

# Explaining Low Marketed Quantities of Gum Arabic in Kenya: An Economic Approach

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## SUMMARY

Gum Arabic has the potential to contribute substantially to the income of poor nomadic and semi-nomadic pastoralists in Kenya. In the study sample of 201 households, observed marketed quantities were found to be low, even though the resource is widely and freely available and most interviewed households were desperately poor. An economic model was developed that offers an explanation for this paradox. In the model, a shortage of rainfall had a larger negative effect on the return to alternative sources of income, thereby increasing the relative return to gum collection vis-à-vis these alternative sources. Regression results corroborate this prediction. It appears gum Arabic is a low return activity which is mainly used as a safety net when other sources of income fall short.

Key words: Non-timber forest products, poverty alleviation, gum Arabic, Kenya, multiple linear regression

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## INTRODUCTION

Gum Arabic is a resin from several types of the acacia tree naturally occurring throughout the arid and semi-arid lands (ASALs) across the whole of sub-Saharan Africa. The trees occur most densely in the so-called gum Arabic belt, which spans an area several hundred kilometres wide to the south of the Sahara and stretches from Senegal in the west to Somalia in the east (White 1983, FAO 1985, ICRAF 1992, Islam *et al.* 1997). Trees are also wide spread in East Africa, from South Africa to Sudan (Raddad *et al.* 2005). Gum Arabic has been traded since ancient history and has a wide range of industrial uses. The chemical structure of the gum is so complex that no synthetic substitute has yet been discovered. It is such a crucial input to industry that the Gum Arabic Company, the largest exporter in the world, was given an exemption from the trade embargo of the United States against Sudan even though it was known this company was owned for 70% by Osama Bin Laden (Van Dalen 2006). Even though worldwide demand for the resource is high and increasing, countries like Kenya are struggling to increase supply, even though the resource is widely available (Beentje 1994). Areas containing gum Arabic trees are among the poorest in Kenya, some having poverty rates of over 90% (GOK 2007). Gum Arabic is traditionally gathered in the wild by nomadic and semi-nomadic pastoralists. Although the gum has some local uses, for local people involved in its collection its main livelihood contribution comes from its marketing. Given increasing world demand (ITC 2008), gum Arabic offers large poverty alleviation potential. However, observed marketed quantities were found to be low, and consequently the contribution to household income limited. In this paper, a model was used that offers an explanation for these low observed marketed quantities. The model was tested using a unique household-level dataset from Kenya combined with publicly available geographic information system (GIS) data. In the remainder of this section, existing knowledge on gum Arabic production and collection is described and compared with studies on other non-timber forest products.

In Kenya gum Arabic is collected from the wild, making it important to know which particular trees produce gum and where such trees naturally occur. Gum Arabic is the natural exudate of several subgeni of the Acacia tree (see Nishinari and Doi (1993) for an overview). In Kenya gum is collected from both *Acacia Seyal* and *Acacia Senegal*. The latter is more common and found as a leguminous tree, deciduous shrub or shrub tree species. It belongs to the subgenus *Aculeiferum* (Arce and Banks 2001). Four varieties within the species produce gum Arabic: var. *Senegal*, *Kerensis*, *Rostrata* and *Leiorhachis* (Brenan 1983, Fagg and Allison 2004). *Acacia Senegal* var. *Senegal* is most valued for quality (Lelon *et al.* 2010) and var. *Kerensis* forms the basis of the international export market. *Kerensis* is also the most commonly found variety in Kenya (Booth and Wickens 1988, Chretien *et al.* 2008). Gum producing trees are found throughout the drylands that cover almost 80% of Kenya (Beentje 1994, Maundu *et al.* 1999). The value of the tree is not limited to its ability to produce gum Arabic. Acacia trees increase soil fertility by fixing atmospheric nitrogen and hence contribute to stabilizing yields (Fagg and Allison 2004) and are used for desertification control (Cossalter 1991). To estimate the gum producing capacity of a region, not only the occurrence of gum producing trees but also the density in which they occur is important.

Only a handful of studies provide information on the density of gum producing *Acacia* trees in Kenya. Olang (1984) was the first to make a vegetation map of part of the study area, Turkana district. He distinguished eight vegetation types, only one of which was specifically mentioned to contain *Acacia Senegal*. Unfortunately, no mention is made of stocking densities. A decade later in the same region, Coughenour and Ellis (1993) found *Acacia Senegal* to be the dominant species on rocky sites with a sloping topography. This more frequent occurrence of *A. Senegal* on hilly sites is corroborated by Chikamai *et al.*

(1995) in a study specifically aimed at establishing its stocking density in Turkana, Isiolo and Marsabit district. However, in their study only sites known or expected to contain *A. Senegal* were included, making it impossible to extrapolate average stocking densities for the region as a whole from their results. Another difficulty with establishing stocking densities is the intensity of anthropogenic disturbances. Trees are cut to produce charcoal, fuel wood, or for building animal enclosures (NAS 1979, Wickens *et al.* 1996). Furthermore, browsing, especially by goats, negatively affects regeneration (Obeid and Seif el Din 1970). These disturbances might explain the lack of up to date stocking density information.

Regional availability of gum Arabic depends not only on occurrence and density in which gum-yielding trees are found but also on their productivity. Tree density itself might have an effect on the productivity per tree, because of competition for nutrients and water between individuals and species (Gaafar *et al.* 2006). Irrespective of density, several environmental factors were also found to influence productivity. Dione (1989) found a strong positive relationship between rainfall and gum yields, a result which was corroborated by Ballal *et al.* (2005). The latter authors additionally showed a positive relationship between yields and air temperature. Wekesa *et al.* (2009) showed a positive relationship between gum yield and soil temperature and a negative relationship with soil moisture content. In addition to environmental factors, harvesting techniques also influence gum yields. Tapping is a technique where part of the bark of the tree is removed to stimulate resin production. It has been shown to improve yields of *Acacia Senegal* (Wekesa *et al.* 2009) and *A. Seyal* varieties (Fadl 2011). Furthermore, yields are influenced by when and how often the tree is tapped, where the tree is cut, and even which tool is used to make the incision (Ballal *et al.* 2005, Wekesa *et al.* 2009, Fadl 2011). It is therefore not straightforward to determine gum production per region, especially when gum is collected from natural stands.

In Kenya, the ASALs where gum Arabic is found are thinly inhabited and pastoralism is the primary source of income for local people. Gum Arabic is only available in the dry season, and hence mainly serves a supplementary function. Non-timber forest products (NTFPs) in general are often used as a safety net, a subsistence product or a cash earner (Belcher and Schreckenber 2007). Especially poorer households depend on NTFPs for subsistence or cash income (Neumann and Hirsch 2000, Shackleton and Shackleton 2004). Sunderlin *et al.* (2005) explain this dependency by the low skill and little capital required for their collection, and their usually open access nature. This situation could also apply to gum Arabic collection in Kenya, because no specific tools or skills are required and lands are communally owned so access to trees is unrestricted. That mostly poor households are involved in gum collection is corroborated by a recent study by Gachathi and Eriksen (2011). They distinguished two main groups of collectors. The first group contained households owning little or no livestock, often because of losses due to raids or droughts, a trend also observed in Ethiopia (Woldeamanuel *et al.* 2011). For this group of households, for whom gum collection appeared to be mainly driven by need, women and girls were found to be the main collectors (Chikamai and Odera 2002, Luvanda *et al.* 2006, Wekesa *et al.* 2010). The second group of identified collectors was considered to be emerging and consisted of opportunists, collecting gum and resins to increase total household income, not out of need.

Gum is collected for use within the household and for income generation through sale in the market. Some gum is eaten as food. Okunomo and Bosah (2007) considered it to have an important contribution to diets, as it provides a source of vitamins, minerals, proteins, carbohydrates and fats. This contribution is especially important in the dry season - called the 'long hunger' in Marsabit (Fratkin *et al.* 2004) - when other sources of income are in short supply (Oni and Gbadamosi 1998). Arabic gum is valued for its medicinal properties, and is used to relieve backache and painful joints. The tree itself has several local uses. Its bark is used to treat stomach related illnesses and to make ropes and fishnets (NAS 1979, Chikamai

and Odera 2002, Obua *et al.* 2006, Watson and Van Binsbergen 2008). Seeds are consumed as vegetables and leaves provide fodder for livestock (Baumer 1983). The wood of the tree is used for fuel, to make charcoal and poles and its branches for fencing of houses and livestock sheds (Barrow 1990, Wekesa *et al.* 2010). This wide range of uses for both the gum and the tree itself indicates that most households will know where to find trees and how to collect gum, and there is expected to be no knowledge barrier limiting collection. Although these direct uses of gum contribute to household income, gum brings most benefits through trade. Gum Arabic has been internationally traded for over five thousand years. Ancient Egyptians used it in paint and for the wrappings used to embalm mummies (Whistler and BeMiller 1993). Although traded throughout the middle ages, organised gum trade only started in earnest in Sudan in the 1820s and has increased in size ever since (Awouda 1988). Gum Arabic is labelled as safe to use in food items by the United States Food and Drug Administration (Dondain and Philips 1999) and enjoys a similar status in the European Union, where it is used under code E414 (Van Dalen 2006). It is used in the food industry as a stabilizer in soft drinks and in candy; in the pharmaceutical industry; and in industries such as printing, ceramics, and textile (Anderson and Weiping 1992, ICRAF 1992, Cunningham *et al.* 2008). The amount of gum used within the household is expected to be more or less fixed, but the amount that can be traded is practically limitless and it is therefore that these latter quantities can be expected to have the largest potential impact on poverty alleviation.

### **Research question**

This study investigates the socio-economics of gum Arabic marketed by households in Kenya and attempts to offer an explanation for the process determining observed marketed quantities. Gachathi and Eriksen (2011) have shown the potential gum Arabic can have in alleviating poverty. The resource is freely accessible, does not require large capital investments, and given the great variety of local uses, techniques required to collect it appear to be common knowledge. Mainly poor households are involved in its collection (Wekesa *et al.* 2010, Woldeamanuel *et al.* 2011), the areas in which it is found are among the poorest in Kenya, and it is available in the dry season, when other sources of income fall short (Oni and Gbadamosi 1998). And yet, it is commonly understood that the resource is underutilised (Chikamai and Odera 2002, Chretien *et al.* 2008, Gachathi and Eriksen 2011). In this paper a model is proposed that offers an explanation for the low observed marketed quantities.

Although it is known that mainly poor households are involved in gum Arabic collection (Chretien *et al.* 2008, Gachathi and Eriksen 2011), no previous work has described the socio-economic characteristics of these households and thus little is known about their main sources of income and how these are obtained. Therefore the first objective of this study was to describe these characteristics. The second objective was to discover the influence of these household-specific characteristics on the relative return to gum collection. In addition to household-specific characteristics, spatial characteristics such as insecurity and gum availability were hypothesised to have a strong influence on this relative return and hence were also accounted for. The final and main objective was to use this information to test an economic model that offers an explanation for the low observed marketed quantities of gum Arabic in Kenya.

The developed model and how it was tested is described below, followed by a description of how the data was employed. The used dataset is unique in its focus on the socio-economics of gum collection and marketing. Therefore, the data are described in some detail in the results section, before showing the results of the tests of the theoretical model. The paper will conclude with a summary of main research results, policy recommendations, and suggest areas for further research.

## METHODOLOGY

### Model

Marketed quantities of gum Arabic were analysed at household level. It was assumed that within each household, labour was allocated to maximise income, given traditional roles. The way labour was allocated to different activities is not necessarily identical from year to year, but always depends on the return to labour in each activity. To simplify the analysis, it was assumed households in the model could allocate labour to only two activities: livestock herding and gum Arabic collection. Livestock keeping was indicated to be the primary source of income of interviewed households, and hence the effect of livestock keeping on gum Arabic collection was expected to be larger than the effect of other income sources. The model covers only dry seasons. The production possibility frontier (PPF) shows potential output combinations households can choose from (Figure 1). It bends outwards from the origin because of the different specialisations of household members. For example, men, who are usually herding livestock, might not know the location of gum yielding trees and conversely, women might have less knowledge of migration routes and watering points. Total household output is therefore higher when a variety of outputs is produced. Income from livestock herding is shown on the horizontal axis and income from gum Arabic collection on the vertical axis. In a normal year, the PPF is presented by continuous line and the return to livestock herding exceeds the return to gum collection. Which level of output the household chooses depends on the relative prices of livestock and gum, represented by the relative price line (PP). Given

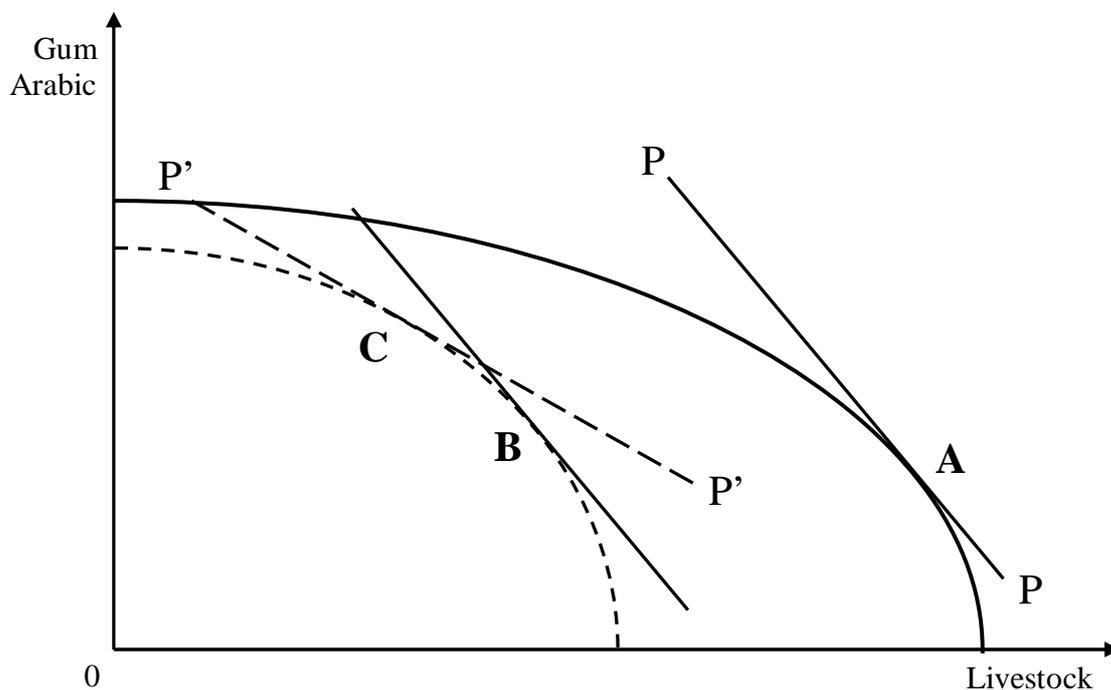


Figure 1: Production possibility frontier

these prices, the households' income maximising output in a normal year is at point A. In a drought year, the PPF shifts inwards: the return to labour falls in both livestock herding and gum Arabic collection. The fall in productivity is expected to be more extreme for livestock: not only is there less forage and water available, but in addition larger distances need to be covered to reach them (Schwartz *et al.* 1991, Coppock 1994, Schwartz 2005, Sadler *et al.*

2010). The shortage of rains reduces the amount of gum produced per tree (Dione 1989, Ballal *et al.* 2005), thereby lowering the quantity of gum that can be collected per unit of time and hence the return to labour in gum Arabic collection. Several authors found that in Kenya only a small part of the available gum is collected (Chikamai and Odera 2002, Chretien *et al.* 2008), which might reduce the strength of this effect. At constant prices, production moves to point B, with a sharp drop in livestock income and a slight increase in gum income. However, during droughts livestock prices fall as a consequence of oversupply caused by distress sales (Fafchamps and Gavian 1997, Barrett *et al.* 2003), causing the price line to rotate to PP'. Now, the new optimal production is at point C, where more gum is collected than in a year with normal rainfall, even though the absolute return to gum collection is lower.

Livestock is a productive asset used to provide households with blood, meat and especially milk, but also serves as a store of value (Barrett *et al.* 2003). During periods of drought, bleeding is reduced to limit stress on animals (Dahl and Hort 1976). Cattle are especially sensitive to rainfall, and produce significantly less milk in periods of little rainfall, sometimes not producing any milk at all (Schwartz and Schwartz 1985, Lesorogol 2008, Sadler *et al.* 2010). When droughts are severe enough, even camels may stop producing milk (Field 1979, Sperling 1987). With severe income reductions because of limited production from livestock, one would expect an increase in livestock sales to smooth consumption. However, several studies have found that consumption smoothing through livestock sales is far from perfect (Fafchamps and Gavian 1997, Fafchamps *et al.* 1998, Lybbert and McPeak 2011), implying that households have to substantially reduce consumption in periods of rainfall shortage. Because pastoralism is the most important source of income for households in the study sample, this fall in income from livestock during rainfall shortages is expected to encourage an increase in alternative income-generating activities, such as gum Arabic collection.

The model was tested using cross-sectional data. The final position on the PPF is determined by the relative price level. Unfortunately, no information was available on livestock prices, so only the gum Arabic price could be included. The shape of the PPF is household-specific, and depends on both the return to labour in gum collection and in livestock keeping. Because the data was cross-sectional, controlling for household-specific factors was not only necessary to allow unbiased estimation of the importance of shifts in the PPF, but also provided an insight into the relative importance of factors hypothesised to influence its shape. Regional gum availability was expected to increase the return to gum collection. Although it is likely that in areas with higher gum availability there were more collectors, this was not expected to outweigh the benefit of increased availability. More severe rainfall shortages were interpreted to indicate larger inward shifts of the PPF and stronger distortions in its shape, as rainfall shortages were expected to have a larger effect on the return to labour in livestock keeping than in gum collection. Finally, the insecurity situation prevailing in parts of the study area was expected to lower the return to both gum collection and livestock keeping, causing the PPF to shift inwards, and hence lower the quantity of gum collected for marketing.

Data were analysed in Stata 10 using linear regression analysis. Ordinary least squares (OLS) estimation was used to obtain parameter estimates (see Wooldridge (2006) for a detailed explanation of this technique). The dependent variable was the natural logarithm of marketed quantity in kilograms per household, because it was found to more closely approximate the normal distribution than the unmodified variable. The independent right-hand side variables were the factors hypothesised to determine which output allocation is chosen by the household.

$$y = \alpha + \beta_1 X_1 + \gamma_1 Z_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \gamma_2 Z_2 + \varepsilon$$

Where  $y$  is the natural logarithm of marketed quantity in kilograms per year,  $\alpha$  is a constant,  $X$  indicates an individual variable, and  $Z$  a vector of variables. Betas ( $\beta$ ) and gammas ( $\gamma$ ) indicate coefficients and vectors of coefficients respectively. Finally, epsilon ( $\epsilon$ ) is an error term.  $X_1$  was price;  $Z_1$  was a vector of household-specific variables hypothesised to influence the relative return to labour in gum collection and livestock keeping. It included household size, wealth, the number of female and male collectors, distance to preferred collection plot, and two binary variables equal to one when households used tapping or migrated with livestock.  $X_2$  was acacia area;  $X_3$  was rainfall shortage and measures the productivity potential of labour, or in model terms, the position of the PPF;  $X_4$  was insecurity; and finally,  $Z_2$  was a vector containing tribe dummies. These tribe dummies were included to control for cultural differences that might influence the relative return to labour in both activities, i.e. the shape of the PPF.

There were several concerns regarding the reliability of estimated coefficients. No data were available on the number of collectors in each region. Exclusion of this variable would induce omitted-variable bias unless so much gum was available that no de facto competition for the resource existed, i.e. when the availability constraint was non-binding. Although gum Arabic was thought to be underutilized, no studies have explicitly tested this assumption. Such omitted variable bias cannot be tested directly, but is one of the main causes of heteroskedasticity. All regressions were therefore tested for heteroskedasticity using the Breusch-Pagan test (Breusch and Pagan 1979). Another potential problem with the specified model was measurement error, especially in the measure for gum availability. Severe measurement error would induce inconsistency not only in the coefficient on the variable measured with error, but also affect other explanatory variables. This problem would be attenuated by finding an instrument for gum availability. However, no such instrument was available. The dependent variable might have suffered from measurement error because of rounding of recalled marketed quantities. The consequent increase in standard errors of the estimated coefficients of the explanatory variables would reduce their observed significance. Neither of the above mentioned concerns was expected to be severe enough to affect the sign of the estimated coefficients, however, care should be taken in interpreting their size.

## **Data**

### *Research context*

Most gum Arabic collection in Kenya takes place in the north, a vast area inhabited by several different tribes, the largest of which are the Turkana, Samburu and Rendille. These tribes are similar in many aspects, such as a common dependence on pastoralism, but the specific ways in which they interact with their environment are quite distinct. In the following subsections, each tribe will be discussed in some detail. Particular attention is given to herd composition, migration patterns, and labour allocation between household members. Furthermore, environmental and institutional trends that are believed to have a direct impact on lifestyles of local people will be discussed. This elaboration serves as an important background against which the results of this study will be interpreted and discussed. The sections draw heavily on the anthropological literature, but also contain contributions from various other disciplines.

### ***Turkana***

The Turkana consist out of several culturally homogeneous groups (Gulliver 1951) inhabiting the North Western part of Kenya, bordered by Sudan and Ethiopia in the north, lake Turkana

in the east, Baringo and Pokot district in the South, and Uganda in the west. The majority of Turkana are nomadic pastoralists, i.e. primarily dependent on livestock, living in an environment with marked seasonality and moving frequently to provide their herds with sufficient food and water (Gulliver 1955, Dyson-Hudson and Dyson-Hudson 1980). Livestock movements in Turkana are irregular, and differ between herders and seasons (McCabe 1994). Turkana move frequently and live in small household groups. McCabe (2004) calls them '*the most mobile of the nomadic people*'. An additional reason for frequently moving livestock is the fear of raids, which is widespread in the region and often causes movements into unfriendly and unknown territory (Pike 2004).

Herds are composed of cattle, camels, donkeys, goats and sheep, which each have different forage and water requirements (Schwartz and Schwartz 1985) and are managed differently. Such a multi-species composition allows households to make use of a wider range of resources (Galvin 1985) and diversify consumption risk (Lybbert and McPeak 2011). Animals provide milk, blood and meat, can be sold to finance household consumption and can be used as a store of value 'on the hoof' (Legge 1989). During the dry season income diversification becomes especially important, because reduced pasture productivity causes a drop in milk production and bleeding of animals is limited to reduce stress to animals (Dahl and Hort 1976). Income from herding is complemented with collection of gums and resins (Chikamai and Odera 2002, Watson and Van Binsbergen 2008), wild food resources (Watkins 2010), and occasional hunting (Broch-Due 1999). Yet another source of income is relief assistance which has been provided nearly continuously in Turkana district since 1999, and includes the distribution of free food, therapeutic feeding programmes, workfare schemes and cash and voucher interventions (Lind 2005). According to a recent Oxfam (2006) study, food aid from household entitlements and school feeding was the second most important source of food in Turkana in the year 2005.

## **Samburu**

The Samburu homelands are at the southern end of Lake Turkana, at the edge of Kenya's highlands and lowlands. About 95% of all 235,000 Samburu people (Kenya National Bureau of Statistics 2010) live within the borders of Samburu county, bordered by Rendille people to the north, Boran to the south and east, and Turkana to the west and northwest. The tribe is closely related to the Masaai, and share a common language and preference for cattle (Spencer 2004).

Cattle herds are kept close to home, usually in combination with sheep and goats. Since the 1980s wealthier households have started including camels in their herds (Sperling 1987). Camels are valued for their ability to produce milk even in the dry season (Spencer 1973), but uptake used to be restricted due to high upfront capital costs and limited knowledge about their tending requirements, which are quite distinct from those of cattle, sheep and goats (Field 1979). Samburu households migrate independently (Spencer 1973). Historically households would migrate several times a year with their herds to available pastures, but recently a more sedentary semi-nomadic lifestyle has been adopted by most (Spencer 2004). In the dry season, when cattle does not produce milk, it is moved to satellite camps, herded by young men, while the rest of the household stays in the home settlement (Lesorogol 2008).

Milk, blood and meat are the main components of the traditional diet, complemented with wild foods obtained through collection or trade with neighbours (Holtzman 2007). Home consumption of milk and sale of animals was found to be the primary source of income for wealthier households by Lesorogol (2008). Poorer households were more dependent on wage labour and trade. Several authors mentioned trade in timber, firewood, charcoal, hides and skins, alcohol and other petty trade (Little *et al.* 2001, Lesorogol 2005, Lesorogol *et al.*

2011). Small scale production of locally consumed products such as beer takes place among poorer households (Smith and Little 2002). Wage labour is increasingly an important factor in household income. Better paid jobs, such as policeman or civil servant, are generally more secure. As a result, diversification of household income sources is lower for such households (Lesorogol 2005). Samburu is the only district in this study where attempts were made to register land holdings. Immediately after independence land was allocated to so-called group ranches, which excluded sheep and goats from using rangelands, and thereby forced poorer families which owned fewer cattle to move to less favourable pastures. In the 1970s and 80s these group ranches were subdivided into individual land holdings (Fratkin 1994).

## **Rendille**

Most of the 60,000 Rendille (Kenya National Bureau of Statistics 2010) live in Marsabit district, which is bordered by Ethiopia to the north, Wajir district to the east, Isiolo district to the southeast, Samburu district to the southeast and lake Turkana to the west. Marsabit is also home to the Gabbra and Boran, who inhabit the entire range from Ethiopia into Isiolo, and parts of various other tribes, such as the Sakuye, Ajuran and Degodia Somali whose homelands lie further to the east (Schwartz *et al.* 1991). In the south of the district Ariaal Rendille, a relatively recent tribe which is a hybrid of Samburu and Rendille culture are found. Spencer (1973) finds them undistinguishable from Rendille proper, apart from their age system (described in Spencer (2004)), which is Samburu. In this study, no distinction will be made between Ariaal Rendille and Rendille proper, and they will jointly be referred to as Rendille. Interestingly, and unlike any of their neighbours, Rendille are monogamous, resulting in smaller households and lower population growth (Spencer 1973).

Camels are the most important component of Rendille herds, and valued for their ability to produce milk year-round. Rendille camels are sturdy and well adapted to the extremely harsh environment (Schwartz 1979). Most households additionally have a stock of sheep and goats, which are kept for their meat and to sell at the market. Camels are usually kept in satellite camps close to permanent settlements (Schwartz and Schwartz 1985). During dry seasons, pasture around permanent settlements depletes rapidly, forcing movement of most of the camel herd to fresh pasture. From there, biweekly trips are made to water holes, which can be up to sixty kilometres away. A small group of lactating camels is usually kept close to the settlement, to provide women, children and older men with milk. Smallstock is far less mobile than camels, and when settlement pastures deplete, are required to move to waterholes where pastures are still fresh. These movements usually take place in groups of herders, since Samburu often attempt to steal animals (Schwartz *et al.* 1991). Groups consist largely out of girls, accompanied by elders, warriors and boys. Herds of only sheep and goats (smallstock) can be driven over distances of 100 or 200 kilometres (Schwartz *et al.* 1991). Roth (1990) found herds started including more cattle as a consequence of the high commercial value of beef and the active push for cattle by various development agencies

In colonial times, policies were developed that allotted fixed grazing areas to different tribes, to reduce tribal conflict. Such policies were continued after independence. As a direct consequence, pastoral mobility was severely reduced (Sobania 1988, O'Leary 1990). Sobania (1988) estimated that the Rendille home range shrank from 57,600 to 8,000 square kilometres over the period 1920 to 1980. This reduced mobility is believed to have increased livestock losses due to drought (Roth 1990, Roth and Fratkin 1991) and consequently increased the rate of sedentarisation. Following the droughts of 1968-73, famine relief missions added to this trend by providing a year-round source of food and also water, through the permanent water holes that were created alongside them (Fratkin 1991, Roth and Fratkin 1991, Fratkin 1992, Smith 1998). Over the last decades, settlements have moved closer to towns, and diets have become more dependent on maize instead of milk (Fratkin *et al.* 2004). This increased

dependency on maize can be explained by its positive caloric terms of trade with milk given low enough transaction costs (Zaal and Dietz 1999). Moving closer to towns also increases opportunities for milk marketing, especially when settlements are within walking distance from towns (McPeak and Doss 2006).

#### *Data collection*

The study area comprised Turkana, Marsabit, Samburu, Isiolo and Mandera County<sup>1</sup> in northern Kenya. Communities were selected in regions where Acacia Senegal and Seyal were frequently occurring and where their gum was actively collected (Beentje 1994, Chikamai and Gachathi 1994, Chikamai and Odera 2002). Baringo, Mwingi, Wajir and Garissa County also contained gum-yielding trees but were excluded from the survey. Although some gum collection and trade was taking place in these regions, this happened on a much smaller scale than in selected counties.

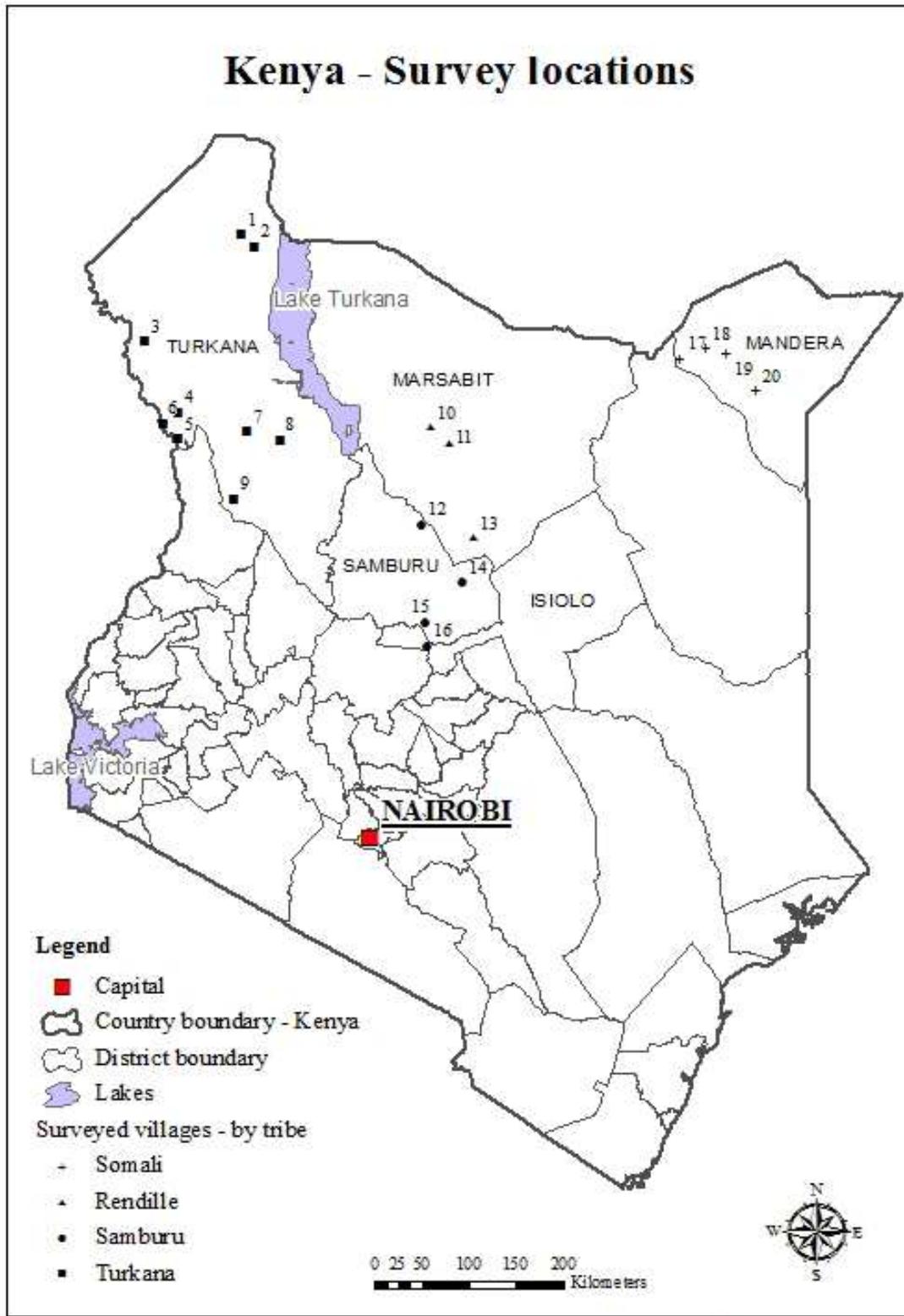
The five included counties were among the poorest in Kenya, with the share of people living below the national poverty line ranging from 71.6% in Samburu to a staggering 94.3% in Turkana (GOK 2007). They were also thinly populated, with population densities ranging from 4.10 in Marsabit to 39.37 inhabitants per square kilometre in Mandera (GOK 2010).

No accurate map containing the location of each village in the area was available. Communities were selected by driving through areas where gum was said to be collected and asking along the road whether particular branches were leading to a settlement. Care was taken to select villages at different distances from main roads. When a village was encountered, but residents indicated nobody there was involved in Arabic gum collection, it was excluded from the survey. A total of 20 villages was located this way and included in the study ( Figure 2). Names of villages are provided in the appendix.

Household-specific data was collected in August-September 2009 as part of the Acacia gum project using a pre-tested semi-structured questionnaire. Data cover the long dry season of 2009. In addition, marketed quantities and received prices in the preceding short dry season were obtained by recall. Up to 21 households were interviewed per village, giving a total of 204 respondents. The data consist of three main parts: respondent and household characteristics, gum collection, and gum marketing. All data were collected by Gaudiose Mujawamariya with assistance from the Kenya Forestry Research Institute (KEFRI). Although the dataset was unique in the broadness of information it provided on characteristics of individuals and households involved in collection, as well as a range of factors influencing characteristics were collected on an individual level rather than household level. Therefore, these variables could not be used to compare households. Second, no household income data was available. Even though the dataset contains information on income sources and their relative importance, there is no information on their size. This is unfortunate, because information on the size of income from livestock herding would have allowed direct testing of the assumption that rainfall shortage has a larger effect on the return to labour in livestock herding than in gum collection. Third, no village level data was collected. As the quantity available per individual household is directly dependent on the number of collecting households, given that the quantity available is fixed, this is a potentially serious shortcoming which might cause omitted variable bias if gum availability is a binding constraint to increasing quantity collected. Fourth, no information is available on non-collecting households, a form of selection bias. Furthermore, this omission prevents statements about the position of gum collectors in the population as a whole, especially

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<sup>1</sup> These counties were called districts before an administrative change in 2009. Currently, each county consists out of several districts.



Cartography: W. Vellema, 2012  
Data sources: World Resources Institute (WRI)

**Figure 2: Location of surveyed villages**

because information on total income was unavailable. This is particularly unfortunate because the poverty alleviation potential of gum is measured not only by the size of its contribution to collecting households, but also by the number of collecting households. The results of this study can therefore only be applied to the former.

### *Variables*

The variables price, number of female and male collectors, distance from preferred plot in minutes, and whether or not a household used tapping or migrated with livestock were taken directly from the data. A binary variable to measure insecurity was constructed, which equalled one when collectors indicated insecurity was their primary concern when collecting gum. Tribe dummies equalled one when a respondent belonged to a particular tribe. The variables on household size and wealth were not directly measured but could be constructed from the data. The dataset contained information on the number of adults and children in each household. In order to compare households of different composition, an adult equivalent (AE) scale was constructed. This measure scales the consumption level of household members of different ages to the equivalent consumption level of an adult. Following Deaton and Zaidi (1999),  $AE = (A + \alpha K)^\theta$ , where A refers to adults, K to children and  $\alpha$  and  $\theta$  are weights. For low-income households where most income is spent on food items as was the case in our sample, Deaton and Muelbauer (1986) and Deaton (1997) recommended setting  $\alpha = 0.3$  and  $\theta = 0.9$ . This variable was used to measure household size. The final variable constructed from the survey data was a measure of wealth.

Wealth is an important indicator of the degree in which households rely on non-timber forest products (Timko *et al.* 2010). Income measurement in developing countries is complicated by substantial self-sufficiency of households. Sahn and Stifel (2000, 2003) proposed a measure of poverty based on an asset index, and found it to outperform more traditional expenditure indices in predicting the nutritional status of households. The authors identified three groups of assets: household durables, housing quality, and human capital. The survey data contained information on household durables such as radios, transport means, and telephones. The number of houses was used as a measure of housing quality. Traditionally, each wife has her own house, and hence several households had multiple houses in their homestead or ‘Kenyatta’ (Spencer 1973). Years of education was used as a measure of human capital. In the study area, the majority of households was dependent on pastoralism, and hence livestock was their most important and valuable asset (McPeak 2004, Lybbert and McPeak 2011). It was therefore deemed important to include in the asset index. However, herds differed substantially in composition for both cultural and ecological reasons. To compare herds of different composition, livestock holdings are commonly converted into tropical livestock units (TLU) (FAO 1972). This concept is based on the metabolic weights of animals. It was found to be a good base of comparison for animals of different species, whether the variable of interest was feed intake, manure produced, or product produced. The following conversion factors were considered appropriate for the Sahel region: 1 TLU = 1 cattle = 1.25 camel = 10 smallstock (Dahl and Hort 1976). For donkeys, a factor of 1 TLU = 2 donkeys was used (Houerou and Hoste 1977). This TLU measure was combined with data on household durables, housing quality, and human capital to construct an asset index. Prices are often used as weights for the contribution of each asset to the index, however, in the absence of well-functioning markets such information is hard to obtain and likely to be inaccurate. Therefore, Sahn and Stifel (2003) suggested factor analysis to determine weights (see Lawley and Maxwell (1971) for an explanation of the technique). The final value of the index for household  $i$  is the sum of the weights times the different assets owned by the household:  $Index_i = \sum_{j=1}^m w_{ij} a_{ij}$ . Where  $w$  are weights and  $a$  are assets  $j = 1, \dots, m$ . To

complement information from the household level survey, rainfall shortage and gum availability variables were constructed using secondary GIS data.

The difference between actual rainfall and long run average rainfall was used as an indicator of the weather conditions. Rainfall data were obtained from the Famine Early Warning Systems Network (FEWS NET) funded by USAID. The survey data described above covered the short and long dry seasons of 2009 and hence rainfall data from the preceding rainy seasons was used. Actual rainfall was subtracted from average rainfall in these seasons over the period 2005-2009 for an area of 10 kilometres around each village using ArcMap 10, such that a positive value of the variable indicated rainfall shortage in millimetres.

To control for the availability of gum Arabic in areas surrounding included settlements, a variable called Acacia area was constructed. No current information was available on the gum producing potential of natural areas. However, as an extension of the UNESCO funded Integrated Project for Arid Lands (IPAL), the German development organisation (GTZ)<sup>2</sup> conducted a study on traditional grazing systems in Northern Kenya to improve natural resource management (Oba 1992). Produced output included GIS data on land cover in northern Kenya. Although the data were quite old, this did not affect its usefulness for our purposes. Vegetation types found in a region are determined by landscape and climate characteristics, factors which do not change within a time span of decades (White 1983). The construction of the variable is discussed in the results section.

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<sup>2</sup> Deutsche Gesellschaft für Technische Zusammenarbeit

## RESULTS

### Data description

Descriptive statistics of variables relevant for gum Arabic collection are presented in Table 1. Households in the sample made on average 2082 Kenyan Shilling (KSH) from marketing gum. In 2006, the rural poverty level was 1562 KSH and the rural food poverty level 988 KSH per adult equivalent (GOK 2007), which are likely to have increased since because of inflation. As average adult equivalent family size in the sample was 3.3, during the study period gum Arabic revenues alone were insufficient to raise household income above even the rural food poverty level. Marketed quantities were low at 44.3 kilograms yearly. Based on the expected daily quantities in the sample, it should have taken an individual collector on average around 14 days to collect the observed quantities. It appears that the poverty alleviation potential of gum was severely underutilised. In most households several people were involved in collection, with an almost equal share of female and male collectors. Average distance to preferred plots was two and a half hours. These distances are impressive given the extreme climate, with temperatures reaching 40°C in the dry season. Because most collectors preferred not to spend the night in the field (field observation), these travel distances severely restricted the amount of time available for collection. Tapping was not common. Only 14% of households indicated to use tapping, and of those only few used specialised tapping tools. Several households indicated damaging the tree by hitting it with a

Variable	Mean	SD
Income	2082	3558.4
Price (KSH)	38.8	7.6
Yearly quantity (kg)	44.3	19.8
Exp. daily quantity (kg)	3.2	2.4
Adult equivalent HH size	3.3	1.2
Women collecting	1.2	1.1
Men collecting	1.1	1.1
Distance in minutes	151	112.5
% tap	14%	-
% migrating	56%	-
Duration of migration*	4.3	2.2
% mentioning insecurity	21%	-

**Table 1: Household-specific descriptive statistics**

*Note: n=201, \* of migrating households. Data source: Acaciagum Project*

stick, others used their knife. The low occurrence of tapping might be explained by the lack of property rights for trees. All interviewed households indicated that the plots where they collected gum were communally owned. Because there are several days between making the cut and collecting the gum, the risk of other collectors taking the gum is substantial, especially due to the presence of migrating herders. Of the interviewed households, 56% practised some form of migration, and one household migrated year-round. Most livestock migration takes place in the dry season, in search for available pasture and water. Traditionally, men and boys are responsible for cattle and camels, while women and girls take care of smallstock. Migration could therefore reduce both male and female household

labour available for gum Arabic collection. Insecurity shows the percentage of households that indicated insecurity was their primary concern when collecting gum. In Turkana, where cattle raiding was part of the culture (Pike 2004) and in Mandera, a region bordered by southern Somalia and Ethiopia, where Al-Shabaab - a Jihadist organization with international ambitions - has staged killings and kidnappings since the 1990s (Marchal 2009), households more frequently mentioned security concerns.

A summary of average household asset ownership is given in Table 2. Average asset holdings were small: the only asset every household was found to own is a house. As polygamy is practiced by all tribes except the Rendille, and it is customary to provide every wife with their own house, households owned multiple houses. Pratt and Gwynne (1977) estimated that 4.5 TLU per adult household member could provide a household with just sufficient food for survival. Based on that measure, average livestock holdings in the sample were below subsistence level. Given average household size, the majority of households would need three times as much livestock to reach this subsistence level. The constructed wealth index averaged zero and ranged from -0.536 to 3.269. Wealth was unevenly distributed. Almost 80% of the observations scored below zero on the wealth index.

Variable	Mean	SD	Min	Max
Houses	1.08	0.36	0	4
Radio	0.15	0.37	0	2
Telephone	0.09	-	0	1
Transport means	0.07	-	0	1
Years of education	0.59	2.02	0	12
TLU	4.73	7.65	0	62
Wealth index	0.00	0.80	-0.54	3.27

**Table 2: Household asset ownership**

*Note: n=201. Data source: Acaciagum project*

Income source	Primary	Secondary
Commerce	5	6
Agriculture	0	0
Pastoralism	154	32
Wage	1	4
Wood products	2	74
Arabic gum	33	68
Remittances	0	0
Relief	9	19
Non-wood products	0	1

**Table 3: Reported sources of income**

*Note: n=201. Data source: Acaciagum Project*

Data were also collected on the main sources of household income, although time and resources did not allow for quantification. The main source of income in the study region is pastoralism (Table 3). For over 75% of interviewed households, pastoralism had the largest contribution to their income. Arabic gum and wood products had the second-largest contribution. This importance of gum Arabic for interviewed households appears to suffer from social desirability bias (Grimm 2010), as the average quantity of gum Arabic marketed by households reporting it to be their primary source of income was 47,5 kilograms, insufficient for subsistence and not significantly different from the average of households not reporting it as their primary source of income. Similarly, it might be that obtaining an income from wood products such as charcoal was considered to be socially undesirable, which would result in underreporting. The predominance of pastoralism as a source of income is confirmed by other authors on the region, and was therefore expected to be relatively reliable. The importance of livestock keeping fits well with our model. Relief, mostly in the form of food aid but also through other means such as cash for work schemes, is common in northern Kenya and has taken structural forms. In 1999, half the people in Turkana county are estimated to have received food aid, a situation which is expected to continue (Lind 2005). Given this institutionalisation of relief, it is surprising that only few interviewed households indicate a sizeable dependency on aid. Another surprising finding is that none of the households mentioned agriculture as an important source of income, especially given the context of ongoing sedentarisation in the region. This finding might be explained by the fact that home consumption was not specifically accounted for, thereby excluding home gardens from being classified as agriculture. Moreover, commercial agriculture may simply not be feasible in areas where Arabic gum-yielding tree varieties are found, which typically have poor soils with low moisture content (Chiveu *et al.* 2008).

The IPAL project data from northern Kenya collected by GTZ classified the various vegetation types into eight physical classes: barren land, bush land, dwarf shrub grassland, forest, grassland, shrub land, wood land, and water. The distribution of these physical classes

Vegetation Class	Most commonly encountered species	Physical Class
8.3	Lintonia - A. Senegal	Grassland
14.15	A. Senegal - Commiphora - Boswellia	Bush land
14.2	A. Senegal - A. Mellifera - Commiphora	Bush land
14.8	Commiphora - A. Senegal - Grewia	Bush land
16.5	Tetrapogon - Aristida - A. Tortilis - A. Senegal	Grassland
16.6	Aristida - Tetrapogon - A. Tortilis - A. Senegal - A. Reficiens	Grassland
20.17	A. Reficiens - A. Senegal	Shrub land
20.8	A. Senegal	Shrub land
21.1	Sporobolus - misc. Acacia species	Grassland
22.13	Aristida - Indigofera - A. Senegal	Grassland
22.15	Aristida Indigofera - A. Tortilis - A. Senegal - A. Reficiens	Grassland
22.17	Aristida - Indigofera - A. Tortilis - A. Senegal - A. Reficiens	Grassland

**Table 4: Vegetation types containing *Acacia Senegal***

*Data source: GTZ*

Variable	Coeff.
Vegetation 8.3	107.953** (2.55)
Vegetation 14.15	-59.779 (-0.82)
Vegetation 14.2	-10.200 (-1.24)
Vegetation 14.8	38.626*** (2.73)
Vegetation 16.5	67.422** (2.27)
Vegetation 16.6	-8.554 (-1.41)
Vegetation 20.17	-16.026 (-1.57)
Vegetation 20.8	24.004 (0.72)
Vegetation 21.1	13.505* (1.77)
Vegetation 22.13	57.756** (2.11)
Vegetation 22.15	10.860 (1.15)
Vegetation 22.17	12.587* (1.96)
Tapping	0.618 (1.15)
Insecurity	-0.836 (-1.57)
Constant	2.800*** (6.59)
Observations	201
Adjusted R-squared	0.103

**Table 5: Expected daily quantity of gum Arabic**

*Note: Dependent variable is expected quantity per day in kilograms.  
T-statistics in parentheses: \* Significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%*

over the study area is shown on the map ‘Kenya – Physical classes’ in appendix 2. For each area of a particular physical class, the most commonly found species were identified, creating a total of 77 distinct vegetation classes. In twelve of these vegetation classes, *Acacia Senegal* was among the most common species (Table 4). Nowhere in the data was mention

made of *Acacia Seyal*. To measure the access to gum Arabic producing trees, these areas needed to be converted into quantities. Therefore, the share of the area covered by each vegetation type within a 15 kilometre radius around included villages was constructed using ArcMap 10. Fifteen kilometres was considered the maximum distance that could be covered within one day for collectors returning to the settlement before nightfall<sup>3</sup>. The distribution of *Acacia Senegal* containing vegetation types within the 15 kilometre radii is shown on the map ‘Kenya – Vegetation containing *Acacia Senegal*’ in appendix 2.

The density of gum yielding trees within the selected vegetation types is not known, and hence a uniform and identical distribution of trees for each of these twelve types had to be assumed. In other words, all areas containing vegetation type 8.3 were assumed to have the same number of gum-producing trees per hectare. This assumption is somewhat restrictive, but impossible to avoid given data limitations. It is still possible to establish a degree of differentiation in densities between different vegetation types. To this end, a regression was run using all twelve selected vegetation types as explanatory variables. The dependent variable was the average daily quantity an individual expected to collect and came from the socio-economic survey. This quantity was expected to be determined both by regional gum availability as well as factors influencing the return per hour of labour in gum collection, such as tapping and insecurity. Regression results are presented in Table 5. Vegetation types 8.3, 14.8, 16.5, 21.1, 22.13 and 22.17 had a significant effect on expected daily quantity. The sign on all of these significant vegetation variables was positive, indicating presence of either of these vegetation types increases the daily quantity an individual expected to collect. Vegetation types 14.15, 14.2, 16.6, 20.17, 20.8 and 22.15 had no significant effect on expected quantity. This result might be explained by the low density with which gum producing trees were found in these areas. Although tapping and insecurity had the expected sign, they were insignificant. A variable called acacia area was constructed by taking the un-weighted sum of the significant vegetation variables, in effect assuming the density of gum-producing trees was the same in each of these vegetation types. This constructed variable was included in the regressions described in the section below and shown in Table 6, together with the constructed rainfall shortage variable.

Village name	Acacia area	Rainfall shortage	Village name	Acacia area	Rainfall shortage
Kakilai	0.08	102.7	Kargi	0.00	63.7
Kariabur	0.22	114.5	Ngurunit	0.00	70.8
Loritit	0.02	32.8	Laisamis	0.00	41.6
Namoroputh	0.37	9.0	Sereolipi	0.00	81.2
Lorengippi	0.42	-6.4	WestGate	0.20	75.4
Lokiriama	0.08	9.3	Ngarendare	0.32	118.6
Kasuroi	0.50	18.0	EIDanaba	0.06	48.5
Nakukulas	0.25	4.4	Gither	0.05	56.8
Kakongu	0.58	-5.8	Takaba	0.10	47.8
Kurkum	0.00	72.3	ShimbirFatuma	0.00	121.3

**Table 6: Acacia area and rainfall shortage variables**

<sup>3</sup> In the sample, 73% of households stayed within three hours walking distance from the village.

## Regression results

Results of regressions on marketed quantity are shown in Table 7. In the first regression only explanatory variables from survey data collected as part of the Acaciagum Project were included, as these were expected to suffer less from measurement error, and thereby provide a means of comparison for results of subsequent regressions. In the second regression tribe dummies were included to check for the existence of regional and cultural differences on gum Arabic collection. In the third regression variables constructed from GIS data - Acacia area and Rainfall shortage - were included. All regressions were estimated using OLS and checked for heteroskedasticity using the Breusch-Pagan/Cook-Weisberg test. Based on this test none of the regressions appeared to suffer from heteroskedasticity problems and hence results of these tests are not included in results tables nor discussed.

The effects of price, household-specific characteristics, and insecurity on marketed quantities are shown in the first regression. The coefficient on price is not significant. The included price variable was the actual price received by the collectors at the time of sale. This insignificance is unsurprising given the cross-sectional nature of the data. Household size in adult equivalent units is a scaling variable. Larger households have higher consumption and more labour available, and therefore their PPF would be higher for both gum collection and livestock keeping. Because marketed quantities were measured on a household level, the coefficient on household size was expected to be positive. This hypothesised relationship was not significant. Wealth had a significant positive effect on the marketed quantity of gum. The strength of this relationship declines for increasing levels of wealth, which is evident from the negative sign on the squared term. At values of the wealth index above one, marketed quantities started to fall with increasing levels of wealth. Around 10 percent of sample households fell into this category. Households on either side of this wealth threshold were compared using independent sample t-tests. The two groups differed significantly only in their sources of income. Households with a wealth index score above one were more likely to derive their income from commerce or wage labour. Wealth index and its square are jointly significant in all regressions ( $p$ -value = 0.0049, 0.0170, and 0.0299). This relationship was not affected by the inclusion of additional explanatory variables (regression 2 and 3) and the size of the coefficients was comparable. The size of the coefficients cannot be interpreted directly, because of the way the wealth index was constructed. One additional female collector increased the marketed quantity collected by around 16%. However, this relationship is not very robust and disappears when the regional dummies are included. The number of male collectors, the distance to the plot where gum was most frequently collected, and whether tapping was used did not have a significant effect on marketed quantities either. Migration with livestock had no significant effect in the first regression. Insecurity was highly significant and had a large negative effect on gum collected for marketing. The size of the coefficient should be interpreted with some caution. It appears insecurity caused a fall in marketed quantity of over 60%. However, insecurity was a very regional problem, primarily affecting Turkana and the border region with Somalia. Therefore, if these regions differed in more aspects than just the level of security, the coefficient might have been biased.

In the second regression differences between regions were explicitly taken into account by including the tribe dummies Turkana, Samburu and Somali, with Rendille as the base group. These dummies measure both cultural as well as other regional differences, as the tribes lived in clearly defined geographical regions (Figure 1). The dummies were jointly significant ( $p$ -value = 0.0032), justifying their inclusion. By their inclusion, migration became significant, and insecurity was no longer significant. The latter effect was most likely due to the localised nature of insecurity. It was only mentioned as a concern by Turkana and Somali. The significance of migration once tribe dummies were included can be

Variables	Unit	Regressions		
		(1)	(2)	(3)
Price	KSH per kg	-0.007 (-0.78)	-0.011 (-1.21)	-0.011 (-1.31)
Household size	Adult equivalents	0.006 (0.08)	0.007 (0.11)	-0.002 (-0.03)
Wealth	Index	0.816*** (3.15)	0.694*** (2.68)	0.555** (2.23)
Wealth squared	Index	-0.404*** (-3.29)	-0.351*** (-2.89)	-0.306*** (-2.64)
Female collectors	Number	0.162* (1.96)	0.085 (1.01)	0.049 (0.61)
Male collectors	Number	-0.109 (-1.33)	-0.059 (-0.72)	-0.092 (-1.17)
Distance	Minutes	0.000 (0.56)	0.000 (0.58)	0.001 (1.12)
Tapping	Dummy	-0.322 (-1.31)	-0.238 (-0.99)	-0.102 (-0.43)
Migrating	Dummy	-0.202 (-1.12)	-0.391** (-2.12)	-0.441** (-2.50)
Acacia area	Ratio			2.305*** (2.71)
Rainfall shortage	Millimetres			0.014*** (4.36)
Insecurity	Dummy	-0.673*** (-3.06)	-0.298 (-1.26)	-0.398* (-1.72)
Turkana	Dummy		-0.912*** (-3.68)	-0.820*** (-3.04)
Samburu	Dummy		-0.229 (-1.05)	-0.580*** (-2.61)
Somali	Dummy		-0.408 (-0.95)	-0.524 (-1.29)
Constant		3.914*** (7.43)	4.525*** (8.39)	3.748*** (6.94)
Observations		201	201	201
Adjusted R-squared		0.082	0.134	0.218

**Table 7: Determinants of marketed quantities**

*Note: Dependent variable is the natural logarithm of marketed quantity per household. T-statistics in parentheses: \* Significant at 10%; \*\* significant at 5%; \*\*\* significant at 1%*

explained by the stark difference in migration patterns between tribes, resulting in different labour requirements. These migration patterns depend not only on cultural differences but also on the vicinity of dry season pastures and water points. Migration had a negative effect on collected quantity, as migrations are labour intensive, leaving less time to collect gum. Although some gum was collected during migrations, most of this is directly eaten (field observation).

The third regression included the GIS variables Acacia area and rainfall shortage. Acacia area was a sum of all vegetation types that had a significant effect on the daily quantity an individual expected to collect. The coefficient on Acacia area was positive and highly significant. In areas where *Acacia Senegal* and *Seyal* were bountiful, households collected more gum. When larger areas containing gum-yielding trees are found around the village, more gum can be collected per unit of time, increasing the return to labour in gum collection. Rainfall shortage had a positive and significant coefficient, which indicated that when rainfall is below average, quantity marketed per individual collector increased. It appears that rainfall shortages reduced the return to livestock keeping by more than the return to gum collection, increasing the relative attractiveness of the latter. The importance of this effect is large: in regions where rainfall fell short by the sample average of 54 mm, marketed quantities were 75% higher. This finding provides evidence for the hypothesis that gum collection is primarily a complementary source of income, which is especially relevant when other sources of income fall short. Sign, size and significance of the household-specific variables were comparable to earlier regressions. Insecurity was significant in the third regression, albeit only at 10%. This variable, because of its localised nature, appears to have picked up a lot of spatial variation. Once the effects of acacia area and rainfall shortage were taken into account, this clutter disappeared. Finally, the tribe dummies are jointly highly significant. The negative and significant sign on Turkana and Samburu implies marketed quantities in these tribes were lower than for other tribes, even after taking into account differences in prices, household-specific attributes, insecurity, acacia occurrence and rainfall. No explanation for this effect could be offered on the basis of results.

## DISCUSSION

Earlier studies on non-timber forest products (NTFPs) found them to have a significant contribution to income (Neumann and Hirsch 2000, Shackleton and Shackleton 2004). This study was the first to quantify actual income generated by gum Arabic in Kenya, and results indicate its contribution to household income is low. In Ethiopia, gums and resins were found to contribute around 30% to household income (Woldeamanuel *et al.* 2011). However, findings are not directly comparable because in this study no data were collected on income generated by sale of resins such as frankincense, myrrh and haggar, which were also marketed in the region, albeit on a smaller scale (Chikamai and Odera 2002). Observed prices were comparable to prices found in an earlier study by Gachathi and Eriksen (2011). The contribution of gum Arabic to income could be increased by increasing marketed quantities, which were found to be low. Given the average number of collectors per household and the daily quantity individuals expected to collect, these low observed quantities could imply either only very few days were spent collecting, which could be explained by the resource being in short supply. However, the resource is considered to be underutilized by most authors (Chikamai and Odera 2002, Frayer 2007). An alternative explanation is offered by Chretien *et al.* (2008), who find that gum collection is usually combined with other household activities, such as collecting firewood, herding livestock or looking for water, which would result in actual daily quantities collected to be much lower than reported expected quantities. On average, households had almost the same number of male and female collectors, a finding which contrasts with earlier studies, which found women and girls to be the main collectors (Wekesa *et al.* 2010, Gachathi and Eriksen 2011). Gum productivity of trees can be improved by tapping, however, this technique was hardly employed. When households did tap, they often used sticks or their own knife rather than specialised tools, a finding in line with results from Wekesa *et al.* (2010). The low observed marketed quantities are most likely a result of the low return using current collection methods and given current market prices, combined with the effort involved in collection, due to high temperatures and long travel distances.

The most important source of household income of interviewed households was pastoralism, followed by wood products and gum Arabic. Pastoralism was the traditional source of income in the region, and is still commonly found to be the most important, even in the context of ongoing sedentarisation (Heald 1999, Fratkin 2008, Little *et al.* 2008). Interviewed gum collectors also indicated to be mainly dependent on pastoralism, although observed livestock holdings were generally far below subsistence levels, indicating the reliance of households on multiple income sources. Income was complemented by forest products, both wood products and gum Arabic. The importance of wood products for income generation is cause for concern, as it is an indicator of deforestation, which is especially a threat in environments with population pressure and without property rights (Geist and Lambin 2002, Sunderlin *et al.* 2005). Respondents indicated all plots where gum Arabic was collected were had unrestricted access. Although free access is important for non-timber forest products to provide a green social insurance (Cunningham *et al.* 2008), it also encourages overuse (Hardin 1968). Deforestation threatens the productivity of livestock, because during the dry season trees are the most important source of fodder (Barrow 1990). Moreover, decreasing tree cover reduces the availability of gum Arabic, which has the potential to contribute substantially and sustainably to household income (Gachathi and Eriksen 2011).

Rainfall was found to have a significant and large effect on marketed quantities of gum Arabic. The effect of rainfall on marketed quantities was negative – when rainfall was below its long-run average, households offered more gum for sale. The model suggested in this study offers an explanation for this observation. The marketed quantity depends on the

return in gum collection relative to the return in other activities. Rainfall shortages lower gum productivity of trees (Dione 1989, Ballal *et al.* 2005), but if rainfall has a stronger effect on the return to alternative activities such as livestock keeping than on the return to gum collection, rainfall shortages increase the relative attractiveness of gum collection, and hence observed marketed quantities. The price of gum Arabic in monetary terms was not found to have any discernible effect on marketed quantities. Although the theoretical model was in terms of relative prices, the monetary price would be expected to have an effect in itself if the sample contained a large share of opportunists, which Gachathi and Eriksen (2011) described as emerging. The results of this study do not support the importance of this group and hence it is concluded that most gum Arabic appeared to be collected by households in need. The almost universal fall in productivity on livelihood activities during rainfall shortages lowers total household income, which is evident from the upsurge in food aid dispensed to the region in such periods (Lind 2005). The concurrent increase in marketed quantities of gum Arabic found in this study provide support to earlier studies on the important safety net function of NTFPs (Byron and Arnold 1999, McSweeney 2004).

Wealth and whether or not a household migrated with livestock were found to be the most important household-specific determinants of marketed quantity. Household size, plot distance, tapping or the number of collectors in the household did not have any discernible effects. No monetary values for wealth of interviewed households were available. However, from the low observed asset ownership most appear to have been quite poor. This finding is in line with previous work, where it was also found mostly poor households are involved in collection (see Timko *et al.* (2010) for an overview). Results from this study indicated the size of the contribution varied with wealth: marketed quantities increased with wealth until a threshold, after which they started to decrease. The increase is in line with findings in a recent study on non-timber forest products in Nepal (Gauli and Hauser 2011) and earlier work in Cameroon (Ambrose-Oji 2003). This result might be explained by the thin market for gum Arabic in Kenya, where trader visits are infrequent and uncertain (Chretien *et al.* 2008). Poor households have less capacity to cope with such market uncertainty than wealthier households, limiting the extent of their market participation, indicating that increased market access would enhance poverty alleviation capacity (Belcher and Schreckenberg 2007). The observed decrease in marketed quantities for household above a certain threshold might be explained by the low return to gum collection, which makes participation only relevant for households in need. This is supported by our finding that households above the wealth threshold were more likely to be involved in wage labour or commerce: activities which are less susceptible to the negative effect of droughts. Migration was also found to have a significant effect on marketed quantities. Migrating households marketed less gum. Because most migration takes place in the dry season (Schwartz *et al.* 1991) it competes directly with gum collection for labour, reducing marketed quantities.

Insecurity had a significant and large negative effect on marketed quantities. The consequences of the insecurity situation prevailing in large parts of northern Kenya have been studied before, but this study is the first to show its impact on gum Arabic marketing. Insecurity was highly localised and mainly encountered in Turkana and along the Somali border. Pike (2004) found cattle raiding in Turkana to have a strong influence on herding strategies, limiting available pastures, especially dry season pastures, and thereby increasing vulnerability to drought. Whereas traditionally these raids were mainly aimed at stealing cattle and their scale was small, in recent decades their size and impact on the human population increased dramatically. Attempts at privatising land tenure and offering large tracts of land to private investors including mining companies decreased resource availability and increased conflict (Mkutu 2007). Insecurity is also a threat among the Somali border where al-Shabaab staged killings and kidnappings (Marchal 2009), and it is yet unclear

whether the recent attack of Kenya on their positions in Somalia will improve this situation. By limiting pasture availability, insecurity limits the ability of local pastoralists to cope with weather risk and result in livestock losses. Losses of livestock due to raids or droughts were shown to increase dependence on gum Arabic (Woldeamanuel *et al.* 2011). This study shows that gum Arabic marketing is also threatened by insecurity, further reducing the food security of households in the region. In fact, findings probably underestimate the true impact of insecurity on marketed quantities, because the most insecure regions were avoided during data collection.

### **Limitations**

The conducted study had several limitations which may affect the quality and external validity of the conclusions. First, data were obtained through non-random sampling and only households that had collected gum Arabic during the study period were included in the survey. Second, no information was collected on total income and income composition throughout the year, or on livestock prices. Third, some constructed variables were suspected to suffer from measurement error. The cause and consequence of these limitations will be discussed below.

The chosen sampling method severely limited the external validity of the results. No prior information existed on the amount of people involved in gum Arabic collection and because entire settlements frequently move, there was no accurate map of the region containing the village locations. It is highly likely that part of the villages where data were collected is no longer in the same location. Therefore, a random sampling design was not feasible without first conducting a large scale exploratory research. Instead, villages were sampled that were spread evenly throughout areas where gum Arabic was marketed. A more limiting decision was to exclude non-collectors from the survey. Were collectors a well-defined subgroup of the population, this would not have been restrictive. However, given how little is known about the socio-economic characteristics and position of households involved in gum Arabic collection, this exclusion severely limited the external validity of the results. Because of the chosen sampling method, results of this study only apply to gum Arabic collectors in the region, and are not applicable to the population as a whole.

The lack of information on sources of income other than gum Arabic limited the extent to which the proposed model could be tested. Given the subsistence level at which most interviewed households lived, determining the contribution of an activity to income would require data on own consumption to be collected. Sources of income differ substantially between seasons, making recall grossly inaccurate and time-consuming. Because the majority of the population is illiterate, asking people to keep track of consumption and income was not an option. Finally, given the large geographic spread of included villages and the limited time-frame, multiple visits were also excluded as a possibility. Missing this income information makes it impossible to determine whether the observed effect of rainfall shortage on marketed quantities resulted from a change in relative productivity or through a change in relative prices. In terms of the model, it could not be determined which part of the differential was attributable to a shift of the PPF and which part to the rotation of the relative price line. Therefore, the full model could not be tested directly, but rather should be interpreted as offering a likely explanation for the observed positive effect of rainfall shortages on marketed quantities.

The variables wealth and acacia area were suspected to suffer from a degree of measurement error that could bias results. No data information on the monetary value of wealth of included households was available. Missing wealth information is characteristic for datasets from developing countries, and a tried-and-tested method to overcome this problem was employed in this study. However, interviewed households had so little possessions, that

the resulting wealth index was expected to measure wealth with a degree of error. *Acacia* area was a variable constructed to control for the quantity of gum available per collector. However, only data on which areas contained *Acacia Senegal* and *Seyal* were available, without any information on density, or on the number of collectors per region. Although this was partially controlled for by regressing the different areas on the daily quantity an individual expected to collect, the variable was hardly a perfect measure. Measurement error affects not only the coefficient of the variable measured with error, but other included variables as well. Whether the measurement error is problematic depends on whether it is random or systematic. Random measurement error inflates standard errors, but does not cause bias. Systematic measurement error, i.e. when the true value of a variable on average deviates from the observed value, does cause bias. Although both variables were suspected to suffer from random measurement error, there was no clear direction for systematic error, and therefore the main consequence was expected to be inflated standard errors. However, systematic error might have been present and consequently the variable coefficients should be interpreted with caution.

Most of the limitations of this study can be prevented in future research by considering a smaller study area or a dramatically larger research budget. In the initial phase an inventory of both gum resources and the human population should be done. Once the populations are known, transects and households can be randomly selected. Using more resources or focusing on a smaller area would allow for more complete and accurate measurement of variables of interests and increase external validity of results.

## CONCLUSION

This study described socio-economic characteristics of households involved in gum Arabic collection in Kenya, related these to marketed quantities and offered an explanation for low observed quantities. Although gum Arabic is generally considered to offer great poverty alleviation potential, current contributions to income were found to be small. The economic model proposed in this study established a relationship between the return to gum Arabic collection and the return to alternative sources of income. Rainfall shortages decrease the absolute return to gum Arabic collection, but have an even stronger negative effect on the return to alternative sources of income such as livestock rearing, causing an increase in the relative return to gum collection. Increasing relative returns can be caused by relative productivity and price increases. In this study, no discern was made between the two effects, and only the impact of the overall effect was shown. The increase in marketed quantities of gum Arabic when other sources of income fall short demonstrate it mainly serves as a safety net, implying low expected returns to collection. Expected returns are lowered by the high uncertainty involved in gum marketing. Interviewed households indicated the lack of availability of buyers for gum to be the main marketing constraint. Although gum collection does not require any upfront capital investments, the uncertainty about the time of sale caused by market thinness requires an upfront investment of labour, a risk which is more easily borne by wealthier households. Another factor currently limiting marketed quantities of gum was the insecurity situation prevailing in Turkana and along the Somali border during the study period, which was found to have a direct and large negative effect.

### **Implications**

Research results indicated the importance of wood products and gum Arabic to household income, the use of gum Arabic as a safety net, and the impact of insecurity on marketed quantities. The implications of these findings provide guidelines for future policy.

Wood products and gum Arabic were found to be the most important secondary sources of income. In addition to their direct contribution to household income, *Acacia* trees provide direct secondary benefits such as medicine and fodder for livestock, and indirect benefits such as maintaining soil fertility and controlling desertification. The sustainable use value of trees could be even further enhanced by encouraging tapping of gum Arabic. Current rates of tapping are low, which might be explained by a lack of knowledge and unclearly defined property rights, limiting incentives to invest in tree management. Increasing the use value of trees and strengthening property rights would reduce deforestation incentives. However, in the study area mobility is an important mechanism to cope with weather risk. Private land ownership, which has been encouraged both pre- and post-independence was found to limit mobility and increase violent conflict. Therefore instead of property rights, user rights to trees either on an individual or community level might be a more viable alternative. A further enhancement of sustainable use value of trees could come from incorporating tree resources in the Reducing Emissions from Deforestation and Forest Degradation (REDD) programme from the United Nations.

In this study gum Arabic was found to be primarily important as a safety net, rather than as a preferred source of income, which indicates returns to gum Arabic collection were low. Increasing these returns would encourage larger quantities of gum to be collected and marketed and hence increase its contribution to income. Prices are determined on the world market and therefore hard to influence directly. Furthermore, prices in monetary terms were not found to have an influence on marketed quantities, which might be explained by the importance of the relative rather than the absolute return. The increase of marketed quantities for lower levels of wealth suggests there is risk involved in marketing which is more easily

borne by wealthier households. This uncertainty is caused by the thinness of the market, i.e. infrequent trader visits. Because uncertainty reduces expected returns, reducing this uncertainty should have a positive influence on marketed quantities. Improving physical and telecommunications infrastructure might encourage more frequent trader visits by reducing the cost of transport and information. Furthermore, community storage facilities could encourage more frequent trader visits by providing more certainty on available quantities. Proper storage facilities could also reduce loss of gum quality during storage.

Insecurity was found to have a significant and large negative impact on marketed quantities of gum Arabic. Previous work has shown that reducing insecurity in the study area would improve mobility and hence the ability of herders to cope with weather variation. This study finds that it will also increase the poverty alleviation benefits of gum Arabic. Insecurity causes livestock losses both directly and by reducing mobility. Loss of livestock is an important motivation for households to rely on the safety net provided by gum Arabic collection. Prevailing insecurity therefore has a double effect on households, with potentially severe impacts on livelihoods and food security.

The established importance of gum Arabic to households in northern Kenya, especially as a safety net justifies policy interventions aimed at increasing its benefits to collectors. Policies aimed at increasing the return to collection and improving the current insecurity situation might be a good starting point. However, further research in these areas is needed to more accurately define the costs and benefits of specific policy interventions.

### **Future research**

Little is known about the socio-economics of gum Arabic collection, giving tremendous scope for further research. The two most promising extensions concern research on the determinants of the participation decision in gum Arabic collection and increased comprehension of the time-dynamics of collection.

Most research on the socio-economics of gum Arabic collection, including this study, focused only on individuals or households involved in collection. The emphasis on collectors and the contribution of gum to their income is restrictive because it is not only the benefit per collector, but also the number of people that benefit from collection that determines the poverty alleviation potential of gum Arabic. Although observational data suggest households involved in collection are generally poor, no complete income data have ever been collected, and hence little is known about the socio-economic position of collectors, limiting the external validity of results. The number of collectors per region and the relationship between environmental characteristics and gum Arabic collection is also unknown. There are more regions with frequent occurrence of *Acacia Senegal* and *Seyal* than regions where gum is actively traded. Increased comprehension of the determinants of the participation decision in gum Arabic collection would provide a more complete understanding of the impact of policy measures.

Little is known about the impact of time-variant factors on marketed quantities. In this study, the model was tested using cross-sectional data. Therefore, only the effect of rainfall shortages between villages was measured, rather than the effect of different levels of rainfall on the same village. Because droughts usually affect large regions, but vary substantially from year to year, the variance in the rainfall variable would also be higher in time-series data. Prices are also more variable over time than between regions. Prices are set on the international market and are subject to severe cyclicity over time. Between regions however, price variations are small, compromising effective measurement of their impact. Finally, time-series data would allow controlling for household and village-specific characteristics which are hard or costly to measure directly, such as skill of household members or productivity of local pastures. The increased variance in variables of interest

combined with improved control of household and village-specific variables affecting productivity, would allow more rigorous testing of the model proposed in this study.

Arabic gum is relatively under researched, yet is a very important input to many modern industries and has large poverty alleviation potential. The mentioned avenues for further research are merely a starting point. Given rapid changes in areas where the resource is collected such as overpopulation and increased sedentarisation, new important areas for research will undoubtedly emerge in the near future. The model proposed in this study could serve as starting point to guide such future endeavours.

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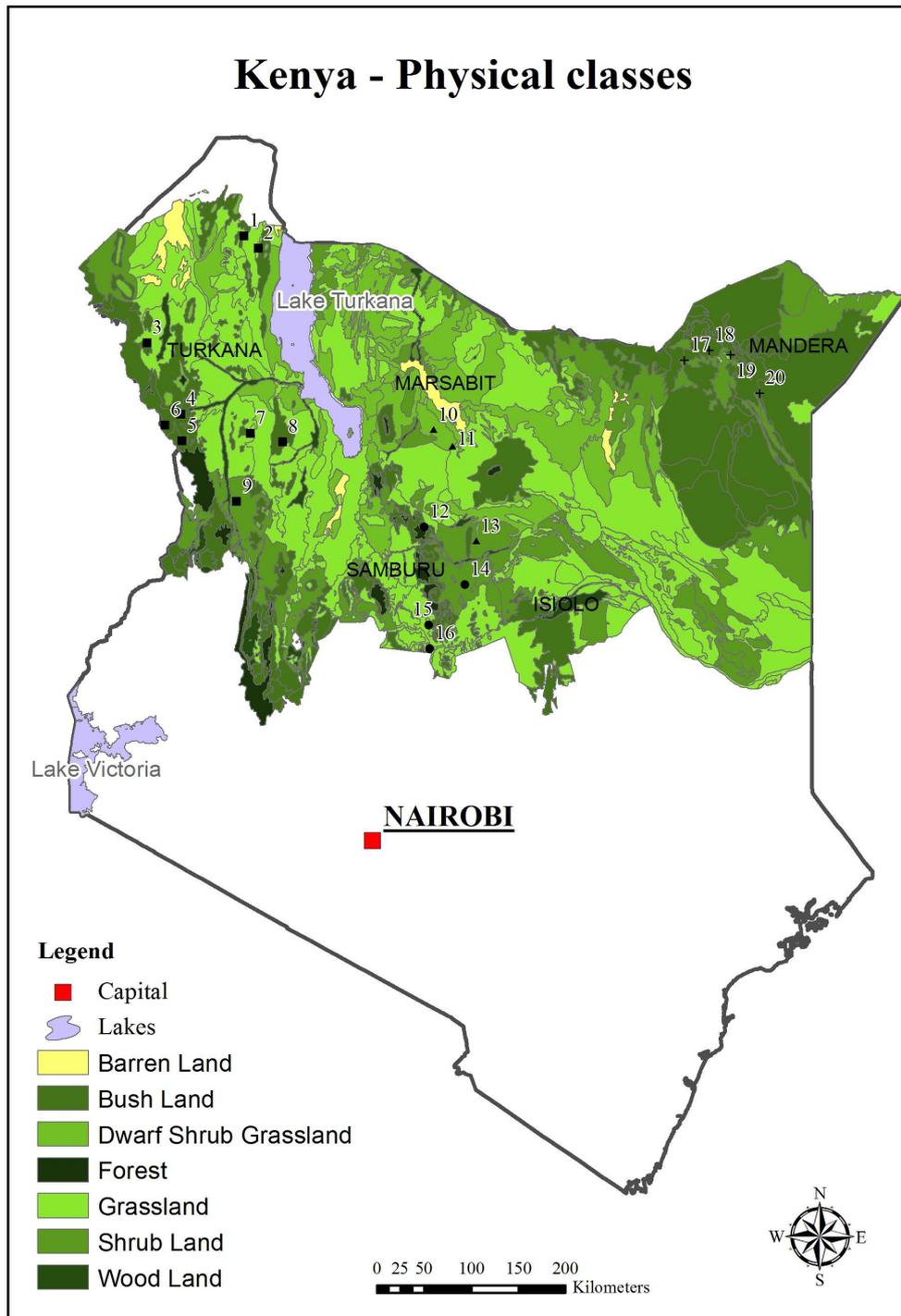
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## APPENDIX 1: LIST OF VILLAGES INCLUDED IN SURVEY

Number	Village name
1	Kakilai
2	Kariabur
3	Loritit
4	Namoroputh
5	Lorengippi
6	Lokiriama
7	Kasuroi
8	Nakukulas
9	Kakongu
10	Kurkum
11	Kargi
12	Ngurunit
13	Laisamis
14	Sereolipi
15	WestGate
16	Ngarendare
17	EIDanaba
18	Gither
19	Takaba
20	ShimbirFatuma

Note: Village numbers correspond to numbers in Figure 2.

APPENDIX 2: GIS VARIABLE CONSTRUCTION - MAPS



Cartography: W. Vellema, 2012  
 Data sources: World Resources Institute (WRI)

# Kenya - Vegetation containing Acacia Senegal

