of bean-stakes from the park |
| Illegal forest use | Harvest of materials for handicraft making |
| Illegal forest use | Harvest of herbs for medicinal use |
| Illegal forest use | Harvest of bamboo for income |
| Illegal forest use | Harvest of Bamboo for subsistence use |
| Illegal forest use | Hunting for bush meat medicinal use |
| Illegal forest use | Hunting for bush meat for income |
| Illegal forest use | Hunting for bush meat for subsistence use |
| Food access constraints | High frequency of eating inadequate food |
| Food access constraints | Inadequate access to seeds for crop production |
| Food access constraints | High frequency of eating non-preferred food |
| Food access constraints | Inadequate access to credit facilities |
| Education constraints | Children do not go to school because of inadequate food |
| Education constraints | Children do not go to school because of lack of scholastic materials |
| Education constraints | Children do not pursue to high school education |
| Food availability constraints[1] | Household does not eat food on time |
| Food availability constraints[1] | Food in the stock is insufficient |
| Food availability constraints[1] | Land is for agriculture is not available |

[1]Food availability measures must be considered with caution because of the validity and reliability concerns. Future research may aim to develop and validate measures for food availability constraints. [2]Code used for latent variables: Illegal forest use=ForestUse, Food access constraints=FsecACC, Education constraints=Esec, Food availability constraints=FsecAVL.

As presented in the next subsections, illegal forest use at Volcanoes National Park is significantly influenced by food access constraints of the poor residents adjacent to the park. The indicators of illegal forest use, with higher standardised loadings revealed some of the illegal activities of concern for poor residents adjacent to the park. They include, harvesting of bush meat for subsistence use (λ=0.793), Harvesting of forest honey (λ=0.776), Harvesting of bamboo for subsistence use, and income (λ=0.745), harvesting of herbs for medicinal use (λ=0.730), and harvesting of forest resources for handicraft production (λ=0.729). These findings suggest that limited resources for law enforcement, and conservation incentives at Volcanoes National Park, could be most impactful if park management resources are targeted toward control of the above illegal forest use activities.

A closer look at covariances between the indicators of illegal forest use revealed a number of significant correlations. For example, harvesting of bamboo for income, and hunting bush meat for medicinal use, are positively, and significantly related (σ = 0.21, p<0.05). This suggests that poor residents, who rely on bamboo harvests for income, are also active illegal hunters for medicinal use. Therefore, controlling hunting could suppress illegal bamboo harvests for income. In addition, addressing health risks for poor residents could help minimise hunting for medicinal use, and bamboo harvests for income.

The findings also revealed that harvesting of bush meat for medicinal use, and harvesting herbs for medicinal use, are positively, and significantly related (σ = 0.24, p<0.05). This finding suggests that medicinal plant gatherers are also active illegal hunters for medicinal use. Therefore, controlling illegal hunting could minimise medicinal plant harvests at the park. Equally, addressing health risks of poor residents could minimise hunting for medicinal use, and gathering plants for medicinal use at the park. The findings also revealed that harvesting bamboo for income, and harvesting forest resources for handicraft production, are positively, and significantly related (σ = 0.25, p<0.05). This finding suggests that poor residents, who harvest handicraft-making materials from the park, could also be active harvesters of bamboo for income.




**Note:** robust statistics; B=unstandardized parameter estimates; SE= standard error; β= standardized coefficients; r=standardized relationship; CFI=0.953; RAMSEA=0.023; SB $\chi^2$ = 925.199 (700), p=0.006.

**Figure 2**
*Structural equation model of livelihood constraints predicting illegal forest use*

Most notable, however, are, the inverse relationships between illegal forest use indicators. For example, harvesting of medicinal plants, and hunting bush meat for subsistence use, was found to be negatively, and significantly related ($\sigma$ = -0.44, $p<0.001$). This finding suggests that reducing illegal hunting for subsistence use could potentially create health risks for poor residents. Therefore, control of hunting, could be supplemented by understanding the health risks to poor residents, and enabling their access to healthcare. Second, harvesting forest resources for handicraft production, and harvesting bamboo for subsistence use, were negatively, and significantly related ($\sigma$ = -0.23, $p<0.05$). This finding suggests that providing alternative sources of handicraft producing materials could reduce harvests of handicraft making materials in the park. In doing so, however, providing alternative sources of handicraft producing materials could at the same time increase demand for bamboo for subsistence use, among poor residents.

***The effect of food access constraints on illegal forest use***

Food access constraints, a dimension of food security constraints, was found to have a strong and inverse relationship with illegal forest use for the poor residents adjacent to the Volcanoes National Park ($\beta$ = -0.537, $p<0.000$). Surprisingly, this finding indicates that, increase in constraints for food access among poor residents at Volcanoes National Park, has the potential to reduce illegal forest use at the park. The findings presented in Table 5 show a few key indicators of food access constraints with the potential to influence illegal forest use, among poor residents at the park. They include, limited access to credit facilities ($\lambda$=0.868), high frequency of eating inadequate food ($\lambda$=0.819), high frequency of eating non-preferred food ($\lambda$=0.774), and limited availability of seeds ($\lambda$=0.769). Considering the inverse relationship between food access constraints, and illegal forest use, conservation incentives enabling access to resources important for food security, such as, access to credit facilities, and seeds, may not be contributing toward efforts to address illegal forest use by poor residents at Volcanoes National Park.

A closer look at covariances between the indicators of food access reveals a positive, and significant relationship between limited availability of seeds for crop planting, and limited access to credit ($\sigma$ = 0.38, $p<0.001$). This finding suggests that addressing limited access to seeds among poor residents may suppress the impact of limited access to credit. However, considering that 60% of the participants do not own land, and the inverse relationship between food access constraints and illegal forest use, the conservation incentives facilitating agricultural productivity, for example by providing seeds, and enabling access to capital, may not reduce illegal forest use, from a poor resident perspective, at the park.

***The effect of food availability constraints on illegal forest use***

Food availability constraints, a dimension of food security constraints, have a weak, and positive relationship with Illegal forest use among poor residents, at the park ($\beta$ = 0.051, $p>0.05$). However, a significant correlation between food availability and food access ($r$ = 0.310; $p<0.05$), suggest that food access constraints could mediate the influence of food availability on illegal forest use. However, this finding should be interpreted with caution, because of the validity and reliability concerns presented earlier, for the measures of food availability variable.

***The effect of education constraints on illegal forest use***

Education constraints variable was also not found to be a strong predictor of illegal forest use ($\beta$ = 0.034, $p>0.05$). Equally, Education Security was not found to have a strong relationship with food access constraints ($r$ = -0.105, $p>0.05$), and food availability constraints ($r$ = -0.121, $p>0.05$). This finding may suggest that education constraints have no impact of significance on food availability, accessibility constraints, and illegal forest use, for poor residents at Volcanoes National Park.

In addition, the findings suggest that food access constraints could be mediating the effect of education constraints on illegal forest use. The inverse relationship indicated above could also suggest that conservation incentives aimed to reduce education constraints for the poor at the park, may increase food constraints, which could result in reduced of illegal forest use, among poor residents at the park. This is a surprising finding, and challenges the rationale for conservation incentives invested in food security programmes, while at the same time, demonstrating the indirect conservation benefit of providing access to education for poor residents at Volcanoes National Park.

## DISCUSSION

This study had two primary objectives. First, it aimed to develop and validate measures for multiple dimensions of livelihood constraints and illegal forest use. Second, it aimed to evaluate the relationship between livelihood constraints and illegal forest use behaviour, and determine dimensions of livelihood constraints with the greatest effect on illegal forest use, for poor residents adjacent to Volcanoes National Park. Prior to a discussion of key findings for each objective, a review of illegal forest use is provided, from the perspective of poor residents at the park.

### A poor resident's perspective of Illegal forest use at Volcanoes National Park

Results identified four main indicators of illegal forest use at Volcanoes National Park, from the perspective of a poor resident in the adjacent community. They include, illegal hunting for subsistence use, gathering forest honey, harvesting bamboo for subsistence use and income, harvesting of medicinal plants, and harvesting of handicraft producing materials.

The findings revealed some of the closely related indicators of illegal forest use, which could have park management implications. For example, hunting for medicinal use, was positively and strongly related to, harvest of bamboo for income, and harvest of medicinal plants. Therefore, limited

park management resources could be put toward controlling illegal hunting, which has potential to reduce illegal hunting, harvest for medicinal plants, and bamboo for income, at the same. It could also be argued that addressing health risks of poor residents could help to reduce other indicators of illegal forest use, such as, hunting for medicinal use, gathering for medicinal plants, and bamboo for income.

Most notably, the results revealed two strong inverse relationships in the indicators of illegal forest use at the park. First, hunting for subsistence use and harvest of medicinal plants were inversely related. This finding supports previous research, recognising the health benefit of bush meat (Golden et al. 2011). This finding could be valuable to park management. For example, it could suggest that efforts to reduce hunting, could actually increase health risks of the poor, and increased reliance on the park for medicinal plants. Therefore, law enforcement efforts aimed to reduce hunting for subsistence use, could also be supplemented by understanding, and addressing health risks of poor residents at the park. Further research is needed to explore the health risks of restrictive biodiversity conservation policies, particularly for poor residents adjacent to natural areas in developing countries.

The second inverse relationship was found between harvest of bamboo for subsistence use, and harvest of handicraft producing materials. This finding could imply that the ongoing efforts to provide handicraft producers with alternative sources of handicraft producing materials, may not be entirely addressing the issue of illegal harvest of bamboo at the park, particularly bamboo harvested for subsistence use by poor residents. The park management may address the issue of bamboo harvest at the park, by providing alternative sources of bamboo for both, handicraft makers, and poor residents who could be relying on bamboo for subsistence use.

## Measures for the livelihood constraints and illegal forest use

This paper has presented the validated measures of food access constraints, education constraints, and illegal forest use (see Table 7). Measures for food availability are not included due the poor reliability and validity finding. We suggest that the measures for food availability constraints be revised and validated, for future use.

One of the notable observations was the split of the food security constraints construct into two dimensions of 'food availability' and 'food access', each with distinct measures. The split of food security constraints into two dimensions is supported in literature (Barrett 2010; Timmer 2000). For example, Barrett (2010) demonstrates three hierarchical dimensions of food security; availability of sufficient quantities, and quality of food (food availability), access to resources for food provisions (food access), and utilisation of available food through diet, water and other resources (food utilisation).

However, studies linking food security constraints to illegal forest use have rarely considered variations in the dimensions of food security constraints and implications for wildlife conservation. The implications of food availability constraints on illegal forest use may be different from food access constraints. For example, it is argued that food availability does not necessarily indicate that food is accessible, and food access is not sufficient for effective food utilisation (Barrett 2010; Sen 1981; Timmer 2000).

Therefore, evaluations of the influence of food security constraints on illegal forest use, may take into account the three dimensions of food security mentioned above. This study proposes measures for only one dimension of food security constraints (food access constraints), providing a partial contribution towards measures for food security constraints. Future research could aim to develop measures for food availability and food utilisation dimensions of food security constraints. Wildlife conservation practitioners will have a better understanding of the impact of food security constraints on illegal forest use in forest-adjacent communities, when the measures for the remaining dimensions of food security constraints are developed, validated and applied.

## The influence of livelihood constraints on illegal forest use

The findings revealed that food access constraints strongly, and inversely influence illegal forest use, for poor residents at Volcanoes National Park. Education constraints were found to have a weak and positive influence on illegal forest use. However, the inverse relationship between education and food access constraints indicates the potential for food access constraints to mediate the influence of education constraints on illegal forest use, for poor residents at the park.

### *Food access constraints and illegal forest use*

Results indicate that food access constraints have a strong, and negative influence on illegal forest use for poor residents at Volcanoes National Park. This finding supports previous research suggesting that food security constraints have the potential to influence illegal forest use (Appiah et al. 2009; Bahuguna 2000; Mackenzie and Hartter 2013; Masozera and Alavalapati 2004; Munanura et al. 2014). However, this study makes a number of contributions. First, it introduces food access constraints variable as a strong predictor of illegal forest use. Second, it suggests an inverse relationship between food access constraints and illegal forest use. Third, it revealed the potential for enabled access to education, to indirectly reduce illegal forest use among poor residents at the park.

Results identified food access constraints as a specific dimension of food security constraints, which has the potential to influence illegal forest use. This finding underscores the value of understanding and considering food access constraints in the sustainable biodiversity conservation discourse. Irrespective of whether food is available or not, access to food for a household rests on its ability to adequately access the food that may be available (Timmer 2000). Evidence shows, food availability does not create access to food (Barrett 2010;

Sen 1981). Rather, adequate access to food is determined by the intra-household's capabilities (Barrett 2010; Sen 1981; Timmer 2000).

Therefore, the effect of other dimensions of food security constraints (food availability and food utilisation) on illegal forest use must be examined in future research. This is suggested because food security constraints emerge in three forms— inadequate availability of food, inadequate access to food and poor utilisation of available food (Timmer 2000). Understanding how each of these multiple dimensions of food security constraints influences illegal forest use is important for research and practice.

The inverse relationship finding, between food access constraints, and illegal forest use, is also noteworthy. Ideally the relationship between food security constraints and illegal forest use in forest-adjacent communities is expected to be positive (Appiah et al. 2009; Mackenzie and Hartter 2013; Munanura et al. 2014). However, the finding of a strong, and inverse relationship between food access constraints and illegal forest use for the poor contradicts this view, and suggests that increase in food access constraints may reduce illegal forest use for poor at the park. For example, this finding implies that when forest-adjacent residents have limited access to resources for food provision, their ability to illegally harvest forest resources is minimal.

This finding supports previous research, which challenges the narrative of poverty driven illegal forest use, and argues that residents with more economic means are more likely to influence illegal forest use (Angelsen and Kaimowitz 1999; Babigumira et al. 2014; Mamo et al. 2007). More research is needed to explore the inverse relationship between food access constraints and illegal forest use, for poor residents and implications for wildlife conservation in developing countries. A hypothesis that may explain this finding could be, that, the increase in access to food provision resources such as land, and financial capital may create wealth, and stimulate demand for forest resources (Angelsen and Kaimowitz 1999; Babigumira et al. 2014; Mamo et al. 2007; Pfaff et al. 2004).

***Education constraints and illegal forest use***

Education constraints were found to have a weak, and positive influence on illegal forest use, for poor residents at Volcanoes National Park. Notable, however, is the finding of an inverse relationship between education constraints and food access constraints. While it was not found to be strong, the inverse relationship may suggest that improving education opportunities for poor residents may limit food access opportunities in the short-term, and at the same time, reduce illegal forest use indirectly. Therefore, this finding may imply that improving education opportunities for the poor has potential to indirectly reduce illegal forest use at Volcanoes National Park.

This view is supported in literature, where it is argued, that education constraints have potential keep children at home, who provide additional labour, which improves agricultural productivity and income of a poor household (Beegle et al. 2006; Edmonds 2006; Guarcello et al. 2009). It is therefore, not surprising to find that, about 63% of poor resident participants do not send their children to school. This implies that, the higher the rate of no schooling for children in poor households at Volcanoes National park, the better it is for food security. This is because, when children do not attend school, poor households will have additional human capital to produce non-forest based livelihoods, which will potentially reduce food access constraints. Unfortunately, however, based on the findings in this study, the implication for wildlife conservation at Volcanoes National Park is undesirable, because, reducing food access constraints has the potential to increase illegal forest use by poor residents at the park.

Without consideration of the study site reality, this finding seems rather odd. It appears improbable that reducing education constraints would increase food access constrains, which in turn reduces illegal forest use. In fact, it was found that 63% of poor households in communities neighbouring the Volcanoes National Park do not send children to school, notwithstanding the universal primary education policy. For most households in extreme poverty in areas adjacent to Volcanoes National Park, school attendance takes away the extra labour that is critical for households to earn and maintain a living. For families in extreme poverty at the park, children would rather help in keeping goats and pigs, guarding crops from animal crop raiding, pursuing menial jobs for additional income, or food for their families (Munanura et al. 2017).

Evidence of such perverse incentives for school dropouts is seen in the literature (Edmonds 2006; Guarcello et al. 2009; Sachs et al. 2004). Based on the finding of an inverse relationship between education constraints and food access constraints, it appears that the Government of Rwanda's universal primary education policy may have negative implications for food access among poor households neighbouring the Volcanoes National Park, and therefore could contribute to illegal forest use at the park. While the long-term value of the universal education policy is undeniable, it may be counterproductive for biodiversity conservation efforts at the Volcanoes National Park in the short-term. This is particularly of interest at Volcanoes National Park, where current policies enabling food security in Rwanda (i.e. one cow per family, supply of goats and pigs), may need to be supplemented with policies that strengthen law enforcement, and monitoring of illegal forest use. For example, when a poor resident, with no land, is provided with livestock through the one cow per family policy, the park becomes more likely source of grass for cattle feed.

## CONCLUSION

The debate on the relationship between poverty and illegal forest use is on-going. This paper, has attempted to contribute toward this debate, buy taking a closer look at the relationship between livelihood constraints, and illegal forest use, from the perspective of poor residents adjacent to Volcanoes National Park. The findings have shown that, food insecure, poor

residents adjacent to the park may not have the capability to influence illegal forest use. Secondly, the positive influence of access to education for the poor, on illegal forest use, may be mediated by food access constraints.

These findings support the research emerging from the Center for International Forestry Research (see Babigumira et al, 2014), challenging the poverty driven biodiversity loss narrative, influencing most of the integrated conservation and development programs in developing countries. While the long-term value of community empowerment for conservation is indisputable, securing wildlife conservation in the short-term could still be dependent on increased investment in law enforcement, creation of avenues for information sharing between park rangers and residents, and establishment of local level participatory park management decision-making opportunities for all residents, including the poor and most vulnerable. Use of modern technology, for example, satellite imagery, and drones, could enable law enforcement, to be much more effective at controlling illegal forest use in the short-term.

The wildlife conservation policy makers in Rwanda, and other developing countries with similar conditions, may investigate the role of economically empowered forest-adjacent residents, in influencing illegal forest use, and the nature of impact to biodiversity. In addition, the pervasiveness of conservation incentives, aimed to economically empower forest-adjacent residents, could be systematically examined, to determine whether, the conservation incentives are not indirectly enabling demand for forest products, and illegal forest use. For example, previous research (Munanura et al. 2017) observed that the increasing demand from economically empowered residents, influences the harvest of grass for cattle feed, bean-stakes, and bamboo from the park. There has also been an increase of conservation incentives investment in local handicraft businesses, and agricultural projects (Munanura et al. 2016). Based on these observations, and findings from this study, a question such as "do the conservation incentives create unintended negative conservation consequences, by creating economic opportunities for park neighbouring residents?" could be relevant and timely.

Further, this study contributes three subscales for food access constraints, education security constraints, and illegal forest use in developing countries. The measures proposed could be useful in assessing the relationships between livelihood constraints and illegal forest use in protected areas, which may be vulnerable to destructive forest-based human livelihood activities. However, these subscales provide only partial measures for livelihood constraints. Future research may aim to develop and validate measures for, food availability and food utility constraints, the remaining dimensions of food security constraints. This will allow for a complete understanding of how food insecurity influences illegal forest use. For example, valuable questions, such as, do food availability and utility constraints, also have a negative and strong influence on illegal forest use, for poor residents at the park? could be answered.

Future research may explore the above question, and others emerging from this study. For example, does the Government of Rwanda's universal education have unintended positive consequences for conservation by diminishing the food access capability of poor residents adjacent to the park? By economically empowering residents adjacent to the park, do conservation incentives create unintended, and negative consequences for conservation? To what extent do food security dimensions of food availability, and food utilisation affect illegal forest use behaviour? In combination with findings in this paper, these questions will advance our understanding of the relationship between livelihood constraints and illegal forest use of forest-adjacent communities in developing countries.

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