

**GUM ARABIC STUDIES IN TANZANIA:
PRODUCTION, UTILIZATION AND ECONOMIC POTENTIALS**

FORTUNATUS B.S. MAKONDA

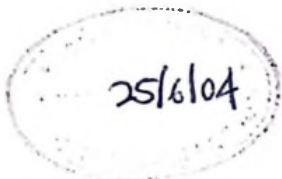
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**A THESIS SUBMITTED IN FULFILMENT FOR THE PHILOSOPHIAE
DOCTOR AT THE UNIVERSITY OF WALES, BANGOR**

**SCHOOL OF AGRICULTURAL AND FOREST SCIENCES, UNIVERSITY OF
WALES, BANGOR, UNITED KINGDOM**

NOVEMBER 2003

13 JUL 2004



DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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ABSTRACT

Studies on gum arabic in Tanzania were conducted in eleven districts aiming at estimating the country's potential and current production, assessing its utilization and contribution to the local and national economies and its marketing channels. For the gum yield studies, 1,106 trees represented in four diameter classes were sampled and tapped by de-barking a portion of the stem at breast height. The tree parameters assessed were dbh, height and number of branches. Gum from the trees was collected four times at an interval of three weeks, and weighed using a sensitive electronic weight scale. A total number of 518 circular 0.1 ha plots each were selected using a systematic random sampling method for the inventory of *Acacia senegal* and other associated woody species. The plot characteristics assessed were elevation, climate, soils, terrain type and disturbance by bush fires whose intensity levels were recognised as 1, 2 and 3. For the studies on actual gum arabic production, economic potentials and marketing data were collected using social survey methods from 630 gum collectors as well as 630 non collectors living in gum producing areas, in 64 villages, eight gum middlemen and three final gum buyers and exporters. The quality of gum was assessed using 90 samples from each district. Secondary data were collected from district and regional forest and natural resources offices in which gum arabic is collected and several other public offices. Data analyses were carried out using the Microsoft Excel package of Microsoft Office 98 and 2000 and SPSS employing descriptive statistics, one-way statistical analysis of variance and regression analyses.

Results indicated that the overall mean gum arabic yield per tree is 246 ± 333 g, greatly influenced positively by tree size particularly diameter, up to an optimum size, temperature, fire intensity and stem crowdedness. The overall mean population density of *Acacia senegal* was estimated as $225 \text{ stems ha}^{-1}$, marginally influenced negatively by altitude and positively by temperature. The actual mean annual gum arabic production was $4,030 \pm 15$ metric tonnes composed mainly of gum from *A. drepanolobium* (65 %), therefore not qualifying for the name gum arabic rather than gum talha. There is a serious lack of a clear definition of gum arabic from the exporters to the collectors, leading to its haphazard collection and trading without processing and grading. All gum is collected from trees in natural stands and not by tapping, by mainly women (44 %), children (30.5 %) and male livestock herders (25.5 %). The gum is important to the subsistence economy of many rural people, using it for food, medicine and glue. The gum is also economically important to the collectors, the middlemen, the final buyers and exporters and local and central governments. The business is however, purely a private enterprise, highly disorganised and controlled by the final buyers and exporters in which the bulk of the gum (75 %) is traded unrecorded. The gum collectors are therefore, the most disadvantaged group receiving the minimum payment in the whole chain. Managing *Acacia senegal* plantations for gum is economically viable with LEV of TShs 814,529, NPV of TShs 469,089 and IRR of 63 % at rotation age of 9 years and interest rate of 10 %. Among the recommendations given by these studies include tapping *Acacia senegal* trees, gum processing and grading, improvement of the existing *A. senegal* resources and closer monitoring of the trade by the local and central governments.

DEDICATION

This work is dedicated to:

- My dad, Stephen and mum, Shillya who convinced me in believing that, in education there was everything
- My wife, Rozalia and daughter, Shillya who shared the pains of loneliness during the first six months while away for studies, and even after the re-union in Wales, they maintained a constant appreciation of what was being done.
- The memories of my dad-in-law, Feroz who passed away just a fortnight before I embarked on the studies. My beloved brother Fidelius, in-laws Nasra, Edgar and Khadija, uncle Emmanuel and grand mum Ng'wana Masasi (Katharina) who passed away while away for these studies.

ACKNOWLEDGEMENTS

I could never have accomplished doing this work without extensive help in one way or another from various institutions and individuals. I would first wish to acknowledge the financial assistance given to me for these studies by the Norwegian International Agency for Development Co-operation (NORAD) in collaboration with Sokoine University of Agriculture (SUA).

Special thanks go to Geoff A. Bright for his tireless supervision and guidance during the whole period of this study, from classrooms, fieldwork in Tanzania to writing up. His cooperation in both academic and social life with his family is highly appreciated. My sincere thanks also go to Dr J.B. Hall for his tolerance in giving frequent advice during the preparation of this work and Dr C. Whitaker for providing guidance on some statistical methods.

In collecting data, I am greatly indebted to the following people who gave information and various assistance:

- The officials of the Division of Forestry and Bee-keeping headquarters, particularly Prof. S. Iddi, the Director for the permission to use the directorate for these studies, S. Hoza and G. Kamwenda for general information on features of forestry in Tanzania.
- The Institute of Resource Assessment (IRA) of the University of Dar Es Salaam (UDSM) for providing the vegetation maps of Tanzania.
- The botanist, Mr C.K. Ruffo who helped in species identification, and other officials of the National Tree Seed Programme (NTSP) particularly Messrs K. Siwa, K. Singo and A. Kindo and my dad, for orienting me to the *Acacias* of Tanzania.
- The gum dealers, Messrs J.B. Nkupa, B. Nkupa, Z. Suleiman, A. Hamoud, H. Abdallah, S. Salum, S. Said, S. Rashoud, S. Ghadiyali, S.M.A. Rizvi and G. Shabbir.
- The forest officers, Messrs M. Sila, C. Thomas, B. Rwebangira, J. Mkonki, A. Lyogello, J.S. Nandrie, J. Manota, E. Shuma, H. Kiiza and M. Sharrif.

- The Executive Directors in the respective districts for the permission to use their districts for these studies.
- The many hundreds of gum collectors and non-collectors interviewed in these studies.
- The staff in the Faculty of Forestry and Nature Conservation, SUA particularly Professors R.C. Ishengoma, G. Monela and W.S. Abeli.
- The officials of the Tanzania Revenue Authority (TRA) particularly Mr J.J. Mbunda and Mrs M. Mwanilwa.
- The officials of the Tanzania Breweries Limited (TBL), the Kibo Breweries Limited (KBL) and the Tanzania Railways Corporation (TRC).
- I shall always remember Mr. A. Masoud, for his courageous and tireless driving over bumpy and dusty roads through the heat of the semi-arid Tanzania throughout the whole period of data collection.

Lastly, but not least, I am grateful for the study leave granted to me by my employer, S U A. Since it is impossible to acknowledge all the individuals who contributed in the success of this work in two pages, I would wish therefore, to hereby, give a collective vote of thanks.

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LIST OF SYMBOLS AND ABBREVIATIONS

ANOVA	Analysis of Variance
Dbh	Diameter at breast height (1.3 m)
EEC	European Economic Community
GDP	Gross Domestic Product
GNP	Gross National Product
g	Grammes
Hlitre	Hectolitres
Ht	Height
IRR	Internal Rate of Return
KBL	Kibo Breweries Limited
kg	Kilogramme
LEV	Land Expectation Value
m.a.s.l.	Metres above sea level
MLNRT	Ministry of Lands, Natural Resources and Tourism
MNRT	Ministry of Natural Resources and Tourism
MJ	Mega Joules
NORAD	The Norwegian International Agency for Development Co-operation
NPV	Net Present Value
NTSP	National Tree Seed Programme
NWFPs	Non-Wood Forest Products
p	Probability value
PRA	Participatory Rural Appraisal
SUA	Sokoine University of Agriculture
TBL	Tanzania Breweries Limited
TRA	Tanzania Revenue Authority
TRC	Tanzania Railways Authority
TShs	Tanzanian Shillings, TSh 1 = GBP 0.00067, US\$ 0.00105 in 2001
UDSM	University of Dar Es Salaam
URT	United Republic of Tanzania
US\$	United States Dollar, US\$ 1 = TShs 950 in 2001.

CHAPTER I

GENERAL INTRODUCTION

1.1 Background

Tanzania covers an area of about 945,000 km² out of which 888,600 km² (94 %) is land. According to the survey conducted by the Hunting Technical Services (1999), reported by FBD (1999), the vegetation cover types of Tanzania can generally be categorised into forest cover (2.9 %), woodland (39.6 %), bush land (18.3 %), grassland (20.6 %), open land (0.2 %), cultivated land (10.7 %) and others (0.1 %). The exceptionally high richness in the indigenous biodiversity (Mziray, 1999) gives the country the potential to deliver diverse forest products in the form of timber, non-timber and non-wood for the domestic and external markets (FBD, 1999; URT, 2000).

This work was conducted amidst the global outcry concerning the high rate of environmental deterioration (FAO, 1985; 2001), in which Tanzania was estimated to be losing 2 % of its forest land (URT, 1998), and the high level of poverty in the country (Collier *et al.*, 1990; World Bank 1994; Booth *et al.* 1998; World Bank 2001; 2002). As a means of conserving these resources, the government reformed some of its environmental policy objectives including ensured sustainable and equitable use of resources to meet the basic needs of the present and future generations without jeopardising the environment.

The importance of non-wood forest products (NWFPs) is most significant in the dry land areas where they form alternative sources of livelihood (O'Kting'ati and Monela, 1990; CIFOR, 1999; Chikamai *et al.*, 2000). However, with very few exceptions, the NWFPs in Tanzania have never been studied in depth, neither in respect of quantities produced nor of their socio-economic importance. Many authors, including Okafor (1985), Appasamy (1993), Chandrasekharan (1993), Coppin (1993), Adger *et al.* (1995), Bourobou and Posso (1995), Lintu (1995), Arnold and Townson (1998) and URT (2000) have reported a similar shortcoming around Africa. This has been largely due to:

- The scattered nature of the NWFP collectors who have a loose social organisation, the use of NWFPs which is mostly for the subsistence economy, often of the very poor, does not attract any monetary value at all,
- Since they are highly disorganised, the NWFP collectors cannot claim land tenure for their activities.

In the light of the above statistics on the Tanzania's indigenous forests cover, FBD (1999) concluded that almost 75 % is composed of different shades of miombo and *Acacia* woodlands and that the somewhat arid areas (about 50 - 60 % of Tanzania) contain vast areas of *Acacia* woodlands. These areas have potential for the production of gum arabic which is also known by other English names as Sudan gum arabic. Payne (2001) and Verbeken *et al.* (2003) considered this product to be the oldest and best known of the plant gums, and whose use could be traced back to about 2,650 BC.

The most recent international specification defines gum arabic as the "dried exudation obtained from the stems and branches of *Acacia senegal* (L) Willdenow (FAO, 1990a, 1999). The *Acacia senegal* trees grow mainly in Sub-Sahara Africa as far as South Africa, but can also be found in Arabia, Sinai desert, Iran, West India and Oman (Cheema and Qadir, 1973; Ross, 1979; Brenan, 1983; Booth and Wickens, 1988; Barnes *et al.*, 1997). The species is represented by four varieties; *senegal*, *kerensis*, *leiorhachis* and *rostrata* (Brenan, 1983; Cossalter, 1991; Fagg *et al.*, 1997; Barnes *et al.*, undated; Timberlake *et al.*, 1999).

The gum has very important and diverse uses including use as a traditional food (Wickens, 1976; Sen and Bansal 1979; FAO, 1989; Lewington, 1990; Walters and Hamilton, 1993; Wang and Anderson, 1994; Soni, 1995) and as a local medicine (Dalziel, 1937; Watt and Breyer-Brandwijk, 1962). The bulk of world production is used as an additive in a variety of food, pharmaceutical and cosmetic products (Booth and Wickens, 1988; Simpson and Ogorzaly, 1995; Timberlake *et al.*, 1999).

Other uses of gum arabic are as adhesive in postage stamps, a sizing agent for fabrics and paper, and an ingredient of lithographic inks, paints and dye (Booth and Wickens, 1988; Wickens *et al.*, 1995).

The gum is produced in substantial amounts in Sudan, Nigeria, Senegal, Mauritania, Chad, Mali, Niger, Kenya, Somalia and Tanzania (Adamson and Bell 1974; NAS 1979; FAO, 2001a). Sudan caters for over 80% of the world's gum requirements (Adamson and Bell, 1974; NAS, 1979; FAO, 1983; 95a; Fagg *et al.*, 1997; Timberlake *et al.*, 1999; FAO, 2001a) supplying an annual average ranging from about 20,000 to 60,000 tonnes. The world total production fluctuates from 25,000 to 70,000 tonnes.

Hitherto, no study on gum arabic from Tanzania has been carried out to quantify and qualify its production and its socio-economic aspects as well. There is therefore, strong disagreement about the veracity of the gum statistics for Tanzania ranging from 350 to 2,000 metric tonnes between 1950's to-date (Adamson and Bell, 1974; Chihongo, 1992; 1995; 2000; Seif el Din and Zarroug, 1998). Moreover, the gum from Tanzania is claimed to be collected in a much less systematic manner than elsewhere, affecting its quality and quantity (Adamson and Bell, 1974). It was nevertheless, concluded that Tanzania has one of the largest export potentials for gum arabic among the East African countries, though the industry is yet to be developed (Chihongo, 2000). The need for the studies on gum arabic in Tanzania were highlighted by Makonda (1997), Makonda *et al.* (1997), Makonda and Ishengoma (1997), Makonda *et al.* (1998a), Makonda *et al.* (1998b), URT (2000) and FAO (2001b).

An FAO project on production, markets and quality control of gum arabic was formulated for 12 African producing countries, unfortunately, Tanzania was not included.

The main objective of the project was to acquire information on all aspects of gum arabic production and quality control in order to assist producer countries in their efforts to improve the quality of their products so as to meet international specifications (Chikamai,

1997). It was recommended that priority be given to undertaking resource surveys in all the countries producing gum arabic and improving the resource base itself.

1.2 Problem statement and justification for the studies on Tanzania's gum arabic

Tanzania, where 80 % of the population is dependent on agriculture, is an overwhelmingly poverty stricken country, particularly in rural areas (Collier *et al.*, 1990; Eriksson, 1993; World Bank, 1994; Booth *et al.*, 1998; World Bank, 2000; 2001; 2002). The situation is exacerbated in the arid and semi-arid agro-ecological regions since the areas are of low potential for sustained arable farming due to severe droughts and environmental degradation (ILO, 1982; Amani *et al.*, 1987; MLNRT, 1989; Ashimogo, 1995).

The accelerated development of these areas lies, therefore, in recognising the potential that exists in the natural vegetation resources and incorporating it in the development and conservation strategies. White (1983) and MLNRT (1984) described the natural vegetation of these areas to comprise mostly of *Acacia spp.*, promisingly, forming a potential zone for gum arabic production in the country. Unfortunately, the potentialities of gum arabic have never been fully utilized, has also been the case with other NWFPs elsewhere, since the importance of these resources has generally been neglected and the emphasis put on conventional agriculture and forestry (MLNRT, 1989; Annon., 1989; Scoones *et al.*, 1992; Woon and Lim, 1995; Arnold and Townson, 1998; FAO, 2001a).

In order for the potential of gum arabic to be recognised, estimates of yield and potential supply to the industry, importance and the production flow must be gained (Chikamai, 1997; Chikamai *et al.*, 2000; Nour, 1999).

1.3 Objectives

1.3.1 Overall objectives

The overall objectives of these studies were to provide national statistics for the production of gum arabic, utilisation and its economic potentials at both micro and macro-economic levels in Tanzania, with hypotheses that the yield of gum arabic can be measured and estimated and the level of production of gum arabic is much less than its potential and is constrained by biological and economic factors.

1.3.2 Specific objectives

The specific objectives were:

- a. To identify the gum arabic production areas of Tanzania.
- b. To determine the country's potential and actual annual production of gum arabic and the determinants of these.
- c. To examine gum arabic harvesting and processing techniques.
- d. To assess the local utilisation of gum arabic.
- e. To assess the actual and potential contribution of gum arabic to the economy at both local and national levels.
- f. To assess the accessibility of rural communities to collection and utilisation of gum arabic.
- g. To identify constraints to increased production of gum arabic.
- h. To assess marketing of gum arabic from Tanzania.

1.4 Study areas description

This study was carried out in eleven districts located in the central part of Tanzania (Fig. 1.1). They are Singida Rural, Iramba, Igunga, Shinyanga Rural, Meatu, Maswa, Kiteto and Babati in which gum arabic collection and trade is already carried out and Dodoma Rural, Geita and Bukombe, which are potential producing districts. Although the focus of this study was on *Acacia senegal* var. *senegal*, unless indicated otherwise, some consideration has been given to other species owing to their present use in the gum trade. Apart from the study areas, Wickens (1976) reported that this species can also be found in Morogoro and Lindi, nevertheless, the latter were excluded from the study owing to their inaccessibility and uneconomic quantities available therein.

Table 1.1 below presents summarised description of the study sites. It should be noted that the human population for each district has been adjusted from the 1988 country census to 2001, using respective growth rates. The following are general observations, which can be deduced from the table:

1.4.1 Physical features and soils

The elevation of the study sites ranges between 800 to 1,500 m above sea level. The predominant soils are described by FAO-UNESCO (1977) as arenosols and luvisols and together with Tosi *et al.* (1982) they qualified the soils as coarse loam to sandy loam developed directly from metamorphic rocks, with low organic matter, low bulk density and low water retention capacity and base exchange.

1.4.2 Climate and economic activities

The districts are located in arid and semi-arid agro-ecological zones in which rainfall is between 500 to 800 mm per year occurring within 60 days (FAO, 1984; NMD, 2001). Evapo-transpiration is four times more than the average rainfall received in the area (Christianson *et al.*, 1991), making famine a recurrent danger. According to Hankins

(1974), Barrow *et al.*, (1988), (92) and Lugeye and Nsolomo (1992), these areas are of low potential for sustained cropping, as severe droughts occur at intervals of 5 – 9 years. Mosha (1990) and Kikula (1996) noted that they are best used for low intensity extensive livestock grazing.

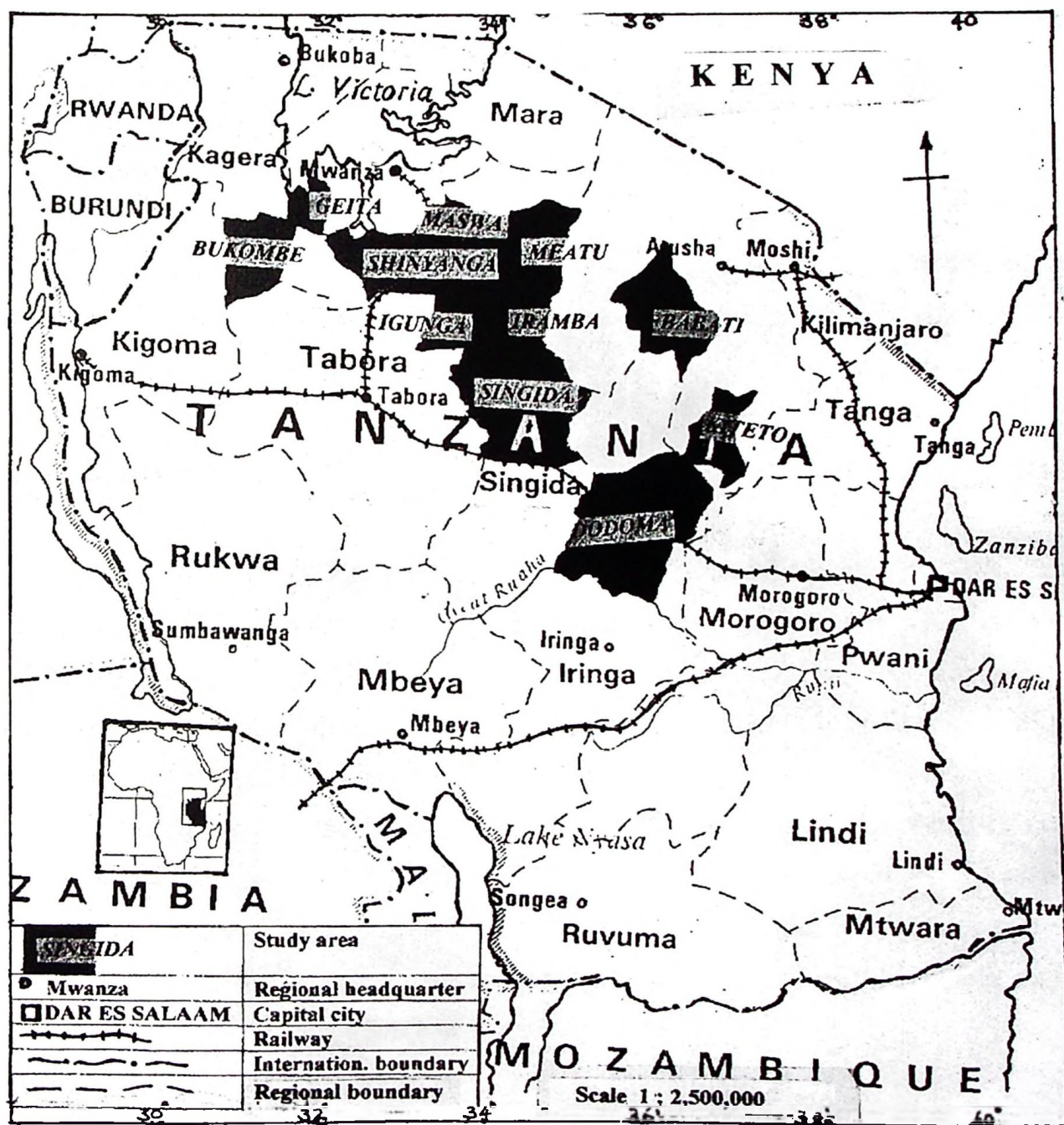


Figure 1.1 Map of Tanzania showing gum arabic study areas

MLNRT (1989) places the study districts in a zone where vegetation is under threats from overgrazing. GDC (1995), Nyamrunda (1997) and Barrow *et al.*, (1992) for example, lamented that Geita, Meatu and Maswa districts were livestock over-populated. Pastoralists graze and browse herds of cattle, sheep and goats, travelling to take advantage of fodder and water as available. Livestock herds are the household's main commercial activity, with incomes and diet enhanced by cultivation of sorghums and millets. Animal products are traded to purchase cereals and other foods.

Sunflower, sesame and groundnut are the major cash crops in Dodoma Rural, Singida Rural and Iramba districts. In the other districts, cotton is the major cash crop, with rain-fed rice production gaining importance as second to cotton as more farmers are reverting to it, responding to increasing uncertainties concerning cotton price and market (Barrow *et al.*, 1992; Otsyina and Asenga, 1993).

1.4.3 Vegetation

According to White (1983), the main vegetation of the study districts is related to the Somalia - Maasai Regional Centre of Endemism in which most of the trees are deciduous and dominated by *Acacia*, *Commiphora* and *Euphorbia* species. However, due to severe deforestation, the land is mostly bare, severely eroded and difficult to re-afforest (Getahum, 1992). The natural vegetation in these areas has changed to secondary wooded grassland but still dominated by the same tree species (Backeus *et al.*, 1996). The main species are *Acacia bussei*, *A. mellifera*, *A. nilotica*, *A. drepanolobium*, *A. senegal*, *Commiphora africana*, *C. schimperi* and *C. mollis* (MNRT 1996a; b; c; d; e; f; g; h; i; j; k; l; m; n; o; p). In the upper canopy are scattered trees of species *Acacia tortilis*, *Adansonia digitata*, *Delonix elata* and *Terminalia spinosa*.

1.5 Summary

The presentation of this thesis is organized in 6 chapters summarized as follows: Chapter I entails a general introduction of these studies divided into 4 sections. Section 1.1 gives a brief background information to the work, Section 1.2 presents the problem statement and justification and the studies' objectives are in Section 1.3. The descriptions of the study sites are presented in Section 1.4 whereas this summary is in Section 1.5. The current chapter is followed by Chapter II which is concerned with gum arabic potential yield studies, broken down into 5 sections: Section 2.1 introduces the subject and presents the problem statement, justification and objectives. The literature survey for gum arabic production and *Acacia senegal* is presented in Section 2.2. Section 2.3 presents the methodology used in sampling, data collection and analysis. Results and discussions are covered in Section 2.4 and conclusions and recommendations are summarized in Section 2.5.

Chapter III presents gum arabic actual production studies, also divided into 5 sections: Section 3.1 presents the subject, problem statement, justification and objectives. Section 3.2 reviews other works on gum harvesting methods, production and quality control worldwide. The sampling techniques, data collection and analysis are presented in Section 3.3 and results and discussions are found in Section 3.4. A summary of conclusions and recommendations on the findings in this chapter are given in Section 3.5.

Chapter IV deals with the economic importance of gum arabic in Tanzania, with the introduction, justification and objectives presented in Section 4.1 and a literature review for the chapter is in Section 4.2. Section 4.3 deals with the methodology for sampling, data collection and analysis.

Results and discussions and conclusions and recommendations are given in Sections 4.4 and 4.5 respectively.

Marketing of gum arabic is presented in chapter V, and as in the other chapters, it has 5 sections: Section 5.1 covers introduction, justification and objectives, Section 5.2 a literature survey, Section 5.3 methodology, Section 5.4 results and discussion and Section 5.5 conclusions and recommendations.

Chapter VI draws together the findings of the studies presented in the previous chapters, giving general conclusions and recommendations, and the main contributions of this work to knowledge.

The thesis was written with the intention that each chapter should constitute a stand-alone paper. Consequently, there is a degree of repetition in the thesis, for which the reader's patience is requested.

Table 1.1 A summarised description of the study sites

District	Location	Altitude (m.a.s.l)	Soils	Climate		Demography		Vegetation type
				Mean annual Rainfall	Temperature	Population	Major tribes	
Dodoma Rural	5°20'-7°00' S 35°00'-36°15' E	1,000-1,500	Course loam-sandy loam (Tosi <i>et al.</i> , 1982)	578mm Oct/Nov and Apr/May (FAO, 1984; Darkoh, 1987; NMD, 2001)	16°C-29°C with an annual mean of 22.7°C (Christianson <i>et al.</i> , 1991)	481,130 (MFEAP, 1988)	Gogo, Kaguru, Irangi and Nyamwezi.	Secondary forest and <i>Markhamia</i> woodland (Backeus <i>et al.</i> , 1996)
Singida Rural	4°30'-5°30' S 33°50'-35°20' E	1,200-1,400	Course loam to sandy loam	n.a	n.a	393,002 (MFEAP, 1988)	Nyaturu, Nyiramba and Taturu,	Miombo woodland to <i>Acacia-Commiphora</i> bushland (MNRT, 1996b)
Iramba	4°00'-4°50' S 33°50'-35°00' E	1,100-1,500	Course loam to sandy loam, Vertisols	n.a	n.a	400,126 (MFEAP, 1988)	Nyiramba, Sukuma, Nyaturu, Taturu and Hadzabe	Miombo and <i>Acacia</i> woodlands
Igunga	3°55'-4°50' S 33°20'-34°17' E	1,000-1,400	Vertisols, sandy loamy	700mm Oct/Nov-Apr/May	Mean annual of 27°C (FAO, 1984)	276,442 (MFEAP, 1988)	Sukuma, Nyamwezi, Taturu, Maasai and Nyiramba	<i>Acacia</i> and miombo woodland
Shinyanga Rural	3°40'-4°00' S 32°30'-34°00' E	1,000-1,400	Vertisols, calcic cambisols and rendzinas (Malcom, 1953; Hankins <i>et al.</i> , 1971)	<800 mm Nov/May (Christiansson <i>et al.</i> , 1991)	19°C-24.9°C with a mean annual of 22.7°C (Getahum, 1992).	580,800 (MFEAP, 1988)	Sukuma	Secondary wooded grassland dominated by <i>Acacia</i> , <i>Commiphora</i> and <i>Euphorbia</i> (White, 1983)
Maswa	3°00'-3°45' S 33°30'-34°00' E	1,050-1,300	Vertisols, calcic cambisols and rendzinas	<800 mm Nov/May (Christiansson <i>et al.</i> , 1991)	19°C-24.9°C with a mean annual of 22.7°C (Getahum, 1992)	320,750 (MFEAP, 1988)	Sukuma	<i>Acacia</i> , <i>Commiphora</i> and <i>Euphorbia</i> species (White, 1983)
Meatu	3°00'-4°00' S 34°00'-35°00' E	1,031-1,100	Arenosols, aluvisols (FAO-UNESCO, 1977)	600-800mm Nov/Dec and Jan/May (Barrow <i>et al.</i> , 1992; Otsyna., 1992)	19°C-24.9°C with a mean annual of 22.7°C (Getahum, 1992)	205,500 (MFEAP, 1988)	Sukuma, Taturu and Hadzabe	<i>Acacia</i> bush savannah (Getahum, 1992)
Babati	3°00'-4°30' S 34°20'-36°30' E	800-2,400	Vertisols, red earths (Berry, 1971; Westman, 1990)	750mm Nov/Dec and Feb/May (Lindstrom, 1998; NMD, 2001)	23°C (Lindstrom, 1998; NMD, 2001)	260,000 (MFEAP, 1988)	Iraqw, Gorowa, Irangi, Mbugwe, Nyaturu, Maasai and Barbaig	Miombo and <i>Acacia-Commiphora-Combretum-Grewia</i> shrubland (Westman (1990)
Kiteto	4°20'-5°58' S 36°15'-37°17' E	950-1,300	Course loam to sandy loam	580mm Oct/Nov and Apr/May (FAO, 1984; NMD, 2001)	Mean annual of 23°C (FAO, 1984; NMD, 2001)	235,340 (MFEAP, 1988)	Kaguru, Gogo, Rangri, Sandawe and Maasai.	Maasai steppe (MNRT, 1996d; 96m; 96n; 96p)
Bukombe	3°00'-4°30' S 31°00'-32°15' E	1,000-1,500	Arenosols, Vertisols, Planosols, Lixisols and Gleysols (BDC, 2001)	900-1,200mm Sep/Dec and Mar/May	Mean annual of 22°C	369,673 (BDC, 2001)	Sumbwa, Sukuma Nyiramba, Taturu and Hadzabe	Miombo, <i>Acacia</i> bushland and grassland
Geita	2°28'-3°28' S 32°-32°45' E	870-1,300	greyish-brown compacted loamy sands (GDC, 1995)	850-1,100 mm Oct/Dec and Feb/May	17° - 29°C	720,000 (MFEAP, 1988; GDC, 1995)	Sukuma, Sumbwa and Rongo	Miombo, <i>Acacia-Combretum-Commiphora</i> woodland

CHAPTER II

GUM ARABIC POTENTIAL YIELD STUDIES FOR TANZANIA

2.1 Introduction

2.1.1 General

2.1.1.1 Non-Wood Forest Products

Many of the indigenous tree and shrub species are potential producers of economically valuable non-wood forest products (NWFPs) (Bicchieri, 1972; Conelly, 1985; Campbell, 1987; Dei *et al.*, 1989; Kowero and O'king'ati, 1990; Lewington, 1990; Davies and Richards, 1991; FAO, 1991; 92; Campbell and Brigham, 1993; Coppen, 1993; Kashio, 1993; Walters and Hamilton, 1993; Coppen, 1995; Coppen and Hone, 1995; Makupa, 1995; Green, 1995; Spore, 1995; Ciesla, 1998; Verbeken *et al.*, 2003) principally gums, resins, oils and extracts. Some species of the genera of *Acacia*, *Spondias*, *Anacardium*, *Combretum*, *Lannea* and *Albizia* for example, yield commercial gums (Anderson *et al.*, 1974; Defaye and Wong, 1986; Lewington, 1990; de Pinto *et al.*, 1996; Mothe' and Rao, 1999; Sarubbo *et al.*, 2000; Lima *et al.*, 2002) and all pines yield resin if tapped (Ciesla, 1998). Extensive pine plantations have proven excellent resin source in the Southern Hemisphere where they have been introduced, including Kenya, South Africa, Brazil, Argentina and Venezuela. Other genera which produce important commercial resins include *Boswellia*, *Commiphora*, *Picea*, *Abies*, *Tsuga*, *Tetraclinis* and *Agathis* (Coppen, 1995; Coppen and Hone, 1995; Green, 1995). Essential oils are produced from such species as Logwood (*Haematoxylum campechianum*), *Acacia catechu*, Sandalwood *Cinnamomum spp* and *Eucalyptus spp*. (Coppen, 1995; Coppen and Hone, 1995; Green, 1995).

The pharmaceutical, fragrance, food, epoxy resin and coatings industries are increasingly searching for natural products from plants (NAS, 1979; Barbier, 1990; Timberlake *et al.*, 1999).

One most important of these products is gum arabic which is also known by other English names as Sudan gum arabic, Senegal gum, gum hashab and Kordofan gum (Booth and Wickens, 1988). Gum arabic is a commodity which fuelled trade in interior Africa and has figured in world trade since earliest times (Adamson and Bell, 1974; FAO, 1983; Lewington, 1990; Fagg *et al.*, 1997; Timberlake *et al.*, 1999; Verbeken *et al.*, 2003).

2.1.1.2 Gum arabic

Traditionally, gum arabic has been an important food for pastoralists, peasants and hunter-gatherers (FAO, 1989; Lewington, 1990; Walters and Hamilton, 1993; Wang and Anderson, 1994; Soni, 1995) and sometimes children (Wickens, 1976). In India, it is reported by Sen and Bansal (1979) that ground gum mixed with fried wheat flour and sugar is fed to women after childbirth. The same authors reported further that small pieces of gum fried in fat could be used as puffs or food.

Gum arabic also finds uses in local medicines including treatment of local inflammations and nodular leprosy (Dalziel, 1937) and as a remedy for dysentery (Watt and Breyer-Brandwijk, 1962).

The gum is described as one of the safest natural ingredients, suitable in a variety of industrial products (Siddig, 1991; Wang and Anderson, 1994). The bulk of world production is used as an additive in a variety of food products. These include a flavouring agent, an emulsifier of fats, a stabiliser in frozen dairy products, stabiliser of foam and clouding agent in beer and moistener. Others uses are as a surface finish coating, flavour particles and thickener (Simpson and Ogorzaly, 1995; Timberlake *et al.*, 1999). The gum is also used directly in sweets, as a stabiliser for emulsions in the

pharmaceutical industry, binder and coating for tablets, emollient and demulcent for cough drops and syrups and used intravenously for nephritic oedema (Booth and Wickens, 1988).

In the cosmetics industry, gum arabic finds applications as an adhesive for facial masks and face powder, and gives a smooth feel to lotions and protective creams (Booth and Wickens, 1988; Wickens *et al.*, 1995). It is also used as an emulsifier for hand lotions and liquid soaps. Since the gum is water soluble, it is used industrially as an adhesive (for example, the glue in postage stamps), as a sizing agent for fabrics and paper, an ingredient of lithographic inks, paints and dye and a range of additional industrial products.

As Timberlake *et al.* (1999) concluded, gum arabic is a potentially valuable product and with improved quality control and a more reliable supply, it could provide income for many more resource-poor farmers in Africa.

Throughout the world, there are more than 1,000 species and sub-species of acacias which exude gum. For commercial purposes, only two species are significant sources of gum arabic, namely, *Acacia senegal* and *Acacia seyal* (Adamson and Bell, 1974; Nour, 1999). However, the authors added that the former is the best and contributes the bulk of world gum.

Gum is produced in sizeable quantities if the trees are wounded either accidentally or deliberately. Other methods include deliberate injury by stripping away the bark. A viscous secretion of gum is exuded in a more or less spherical ball, hardening gradually and remaining stuck to the tree ready for hand picking after 3 to 6 weeks.

2.1.2 Problem statement and justification for this study

Adamson and Bell (1974) stated that gum arabic from Tanzania is collected in a much less systematic nature than elsewhere, depending to a large extent on the progress of the

collectors' other crops. This method is inefficient and has no quality controls at source. Operations are naturally subject to the traditional, though inefficient, practice that relies totally on independent, individual pastoral-nomadic, part-time collectors. The collectors' action is in routine reaction to gums on a tree, rather than a well-planned exercise based on a specific time schedule.

As a consequence of the collection system, gum traders and consumers have little or no control over the quality and quantity of gum arabic supply to the market and the scheduling and planning of procurement to meet export orders become rather haphazard and erratic.

As noted by AGL (1993) in Kenya, the regular gum traders reject a high proportion of such gums. The inevitably high rates of rejection of gums delivered for sale by the collectors to bulk gum traders has the regrettable effect of negating the collectors' already minimal interest in the exploitation of gum trees. This loss that would otherwise have been avoidable is attributable to the collectors' tendency to scrape and collect exudations from inferior or even non-marketable gum trees. In a study on trees and indigenous knowledge in Shinyanga, Kilahama (1994) noted collection of gum not only from *Acacia senegal* but also from *A. drepanolobium*. Adamson and Bell (1974) further criticised gum arabic from Tanzania as the bulk of it was collected from *A. drepanolobium*.

Production of gum arabic in Tanzania has been reported to be on a definite downward trend from 2,000 tons during the 1950s to 1,000 in the 1960s and 500 in the 1970s (Adamson and Bell, 1974; Chihongo, 1992; 1995; 2000).

NAS (1979) advocated research aimed at improving and streamlining the production of gum arabic with a goal of changing it from a haphazard effort to a well-organised, systematic occupation. Chikamai (1997) commented that one of the recommendations of FAO regarding production, markets and quality control of African gum arabic is to give priority to undertaking resource surveys in all the producing countries and to improve

the resource base itself. Nour (1999) pinpointed elements necessary for quantifying the production potential of gum to include land use trends, areas currently under *A. senegal*, tree densities and current production trends. However, no maps have been produced showing coverage or any inventory made of the main gum arabic resources of Tanzania.

A more aggressive intervention in the exploitation of gum trees will encourage increased production and thus incomes for the local people. This is important as there are few income generating opportunities for the local people in the gum areas. The intervention could create employment opportunities for them and earn the country foreign exchange in sizeable and significant amounts.

Tapping of trees to ensure constant quality of gum was recommended by Adamson and Bell (1974). This method also gives a more consistent and better-formed gum than collection from wounds caused by insect borers or other injuries (Chikamai, 1997).

2.1.3 Objectives

2.1.3.1 Overall objectives

It is against the above background that this study was carried out, with an overall objective of estimating the annual potential capacity of Tanzania for the production of gum arabic.

2.1.3.2 Specific objectives

The specific objectives were:

- a. To identify the potential gum arabic production areas of Tanzania
- b. To conduct field studies to estimate gum arabic yields by tapping trees
- c. To examine factors which influence gum arabic yield
- d. To conduct an inventory to estimate the country's *Acacia senegal* populations
- e. To examine factors which influence the country's *Acacia senegal* populations
- f. To determine the country's potential annual production of gum arabic

2.2 Literature review

2.2.1 Gum arabic

2.2.1.1 Definition and source

Various regulatory organisations have attempted to define gum arabic (ITC, 1978; US Pharmacopoeia, 1985; FAO, 1986). Despite disagreement in the wording of their definitions, there is a general consensus that gum arabic is “a dried gummy exudate obtained from the stems and branches of *A. senegal* (L.) Willd. or closely related species particularly *A. seyal*”. FAO (1990a; 1999) however, proposed a more restrictive definition where food use is planned, to tighten trade specifications and labeling regulations, identity and purity characterising more specifically “gum of commerce from *Acacia senegal* whose specific optical rotation ranges between -26° and -34° and Kjeldahl nitrogen content of between 0.27 and 0.39 %, to avoid the presence of carcinogenic substances” (Wickens *et al.*, 1995).

Structurally, gum arabic has been found to have a core of β 1,3 and 1,6 linked D-galactopyranose with branches at 0-6 on the 1,3 linked residues. The branches consist of L-arabinofuranose, L-arabinopyranose, L-rhamnose and D-glucuronopyranose. It also contains about 2 % proteinaceous material which forms an integral part of the structure (Anderson and Stoddart, 1966; Churms *et al.*, 1983; Defaye and Wong, 1986; Williams *et al.*, 1991).

Gum arabic has different names given in different countries and in different vernacular (Adamson and Bell, 1974; Booth and Wickens, 1988; Ballal, 1991; Coe and Bentjee, 1991; FAO, 1999). For example, gum from *A. senegal* is referred to as gum hashab or verek, Kordofan gum, Senegal gum or Sudan gum (English), ka'kul (Arabic, Sudan), samgh 'arobi (India) and that from *A. seyal* is gum tahl or talha (English, Arabic). In Tanzania, the gum is known as gum arabic (English), gundi, gundi gundi (Swahili),

Ugondo (Gogo, Nyiramba) and Bugondo (Nyamwezi, Sukuma) and with no differentiation of sources, whether from *A. senegal*, *A. seyal* or *A. drepanolobium*.

2.2.1.2 Formation

Chemically, gums are complex polysaccharides (NAS, 1979) whose process of formation is not quite understood (NAS, 1979; Ballal, 1991; Bhausar and Tiwari, 1995). However, there are two main theories which attempt to explain the exudation of gum by trees:

- As a natural metabolic process of plants
- As a protective measure by the tree, following injury, bacterial or fungal infection.

According to Dwivedi (1993), gum is formed as a result of disintegration of internal tissues through a process known as gummosis. Gummosis, which is defined by Saniewski *et al.* (1998) as a process of the accumulation and exudation of gum from plants, was in the past suspected to be caused by parasites such as microscopic fungi or bacteria (Dione and Vassal, 1993). Today, these microbes are considered only to represent gum micro-flora without pathogenic function. Gummosis is thought to be regulated by ethylene induced in response to injury by insects and pathogens, wounding and some stresses in many plants, especially in the species of stone-fruit trees and their fruits (Abeles, 1973).

Smith and Montgomery (1959) supported by Obeid and El Din (1970) and Awouda (1973) strongly believed that gum is formed to prevent water loss on wounds as it is noted in natural lesions caused by drought, sun scorch and fire or from wounds caused by animals.

The wound, whether natural or provoked, is therefore one condition needed to start the exudation. It was, however, noted by Mouret (1987) that some of wounded trees do not

produce gum, at least not in a quantity large enough to be perceived. Simpson and Ogorzaly (1995) documented the same observations that gums are produced only at specific times in response to injury or wounding and that appear to come from the breakdown of compounds in the injured cells, sealing the wounds.

According to Vassal and Mouret (1991), when the tree is wounded, gummosis affects all tissues, eventually being replaced by a more or less thick gum material which progressively strengthens when exposed to air. It was observed by Gosh and Purkayastha (1962) that gum comes from gum cysts which develop in the bark of gum exuding trees, in the tangential rows of the axial parenchyma strands of the phloem adjacent to the cambial zone. The formation is accompanied by such profuse development as formation of parenchymatous tissues and disappearance of starch in both xylem and phloem.

The effect is spread even to those cells away from the point of wounding, gum pockets initially build up in the phloem sub-cambial area, particularly inside big cells rich in tannin interposed between packs of stratified fibres (Vassal and Mouret, 1991). Gaps are formed by dislocation and progressive lyse of tanniferous cells. Their inert content gradually acquires gum properties, which can be detected by selective colourations. Other tissues, conductive or supportive as well as rays are gradually lysed and enclosed in pockets, which enlarge tangentially and radially.

Joseleau and Ullman (1990) provided biochemical evidence of gum formation sites in *A. senegal* by analysing and comparing the carbohydrates of the tissues from the inner bark, cambial zone and xylem of the gum producing branch with corresponding tissues of a non-producing branch. Comparable molar proportions of the sugars were found in the inner bark of the gum-producing branch as in gum arabic.

Seif El Din (1981a) disclosed results on microscopic sections of different tissues, which showed that the bark and outer wood contained high amounts of gum, deposited in parenchyma, vessels and ray cells. Inner wood contained less gum, and roots contained

only very small amounts. This was further confirmed by Mouret (1987) who discovered a decline of gum modification in cells and the quantity of gum as one moves from the superficially injured tissues. The gum induction gradient is expressed both tangentially and longitudinally beyond the point of wounding.

Some of the xylem vessels and ligneous parenchyma cells can also contain the gum product. Ligneous parenchyma cells contain abundant amylaceous reserves particularly near the vessels whose density decreases at the proximity of wounding points. Colourations reveal a degradation of the amylaceous reserves and their replacement by a gum product as well as an increased amylaceous activity (Joseleau and Ullmann, 1990). The gum in the vessels might be originating from adjacent parenchymatous cells, by filtration through the vascular punctuation.

2.2.1.3 Gum tapping

Ninety percent of the world gum supply is obtained from unattended wild trees that are slashed or punctured using machetes to induce a wound reaction (Simpson and Ogorzaly, 1995). However, Shiva *et al.* (1994) reported that today, there are improved tools for gum tapping.

Many authors have described the gum arabic tapping process to involve wounding a tree by stripping a portion of the stem or main branches of a mature tree about 4 to 5 m high and 5 to 25 years of age. This is done immediately after the rains. The wound is made normally about 8 cm wide and 20 cm long (AGL, 1993) or 2 to 4 cm wide and 10 to 20 cm long (Obeid and Seif El Din, 1970; FAO, 1983; Payne, 2001). Dwivedi (1993) used blazes of 5 cm wide and 10 cm long made at breast height of *Acacia nilotica* when studying Indian 'gum arabic'. In pine resin tapping a tree is wounded by debarking 2 to 2.5 cm wide and 10 to 32 cm long strips on the stem (Coppen, 1995). The resin is collected in a manner more akin to rubber rather than gum arabic tapping since a cup and gutter system is installed on the tree into which the resin flows.

The fluid gum arabic oozes from the injured portion of the tree and dries on the surface below it. Gum is exuded in the form of large nodules or tears, roughly spherical of diameters between 2 and 10 cm (Obeid and Seif El Din, 1970; Awouda 1973; FAO, 1978; Payne, 2001) which are manually collected.

In order to achieve the required optimum quality, AGL (1993) advocated a drying period of the exudates of at least two to three weeks before it is plucked off the tree. Payne (2001) explained further that the first crop of nodules takes 3 to 6 weeks to harvest, the exact period depending on climatic conditions. In general, the higher the average temperature, the greater the production of gum and the shorter the drying period. Subsequent crops are harvested at shorter intervals of 1 to 2 weeks. Observations made by AGL (1993) indicated that gum arabic collection by nomads in Kenya, which would also be the case in Tanzania, is not based on a specific time schedule as it was mostly premature or delayed.

2.2.2 *Acacia senegal*

2.2.2.1 Description

Acacia senegal (L.) Willd. belongs to the family Fabaceae syn. Leguminosae (Mimosoideae) and it is known with different vernacular names in different areas for example: Gumtree, Gum arabic tree (English), Gommier (French), Hashab, Ketr el Abyad, Asharat (Arabic) and in Tanzania, it is known as Kikwata (Swahili), Igwata (Sukuma), Ilela (Nyiramba) and Ol munshuin, Osbiti (Maasai) (FAO, 1983; Booth and Wickens, 1988; Coe and Beentje, 1991).

The species forms a deciduous thorny tree in areas of 120 mm of rainfall but may reach 3 to 6 m in areas of between 300 and 500 mm. In favourable sites the tree may grow up to 9 or even 15 m with diameter reaching 40 cm (FAO, 1983; Booth and Wickens 1988). Its stem is irregular in form and often highly branched. It has characteristic sets of prickles on the branches and stems, usually in threes with the middle one hooked



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downward and the lateral ones curved upward (Booth and Wickens 1988; FAO, 1983; Coe and Beentje, 1991).

A. senegal is represented by four varieties namely *senegal*, *kerensis*, *leiorhachis* and *rostrata* and, according to Anderson and Wieping (1990) each variety has a distinct and characteristic gum exudate. Variety *senegal* which was used in this study, forms the major source of commercial gum arabic and is found in Tanzania together with *kerensis* and *leiorhachis* (Brenan, 1983; Cossalter, 1991; Fagg *et al.*, 1997; Barnes *et al.*, undated; Timberlake *et al.*, 1999).

The bark is light-grey or light-brown, not papery nor peeling, smooth in young trees but slightly scaly and somewhat creviced in old individuals (FAO, 1983). The author described further that the tree's branches are much ramified, difficult to penetrate when trees are close together, and the spines make the gum harvesting difficult. The twigs are dull grey to grey-brown or purplish-grey (Brenan, 1959).

2.2.2.2 Distribution

The tree is a dominant component of the woody vegetation on light sandy soils (FAO, 1999). It is characteristic of the African dry lands, in area receiving rainfall of between 250 and 750 mm per year and mean annual temperatures of between 25 and 27⁰C. It cannot withstand an excess of moisture and is sensitive to frost (FAO, 1983).

Figure 2.1 below shows the worldwide distribution of *Acacia senegal* and its varieties. *Acacia senegal* is a widespread species occurring naturally from Mauritania to Sudan, Ethiopia, Somalia, East Africa and extends southwards to Mozambique and South Africa. It also occurs beyond the Red Sea in Arabia, Sinai desert, Iran, West India and Oman (Cheema and Qadir, 1973; Ross, 1979; Brenan, 1983; Booth and Wickens, 1988; Barnes *et al.*, 1997).

According to FAO (1999), *Acacia senegal* var. *senegal* occurs naturally over the large area referred to as the Gum Belt which covers about 45 % of Sudan and is the only variety that is being cultivated for the production of gum in the Sudan and other Sahelian countries (FAO, 1999). Barnes *et al.* (undated) and Wickens (1976) observed the highest diversity of *Acacia species* across the Kenya-Tanzania and Zimbabwe-South Africa borders.

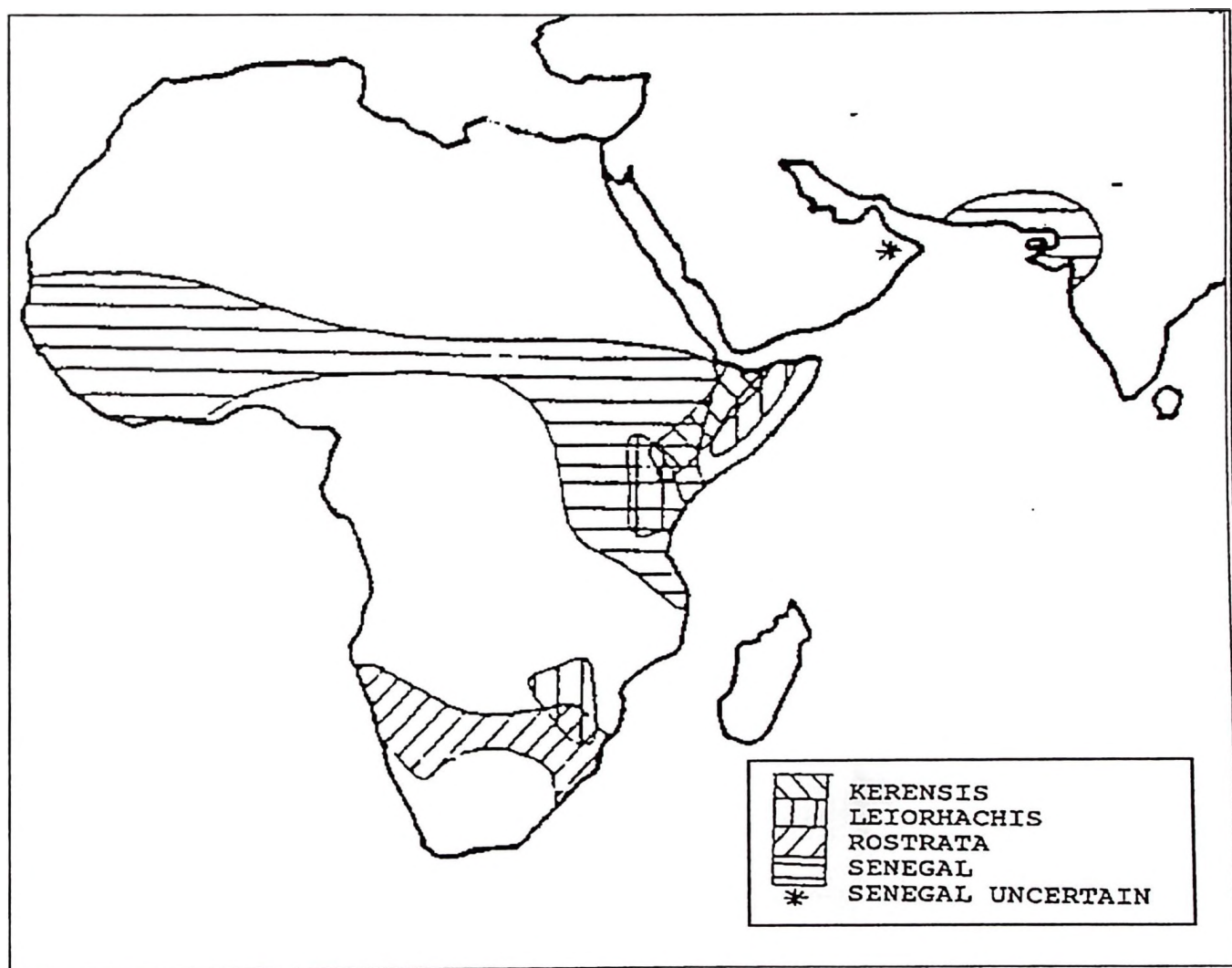


Figure 2.1 *Acacia senegal* – Map showing approximate distribution of the species and its varieties (Source: Brenan, 1983)

2.2.2.3 Other uses of *A. senegal*

The wood of *A. senegal*, whose calorific value is 3,200 Kcal. kg⁻¹ (NAS, 1980) is sought after for meeting wood fuel requirements (NAS, 1979; 1980; Kaba, 1989; Badi *et al.*, 1989). According to Badi *et al.* (1989), *A. senegal* provides most of the fuel wood supply in Western Sudan.

The wood is considered heavy and tough so is employed in agricultural implements, roofing, lining wells, timber framing of huts and poles (NAS, 1979; FAO, 1983). In Sudan, *Acacia senegal* is incorporated in a bush-fallow system of shifting cultivation, described by Seif el Din (1981b), for improvement of soil fertility during the fallow period. Being a legume, it has the ability to harbour nitrogen-fixing bacteria. The resource is also useful for protecting the soil from erosion and for curbing desertification (Sharawi, 1987; Booth and Wickens, 1988; Seif el Din and Zarroug, 1998).

FAO (1983) attempted an explanation of how the long lateral roots of *A. senegal* can be put into use. It was documented that the roots can be used as twine either directly or after beating them to extract the fibres.

The leaves and pods, which have adequate phosphorous content ranging between 0.12 to 0.15 % are used as animal fodder. They are palatable to animals with an energy value of between 6.8 to 7.5 MJkg⁻¹ DM and 4.0 to 5.0 MJkg⁻¹ DM and nutritional ratio DP/FMJ of between 125 to 160 and 200 to 230 for leaves and pods respectively (FAO, 1983).

2.3 Materials and methods

2.3.1 Study sites

This study was carried out in all of the eleven districts namely, Dodoma Rural, Singida Rural, Iramba, Igunga, Shinyanga Rural, Meatu, Maswa, Kiteto, Babati, Bukombe and Geita.

2.3.2 Sampling and data collection

2.3.2.1 Sampling

Vegetation maps of Tanzania (MNRT, 1984) and those specific for each area (MNRT, 1996a; b; c; d; e; f; g; h; i; j; k; l; m; n; o; p) formed a starting point for the survey, as a similar approach was successfully applied by Chikamai (1994), when studying gum arabic in Kenya. In addition to this, local people knowledgeable in gum arabic sources, including forest officers, assisted in area identification. Vegetation units described as containing *Acacia* species and specifically *A. senegal* were identified and marked for the field survey. Stratified random sampling techniques were necessary for attainment of fair representation and increasing precision (Richards 1980; Fowler 1993). For this case, each site constituted a stratum in which sample trees and plots were picked for the study. This started by running a preliminary survey employing 30 sampling units, whose results are presented in Table 2.1 below. The sample size (N) was calculated as:

$$N = \frac{CV^2 \cdot 1.96^2}{AE^2}$$

Where: N = Size of sampling units,

CV = Coefficient of variation among the sampling units,

1.96 = t-value at the 95 % probability level, and

AE = Desired allowable error, of 5 %.

Gum arabic yield sample trees

Careful observations of living *A. senegal var. senegal* supplemented by specimens and habit-sketches and/or photographs were adhered to as Brenan (1959) cautioned about the ambiguity in identifying the species. In the preliminary survey, 30 sample trees representing small, medium and large trees were objectively picked in each district for gum yield studies. Results in Table 2.1 indicate high variability in gum yield tree⁻¹ within districts, it was therefore decided to use the overall sample size requirement of 1,103 trees for the whole major study, bearing in mind the time and financial constraints. In the major study almost a hundred trees were sampled in each district totalling 1,103 trees specifically stratified to represent four diameter classes: 0 – 4 cm, 4.5 – 8 cm, 8.5 – 12 cm and >12 cm. Chikamai (1994) classified the trees into five basal diameters when studying *A. senegal* of Kenya.

The trees were also selected to represent different slopes of the landscape and human disturbances particularly bush fires. For the effect of fire, 402 trees (36 %), 403 trees (37 %) and 298 trees (27 %) were sampled for intensity 1, 2 and 3 respectively.

***Acacia senegal* population sample plots**

In the preliminary sampling exercise (Table 2.1), it was dictated that 1,700 plots were adequate for the study on the stocking levels of *Acacia senegal*. However, due to the expansive nature of the study areas, the time and financial constraints, only a total number of 518 circular 0.1 ha plots each could be surveyed, making the allowable sampling error for the study change to 9 %. The plots were picked using a systematic random sampling method employing transects on a set bearing for each vegetation unit in a district (Figure 2.2). The whole exercise started by predetermining the plots' locations on the maps from the first randomly picked plots for each vegetation unit and computing their distances in relation to such benchmarks as motorable routes, streams, settlements and hills. All plots were located at least 500 m inside the unit and also 500 m from the nearest road to minimise the effects of human impacts, the technique which

was successfully used by Amanyunzu (1988), and reported and applied by Chikamai (1994) in Kenya. Chikamai (1994) however, used 28, 25 and 12 plots for Isiolo, Marsabit and Turkana districts respectively.

2.3.2.2 Data collection

Gum arabic yield

The sample trees were measured for dbh and heights, adhering to standard methods (Philip, 1994). Other tree parameters assessed and recorded were the number of branches and the tree form. Each sample tree was wounded by de-barking a 2 cm x 10 cm portion of the stem at breast height, the method being adopted with modification from Dwivedi (1993). For those trees, which were small or branched below the breast height, wounding was effected just below the branches. The wounding activities were carried out simultaneously on 24/06 for all sample trees, the period in which the weather conditions, as indicated in Table 1.1 were conducive for gum tapping (Siddig, 1991; AGL, 1993; Payne, 2001). As FAO (1977) noted, customary rights exist to use fire for shifting cultivation, hunting and establishment of new grazing areas. It is between this period and October when the occurrence of bush fires in the study areas is apparent. Gum from the trees was collected on 16/07, 08/08, 01/09 and 24/09 (four times, referred to as cycles in this study). The interval between cycles was three weeks to allow maximum yield and adequate drying of the gum, as advocated by AGL (1993) and Payne (2001). Control of unauthorized collection of gum on the experimental trees was ensured. The samples from each tree were kept separately in polyethylene bags, labeled for identification and weighed in the field, using a sensitive electronic weight scale.

The plot characteristics were also assessed and recorded. These included elevation, climate, soil and terrain type and disturbance by wild bush fires and their intensity. Three levels of fire intensity were recognised and recorded as 1, 2 and 3. There were no signs of fire occurrence in plots with fire intensity 1, whereas plots with intensity 2 had signs of fire occurrence but whose effects could only be observed on its undergrowth. Plots with fire intensity 3 had effects of fire spread all over the vegetation with *A. senegal* trees being remarkably scorched.

Table 2.1 Summary of results of preliminary sampling for studies on gum arabic yield and *A. senegal* stocking levels in Tanzania

District	Gum arabic yield (gm tree ⁻¹)				<i>A. senegal</i> stocking level (trees ha ⁻¹)									
	Mean	Std dev	C.V	N trees calculated	N trees sampled	Mean	Std dev	C.V	N plots calculated	N plots sampled	Village	1 st plot description	Location	Next plot
Dodoma														
Rural	128	63	0.5	372.2	103	381	401	1.1	1702.2	58	Chigongwe	6°04'52"	35°31'52"E	S25°W 2.7 km
Singida														
Rural	114	122	1.1	1,760	101	116	107	0.9	1307.4	50	Mwanduigembe	4°48'42"S	34°22'07"E	S48°E 1.3 km
Iramba	107	92	0.9	1,136	103	150	178	1.2	2163.9	46	Kibaya	4°38'52"	34°22'09"E	S53°E 3.4 km
Igunga	264	168	0.6	622	100	187	183	1.0	1471.6	52	Nkinga	4°27'11"S	33°28'04"E	N19°E 2.9 km
Shinyanga														
Rural	364	371	1.0	1,596	100	365	371	1.0	1587.6	46	Bulimba	3°44'52"S	33°37'07"E	N71°W 4.1 km
Maswa	224	228	1.0	1,592	100	283	291	1.0	1624.7	50	Mwalata	3°16'42"S	33°50'38"E	N13°W 3.8 km
Meatu	405	314	0.8	924	99	300	314	1.0	1683.4	38	Ilumalo	3°42'09"S	34°37'13"E	N50°E 2.4 km
Babati	79	48	0.6	567	100	68	69	1.0	1582.2	48	Laghranbeg	4°20'07"	35°20'33"E	N46°E 1.7 km
Kiteo	183	191	1.0	1,674	102	322	340	1.1	1713.2	46	Makami	4°52'06"	36°41'52"E	N8°31'W 2.3 km
Bukombe	217	182	0.8	1,081	88	86	94	1.1	1835.8	34	Lugunga	3°32'11"S	32°11'08"E	N45°32'E 1.2 km
Geita	194	152	0.8	943	107	206	220	1.1	1752.6	50	Kasamwa	2°44'23"S	32°15'56"	S35°W 2.3 km
Overall	207	176	0.8	1,103	1,103	224	234	1.0	1669.1	518				



Plate 2.1 Tapping *Acacia senegal* for gum arabic. Left: gum exudation on a wound, Right: gum ready for collection

***Acacia senegal* population**

Forest resource assessment methods were employed in data collection. These encompassed inventory of *Acacia senegal* in each plot. Data recorded from each sample plot included *A. senegal* tree dbh distributed in classes to reflect age structure and density per diameter class.

Other woody plants growing in association with *A. senegal*, some of which are possibly Tanzania's gum arabic contaminants, were also recorded using vernacular and, where possible, scientific names. Identification using scientific names was accomplished by consulting Burtt (1940), Eggeling (1940), Dale and Greenway (1961), Blundell (1987), Westman (1990), Hines and Eckman (1993), Mbuya *et al.* (1994) and Timberlake *et al.* (1999). Photographs of unidentified plant species were taken for later identification by botanists. The plot characteristics, i.e elevation, climate, soil and terrain type, were also assessed and recorded.

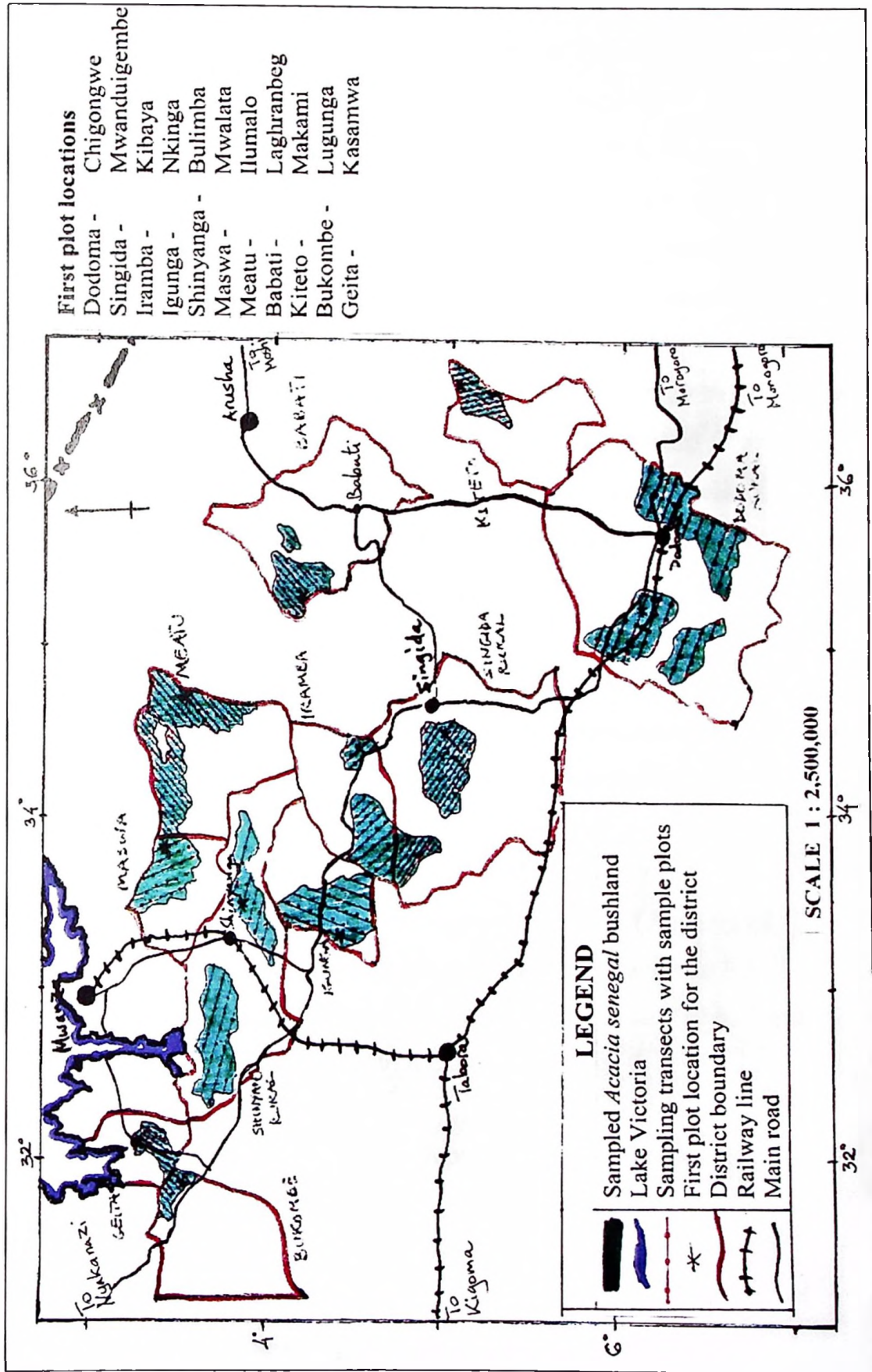


Figure 2.2 Location of plots for *Acacia senegal* population sampling

2.3.3 Data analysis

Data analysis was carried out using the Microsoft Excel package of Microsoft Office 98. Descriptive statistics facilitated determination of such important information as means, standard deviations and minimum and maximum values. One-way statistical analysis of variance (ANOVA) was important in determining the least significant difference between means. Regression analysis was used to assess relationships between quantitative data, i.e influence of tree characteristics and environmental factors on gum yield and environmental factors on *A. senegal* stocking levels, in which the strength of the relationship was measured employing R^2 . This was also supplemented by a logistic regression employing binary logistics with a Wald Forward Stepwise entering method and a cut value of 0.50, in SPSS version 11, for factors controlling a tree whether or not to produce gum. For the logistic regression, the strength was measured using Percentage Correct, β , Wald, t-statistics and probability levels.

Since fire intensity is qualitative in nature, it was treated as an indicator or dummy variable whose three intensities 1, 2 and 3 were employed in assessments in order to test their influence on yields in a way described and recommended by Dougherty (1992) and Zar (1996).

Several equations for regressed parameters were derived (Appendix I, Table 1, 2, Figure 1, 2) using factors expected to influence yield and tried and the best fits were short-listed basing on R^2 , t-statistics and probability levels. Graphical, tabular and pie-chart methods were also employed to analyse quantities of gum yields.

The stocking level of *A. senegal* in each plot was calculated as:

$$N = n / a$$

Where: $N = A. senegal$ stocking level, ha^{-1} ,

$n = A. senegal$ stocking level, $plot^{-1}$, and

$a =$ Plot area (0.1 ha).

The same equation was applied for the other species found in association with *A. senegal*.

Weighted means of gum yield per tree and *A. senegal* stocking level ha⁻¹ were calculated using the two equations shown below, respectively:

$$\bar{Y} = \frac{\sum [f_i Y_i]}{\sum f_i}$$

$$\bar{X} = \frac{\sum [f_i X_i]}{\sum f_i}$$

Where: \bar{Y} = Weighted mean for gum yield,

\bar{X} = Weighted mean for *A. senegal* stocking level,

f_i = Number of sample trees for gum yield tree⁻¹ and sample plots for *A. senegal* stocking level ha⁻¹, in district i , respectively, and

i = District 1, 2, 3, ... n .

The potential gum arabic yield ha⁻¹ was calculated as $\bar{Y} * \bar{X}$

Where: \bar{Y} = Weighted mean of gum yield, in kg ha⁻¹, and

\bar{X} = Weighted mean of *A. senegal* stocking level, in Number of stems ha⁻¹.

2.4 Results and discussion

2.4.1 Gum arabic yield per tree

Figure 2.3 below shows the mean gum arabic yields per tree in the different districts of Tanzania. The overall mean yield per tree was 246 ± 333 g with weighted mean of 236 g if district variations are considered, and mode of 0 g per season. The high standard deviations values are influenced by the fact that even those trees that did not produce gum (30 % of the trees sampled) were considered in the experiment. When considering only those trees which produced gum, the overall mean yield per tree is improved to 338 ± 374 g with a mode of 12 g.

In Sudan, the average production per tree was 250 g (NAS, 1979) but in Mauritania it was only 100 g (FAO, 1983). Studies in Kenya by Mulinge and Abdille (1988) show that mean yield varies from 250 and 2,000 g. FAO (1995b) suggested that the gum yield of 250 g per tree per season is often cited as average yield, with upper extremes of between 1,000 and 5,000 g.

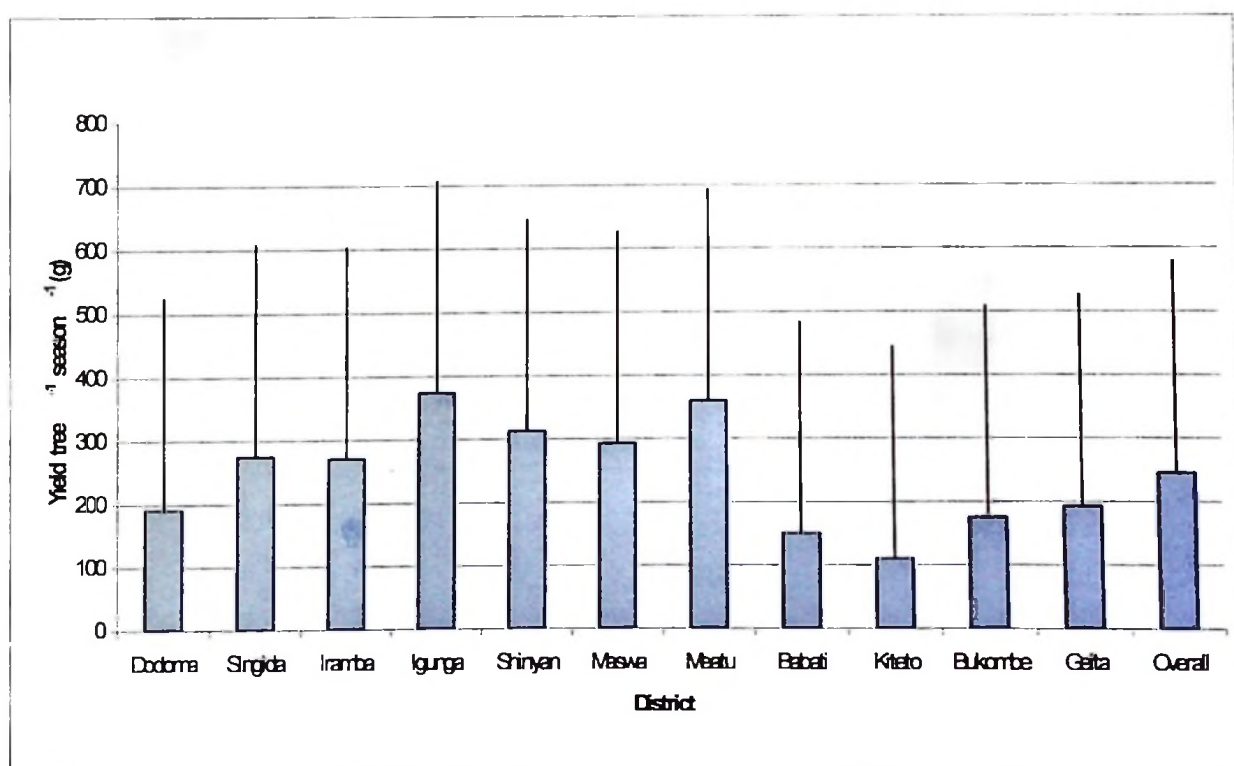


Figure 2.3 Mean gum arabic yields per tree per season in different districts in Tanzania.

Note: Only positive standard deviations have been plotted due to high variability, most exceeding the means.

2.4.1.1 Gum arabic yield variations

In this study, the observed variation in gum arabic yield per tree can be separately described: between trees in the producing zone, within trees but between tapping cycles, between plots and between districts.

Variation between trees

There was a high variation in the gum yield between trees ranging from 0 to 1,811 g. Out of 1,103 sample trees studied, 333 trees (30 %) did not produce gum at all. Of the entire sample trees, 574 (52 %) produced gum between 0 to 100 g then the number dropped abruptly from 146 trees for 100 – 200 g, 112 trees for 200 – 300 g to 30 trees for gum yield over 1,200 g. The gum yield frequency distribution is presented in Figure 2.4 below.

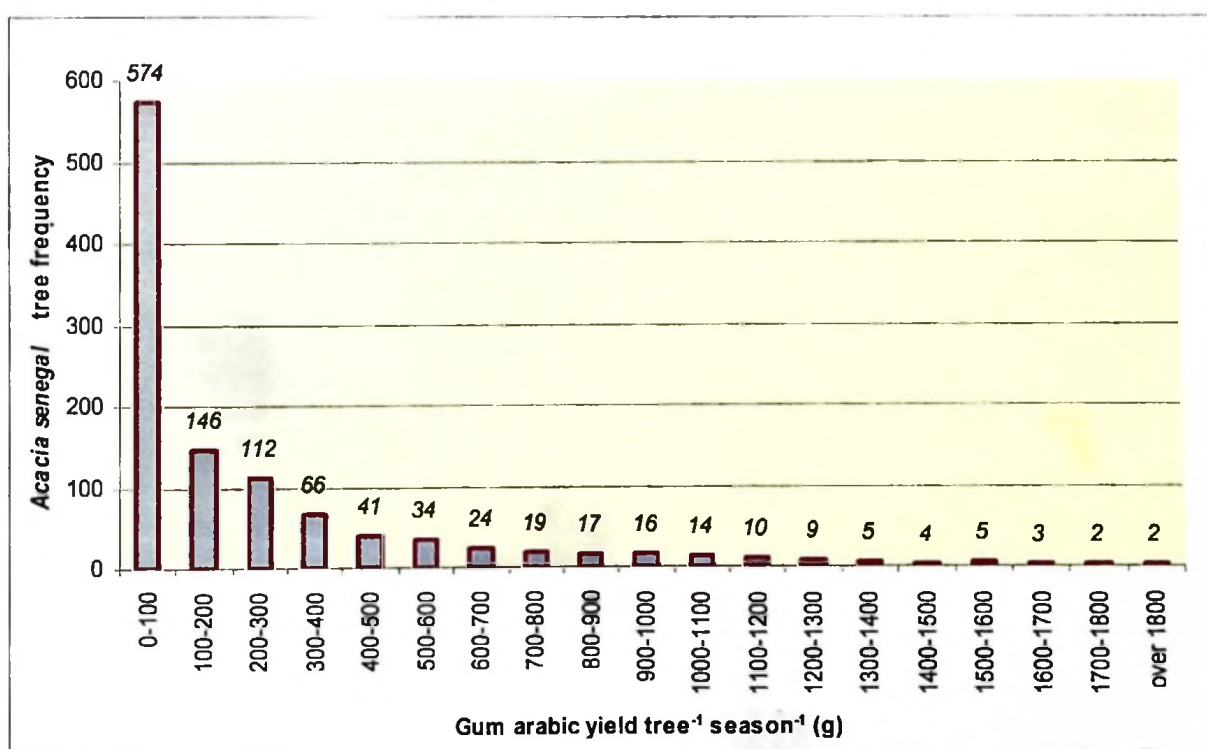


Figure 2.4 Gum arabic yield frequency distribution by trees

The between-tree variations might have been caused by differences in the genetical make up of individual trees, tree characteristics such as age and size, the environmental conditions such as climatic factors, namely rainfall and temperature, soil characteristics and the biotic environment. The distribution patterns of the yielding and non-yielding trees by diameter and height are presented in Appendix II, Figure 1 and 2 respectively.

In a given population, some trees of *Acacia senegal* could produce gum more readily than others. FAO (1983) estimated variation in gum production per tree from a few grams to 10 kg. This statement has been supported by many authors: for example, in Sudan FAO (1978) reported a yield range of between 100 and 200 g, Muthana (1988) of 225 g, NAS (1979) of 250, Badi *et al.* (1989) of between 250 and 600 g, ITC (1972) of between 900 and 2,000 g and ISC (2002) of between 400 to 7,000 g, and in Kenya, Mulinge and Abdille (1988) of between 250 and 2,000 g However, according to Badi *et al.* (1989) yields of above 300 g are unusual.

The variation in average yield of gum per tree is also reported by Anon. (1972) for *Acacia nilotica*, which produces Babul gum, ranging from 100 to 1,000 g.

Variation between tapping cycles

Figure 2.5 below represents the general trend in the variation between the tapping cycles. It is evident that the first two tapping cycles constituted about 66 % of the gum yield. In fact, although yield fell by a smaller and smaller actual amount, it drops by a greater proportion of the previous yield between each cycle: from 26 to 30 % over the four cycles.

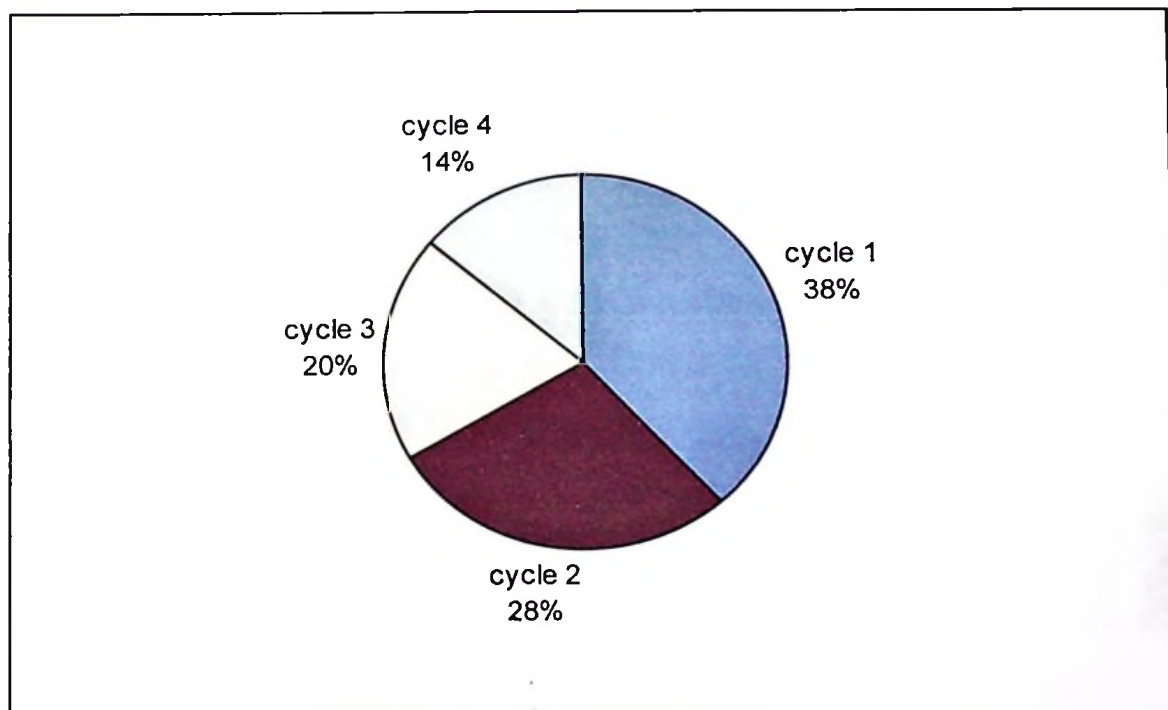


Figure 2.5 Overall mean variations of gum arabic yield between tapping cycles in Tanzania

The differences between cycle yields tested highly statistically significant ($p < 0.01$). Studies on effect and intensity of tapping in Sudan, reported by FAO (1983), have shown that higher yields are realized shortly after the rains rather than later in the dry season. This could be related to findings by Campa *et al.* (1998) that highest mean yields are obtained during the early tree leaf fall. In his investigation on time of tapping, Ballal (1989) found a significant increase in gum yield with earlier tapping with percentage contribution of 46 %, 27 %, 16 %, 6.7 % and 5.4 % for cycles one to five. According to Sharawi (1987), in Sudan, successive pickings of gum nodules take place several times within one season, four as an average, with intervals of about 10 days. Frequent tapping stimulates higher yields of gum than infrequent tapping, but the former treatment weakens the tree. ITC (1972) and Ballal (1989) therefore suggested keeping the tapping at a minimum in order to increase the production span of the tree.

FAO (2001b) noted that gum arabic tapping in Chad is carried out by using destructive harvesting techniques. For tapping of other exudates from trees, pine resin for example, if done properly causes no damage and can continue for up to 20 years or more (Ciesla, 1998).

Variation within districts

Using a one-way analysis of variance, there was an indication of statistically significant difference ($p < 0.01$) in the variation of gum yield per tree within districts. This is in agreement with observations made by Ballal (1986) within Demokeya Forest Reserve of Sudan, in which there were notable differences in gum arabic yield between plots ranging from 0 g to 1,863 g per tree.

The variations within districts may be attributable to differences in tree genetics and micro environmental factors such as temperature, soil moisture, nutrients and number of stems per unit. Aspect, for example, influences the intensity of sunshine on plots thereby influencing temperatures. Soil structure determines the availability of both soil moisture and nutrients and also influences aeration and soil temperatures.

Variation between districts

As depicted in Figure 2.3 above, mean gum yield per tree varied from one district to another, with Igunga in the lead with 374 ± 559 g followed by Meatu (359 ± 407 g), Shinyanga (313 ± 484 g) and Maswa (292 ± 327 g). The medium yields of gum per tree which are a bit higher than the country's overall mean of 246 ± 303 g were observed in Iramba (270 ± 435 g) and Singida (275 ± 431 g), whereas the lowest yields were in Kiteto (111 ± 192 g), Babati (150 ± 232 g), Bukombe (175 ± 178 g), Dodoma (191 ± 186 g) and Geita (193 ± 205 g).

The general pattern in this study indicated highest gum yield around the Igunga – Shinyanga – Meatu zone in a Southwest – Northeast strip and lowest in the peripheral areas. The one-way analysis of variance revealed a highly significant difference in gum yield between sites ($p < 0.01$) despite large standard deviations.

As documented by several authors such as Obeid and Seif El Din (1970), FAO (1983) and Booth and Wickens (1988), the yield variation between sites is common.

2.4.1.2 Assessment of factors related to gum arabic yield variations

The possible factors related to gum yield variations between trees, within and between sites can generally be grouped into two categories namely, tree characteristics or biological factors and environmental or physical factors. It was hypothesized that gum yield is a function of tree characteristics (Dbh, height and branches) which are themselves likely to be influenced by the environmental and genetic factors and the environmental factors (fire, weather, altitude, stem density and slope of the landscape).

There might be short-term (high temperatures this year, fire occurring this year) and longer term (average temperatures, average rainfall and fire incidences over a number of years) effects of the environment factors on gum yields. In these studies, it was possible to pick up tree characteristics and some short term, some long term environmental factors but not others and not tree genetics.

The assessed tree characteristics for each district are summarized in Appendix I, Table 1.

The summary of regression analyses of gum arabic yield and the assessed tree and environmental factors is presented in Table 2.2 below.

From the table, it is evident that, of the tree characteristics, size is an important determinant of gum production. Environmental factors have much poorer explanatory power, with temperatures of the locality and fire intensity most significant.

Tree characteristics

Tree diameter at breast height

Tree diameter alone could explain the variation in gum yield by 36 to 51 % ($p < 0.01$). When yield is unadjusted and Dbh is both in unadjusted and natural logarithmic terms the R^2 is 0.36 (equation 8) and becomes further improved to 0.41 when both the yield and Dbh are considered in natural logarithmic terms (equation 3). The gum yield per tree – Dbh regression showed strongest relationship with an R^2 of 0.51 ($p < 0.01$) when considering the logarithm of adjusted yield against Dbh in both unadjusted and natural logarithmic terms (equation 4 in Table 2.2). As the scatter diagram (Appendix I, Figure 1) suggests, a straight line does not provide the best fit as the yield appears to peak at a Dbh of around 12 cm and then shows a tendency to decline. Thus equation 4, shown below and plotted in Figure 2.6 is bell shaped.

$$\ln Y = -10.35 - 0.94 \text{ Dbh} + 11.17 \ln \text{ Dbh}$$

this can be written as,

$$Y = 0.000032 * \exp^{-0.94\text{Dbh}} * \text{Dbh}^{11.17}$$

Where: Y = Gum arabic yield per tree, in g,

Dbh = Diameter at breast height of *Acacia senegal* tree, in cm.

Table 2.2 Summary of regression analyses of gum arabic yield per tree and the related tree and environmental characteristics

No.	Yield term	Coefficients														R ²			
		Constant	Dbh	In Dbh	Height	In Height	Branch	Rain	In.Rain	Temp	In.Temp	Fire2	Fire3	masl	In.masl		Stems	Slope	Slope ²
1.	ln Y	-7.39 (-14.56) p<0.01			-2.71 (-9.69) p<0.01	16.39 (15.23) p<0.01													0.24
2.	Y	237.34 (6.61) p<0.01					-0.23 (-0.03) p=0.97												<0.01
3.	ln Y	-9.74 (-22.66) p<0.01	7.07 (27.48) p<0.01																0.41
4.	ln Y	-10.35 (-25.92) p<0.01	-0.94 (-12.23) p<0.01	11.17 (24.24) p<0.01															0.51
5.	ln Y	-13.29 (-24.19) p<0.01	-1.14 (-11.39) p<0.01	13.34 (22.13) p<0.01	-0.06 (-0.12) p=0.90														0.47
6.	Y	-64.80 (-0.27) p=0.794							13.91 (1.36) p=0.22										0.24
7.	ln Y	-21.40 (-2.55) p=0.01	-1.02 (-12.80) p<0.01	11.27 (22.35) p<0.01				-0.29 (-0.41) p=0.68	1.34 (1.47) p=0.14	-0.36 (-1.37) p=0.17	0.96 (3.37) p<0.01			1.31 (1.18) p=0.24				-1.63 (-0.73) p=0.47	0.51
8.	Y	-403.26 (-11.70) p<0.01	3.02 (0.46) p=0.65	389.69 (9.80) p<0.01															0.36
9.	Y	-38.35 (-0.54) p=0.59	73.03 (17.15) p<0.01		-40.51 (-4.12) p<0.01		4.47 (0.77) p=0.44			49.01 (2.40) p=0.02	140.50 (6.31) p<0.01	-0.10 (-1.85) p=0.06			0.01 (2.17) p=0.03	-1158.84 (-1.70) p=0.09		0.34	
10.	Y	-388.69 (-2.49) p=0.01	66.60 (12.69) p<0.01		-38.27 (-3.29) p<0.01		-2.26 (-0.30) p=0.77	0.24 (2.48) p=0.01	15.65 (3.84) p<0.01	29.29 (1.14) p=0.26	158.13 (5.72) p<0.01	-0.21 (-2.24) p=0.03			0.01 (1.92) p=0.06	-2101.18 (-2.44) p=0.01		0.30	
11.	ln. Y	-10.56 (-25.60) p<0.01	-0.96 (-12.66) p<0.01	11.21 (24.59) p<0.01						-0.04 (-0.19) p=0.80	1.13 (4.61) p<0.01							0.52	
12.	ln. Y	1.75 (10.95) p<0.01																	0.03
13.	Y	-95.02 (-0.55) p=0.58						0.06 (0.61) p=0.54	12.65 (2.76) p<0.01	59.35 (2.01) p=0.04	211.55 (6.77) p<0.01	-0.05 (-0.47) p=0.64				-1397.40 (-1.42) p=0.156		0.07	

Figures in parentheses indicate t - statistics, cells in bold have p < 0.05.

This equation suggests that initial production of gum starts when the diameter of an *A. senegal* tree is above 2 cm. The observed yield of gum arabic indicated a sharp rise with increasing tree diameter between 6 to 10 cm then after which there is a diminishing rate of increase with gum yield peaking at about 430 g, at a Dbh of 12 cm. Beyond a Dbh of 12 cm, gum yield per tree declines steadily until a total cessation of gum production is reached at a Dbh of 28 cm.

Nevertheless, the best fit lines in Appendix I, Figure I do not look very convincing, suggesting the possibility of the use of a two-stage model-logit to predict production or not, and another one to predict production of trees that are yielding.

When only the gum yielding trees are considered, with logarithm of adjusted yield against Dbh in both unadjusted and natural logarithm terms, the relationship is expressed by $R^2 = 0.48$ ($p < 0.01$). The equation is shown below, which was used to compare the yield pattern with that of equation 4 (see Appendix II, Figure 3).

$$Y = 1.109 * e^{-0.16 \text{ Dbh}} * \text{Dbh}^{3.39}$$

s.e	(0.59)	(0.11)	(0.69)
p-value	<0.01	<0.01	<0.01

The plotted curve ties very much with the curve in Figure 2.6, however, there are suggestions that gum production starts a bit earlier, peaks at about 1,150 g when a tree is around 22 cm in Dbh and beyond this size there is a steady decline in gum production until a total cessation which is reached at a much later size (see Appendix II, Figure 3).

The above observations suggest that juvenility and senescence are responsible for the gum production dormancy.

The tree Dbh sizes that were identified and sampled (see Table 2.4, Appendix I, Table 1) were characterized by 66 % of the population under 4 cm, 25 % between 4 and 8 cm and the balance of 9 % was above 12 cm, so about 90 % of the trees were at the lower end of the curve and only 0.3 % of the trees were beyond the peak.

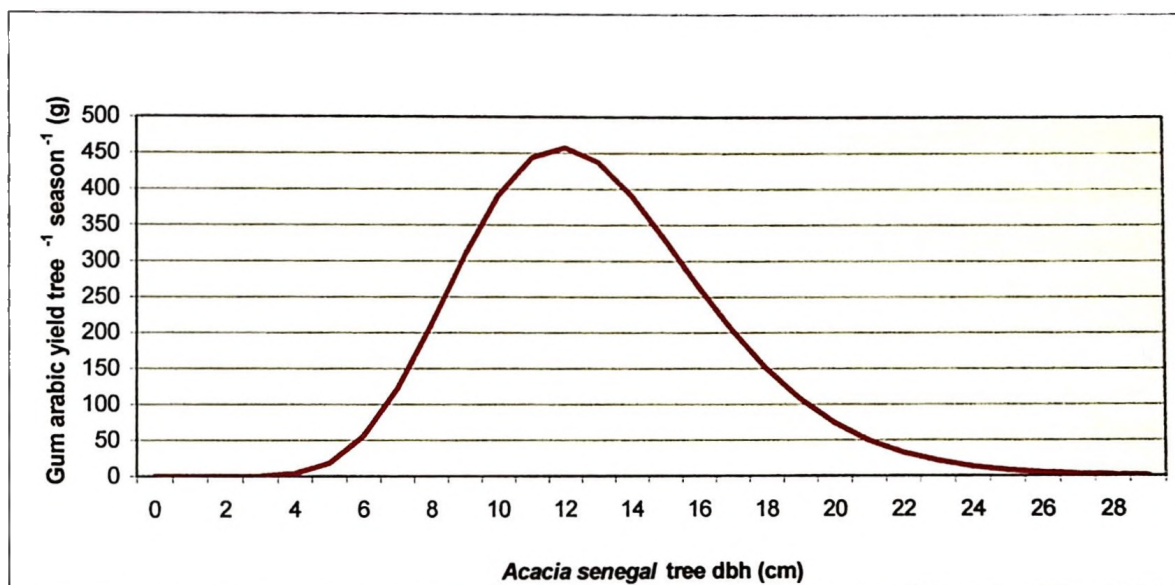


Figure 2.6 Model of relationship between gum arabic yield and *A. senegal* tree diameter in Tanzania. For scatter plot see Appendix I, Figure 1.

A similar trend was observed by Ballal (1986) in western Sudan in which maximum yield of gum (1,863 g) was tapped from trees with 7.5 cm diameter after which the yield declined from 1,350 g for 10.5 cm to 380 g for 12.8 cm trees. This author pointed out further that gum tapping in Sudan starts when the trees are at least of 5 cm diameter.

Tree height

The relationship between gum yield per tree and tree height and the logarithm of tree height was highly significant ($R^2 = 0.24$, $p < 0.01$).

The following relationship (equation 1) was used to derive Figure 2.7.

$$\ln Y = -7.39 - 2.71 Ht + 16.39 \ln.Ht$$

Therefore,

$$Y = 0.000617396 \cdot \exp^{-2.71Ht} \cdot Ht^{16.39}$$

Where: Y = Gum arabic yield per tree, in g,
 Ht = Tree height of *Acacia senegal*, in m.

The general pattern of the relationship between gum yield and tree height as depicted in Figure 2.7 is similar to that between gum yield and tree diameter in the way that it followed the same trend. However, although this equation provides the best fit for the scatter diagram shown in Appendix I, Figure 2, it is also apparent that the bulk of the variation in yield is not explained by tree height.

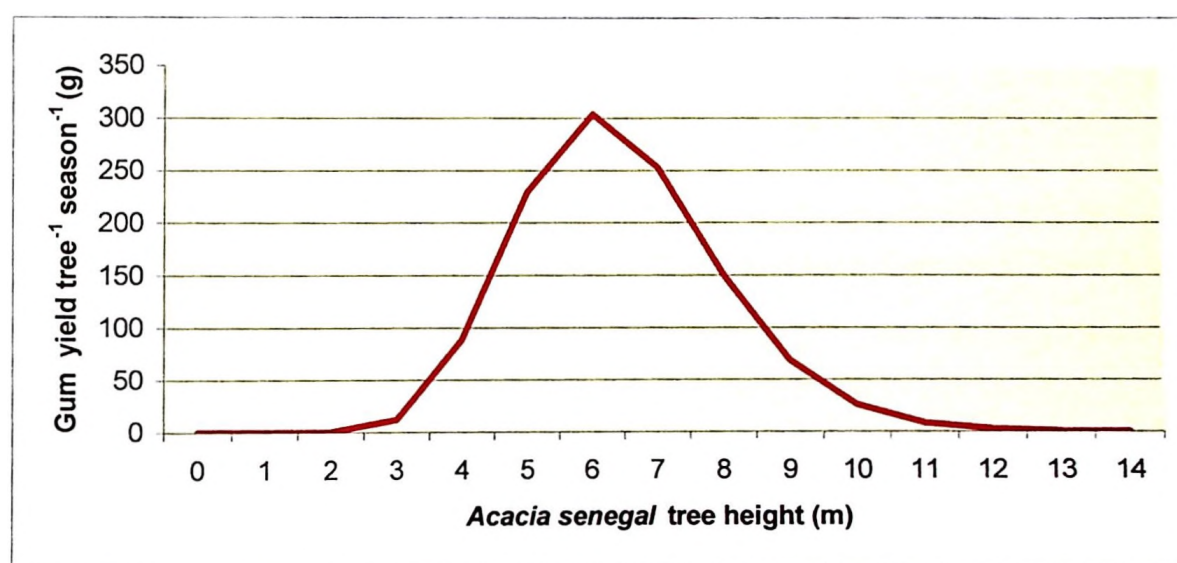


Figure 2.7 Model of relationship between gum arabic yield and *A. senegal* tree height in Tanzania. For scatter plot see Appendix I, Figure 2.

The equation suggests that gum production commences when the tree is above 2 m high and the maximum production of 300 g is attained at height of 7 m. However, in the field gum yields were observed for trees attaining a height of 1 m. The maximum gum yield was obtained at 2.0 m height and tended to decline at 4.0 m. There is an agreement between the two in that, gum production ceases after height of 12 m. The observed trend is again in strong agreement with observations made by Ballal (1986) in western Sudan. In his findings, he noted the highest yield from trees with average height of 1.6 m after which there was a decline through 1,544 g for 2.3 m, 1,094 g for 2.9 m, 694 g for 3.3 m and 380 g for 3.5 m trees. This author concluded that trees

growing naturally could be tapped annually once they attain a height of 1.2 m, which occurs at around 6 – 7 years of age.

In this study, when both diameter and height were regressed against gum yield, the equation was highly significant ($p < 0.01$) but the R^2 was not improved and the height variable was not significant ($R^2 = 0.51, 0.47$, c.f. equation 5 with equation 4). This could be due to multicollinearity between tree diameter and height, the residual effect of which adversely affects the gum yield on excess tree sizes in terms of height, indicated by a negative height coefficient. The regression results suggest that diameter is a better predictor of gum yield.

Using age as a criterion, Duke (1981) reported that annual yields from young trees in Sudan vary from 188 to 2,856 g per tree and from older trees the yields are in a range of 379 to 6,754 g per tree. Hunting Technical Services (1964), using a criterion of tree size, reported that annual yields from small trees in Sudan range from 100 to 300 g per tree while those from large trees range from 450 to 2,000 g per tree. Dale and Greenway (1961) and Weber and Stoney (1986) suggested that tapping can be sustainable only to an age of 18 years. This is supported by FAO (1983) who noted that maximum yield of gum is expected within a period of 20 – 25 years.

Further evidence concerning gum arabic production was presented by Siddig (1991) who stated that production starts at age of 3-4 for coppices, 5 years for plantations and 6-7 years for natural stands. FAO (1983) documented that the highest gum yields are obtained from trees aged between seven and fifteen years. According to Seif El Din (1981a), healthy trees produce more gum over a period of years than unhealthy trees, although the latter may produce large amounts of gum shortly before they die. Anon. (1972) noted that the yield of Babul gum goes down with increased age of the tree and old trees produce no gum.

These observations made elsewhere suggest that yields rise but then eventually diminish as equations 4 and 1 for diameter and height indicate. As far as diameter and height indicate age, the results here would seem to confirm findings elsewhere. However, because of the additional effect of environmental factors on diameter and height these latter two variables would seem to be better indicators of gum yield.

Tree branch abundance

The *Acacia senegal* sample trees had branches ranging from 2 to 10 with a mean and mode of 4.8 ± 1.5 and 4 respectively. This finding concurs with the FAO (1983) and Booth and Wickens (1988) description of the species that it is often highly branched.

The parameter of tree branch abundance showed no relationship with gum arabic yield ($R^2 = 9.4 \times 10^{-7}$, equation 2) when considered singly, nor when considered with tree diameter, height, fire, altitude, stems, gradient and rainfall despite R^2 values of 0.34 and 0.30 (equation 9 and 10). The variation in yield caused by this parameter was statistically insignificant throughout ($p=0.97, 0.44$ and 0.77 respectively).

Environmental factors

Rainfall

Regression analysis indicated an adverse effect of mean annual rainfall on the yield of gum arabic (equation 7) although the relationship was statistically insignificant ($p=0.68$) and with a low R^2 (0.03) when considered singly.

From the analysis, rainfall does not affect gum yield significantly ($p=0.68$ and 0.54 , equation 7 and 13 respectively) when considered along with either Dbh and other environmental factors or environmental factors alone. However, its effect becomes positive and significant ($p=0.01$) when both tree and environmental characteristics are included (equation 10) although the R^2 value is relatively low. This could be due to the small number of observations made on the climatic data, since data were grouped into eight areas.

Phyto-physiological studies documented by AGL (1993) have shown that trees grown under adverse conditions of scarcity of moisture produce larger quantities of gum. Work done in Senegal by ORSTROM (Fagg *et. al*, 1997) revealed that the best gum production appears to be from areas with low annual rainfall ranging from 300 to 400 mm and a long hot dry spell of 8 to 11 months. This conforms further with findings reported by Dione and Vassal (1998) in Senegal in which there was an

increase of the mean gum yield per tree parallel with a decrease in means and amplitude of soil water stocks.

These results could confirm the hypothesis that water deficit in the soil and general atmospheric lack of humidity induces gum exudation (AGL, 1993). However, Mulinge (1990) observed a declining production of gum with increasing drought and during the peak of drought, trees stopped producing gum at all.

Temperature

When considered alone, the mean annual temperature was observed to positively influence gum arabic yield in a linear manner, accounting for 24 % of the variation in yield (equation 6). However, statistical analysis did not establish significance in the difference caused ($p=0.22$). Also, when combined with tree diameter, rainfall, fire, altitude and gradient, temperature has a positive but non-significant effect on gum yield ($p=0.14$, equation 7). The effect of temperature becomes significant when either all of the assessed environmental characteristics or both tree and environmental characteristics are considered ($p<0.01$, equation 10 and 13).

The above observations could also be explained as a result of limited climatic data obtained during this study and the fact that variation between districts was not very wide. The analysis suggests that for every 1°C rise in temperature, gum yield increases by 14 g.

The results were expected, as Philip (1975) and Fagg *et al.* (1997) suggested that, the best gum production appears to be from areas with long hot dry periods. Observations made by AGL (1993) and ISC (2002) indicate significant dependency of gum yield on temperature. These authors pointed out that if, after tapping, there is a very hot spell, the gum exudes well, with the maximum exudation occurring during the hottest part of the day. It was observed further that a cold spell delays and restricts the yield.

Altitude

When the altitude is considered singly, the analysis suggests that for every 100 m rise, gum yield is decreased by five grammes. The variation in the yield caused by changing the altitude however, is statistically insignificant ($p=0.45$) and the influence of altitude is very much limited ($R^2 = 5.1 \times 10^{-4}$).

Altitude influences gum yield ($p=0.03$) when looked at together with all the other assessed tree and environmental characteristics suggesting a 21 g fall in gum yield for every 100 m rise. But the influence is again insignificant when considered along with other factors for example, all factors except climate ($p=0.06$, equation 9), tree diameter, rainfall, temperature, fire and slope ($p=0.24$, equation 7) and all environmental factors except stems ($p=0.64$, equation 13).

Altitude might be expected to have an influence on the gum yield as it has direct influence on the climate. There is a thermal gradient of -1°C for each 30 m ascended (Tarbuck and Lutgens, 1976), which also influences rain through condensation of atmospheric moisture. The direct negative relationship between gum yield and altitude is expected since the former is adversely affected by the increase in moisture conditions and cool temperatures as observed earlier.

Stem crowdedness

Stem crowdedness, fire intensity, altitude and slope were observed for each plot, so measurements were not restricted to a small number of values as occurred with the rainfall and temperature variables.

Crowdedness had a statistically significant positive influence on gum ($p=0.03$) when considered along with all other assessed factors except climate. The analysis suggests that for every 100 trees per hectare, gum yield improves by 1 g per tree. However, when climate is included in the analysis, the effect of stem crowdedness becomes marginally insignificant ($p=0.06$). Moreover, when this factor is considered singly, its effect on gum becomes insignificant ($p=0.63$) with almost no explanation of yield variation ($R^2 = 2.1 \times 10^{-4}$).

The influence of stem crowdedness on gum yield could be due to the effect pointed out by AGL (1993), Dione and Vassal (1998), ISC (2002) and Verbeken *et al.* (2003) that gum production is induced by stresses, to which the tree is subjected. Crowdedness increases competition for resources such as soil water content and nutrients.

Fire intensity

Gum arabic yield was positively influenced by fire intensity 2 when considered along with all other assessed tree and environmental factors except temperature and rainfall ($p=0.02$) and all the assessed environmental factors except stem crowdedness ($p=0.04$). However, if considered alone, fire intensity 2 did not influence gum yield relative to fire intensity 1 ($p=0.79$) with a very low R^2 (6.7×10^{-5}). Fire intensity 3 had a significant positive influence on yield of gum relative to intensity 1, when considered singly and also in all of the above combinations ($p<0.01$), although the R^2 value is only 0.03 (equation 12).

The influence of fire of both intensities on gum yield portrayed a positive linear relationship when plotted, using equation 10 (Figure 2.8).

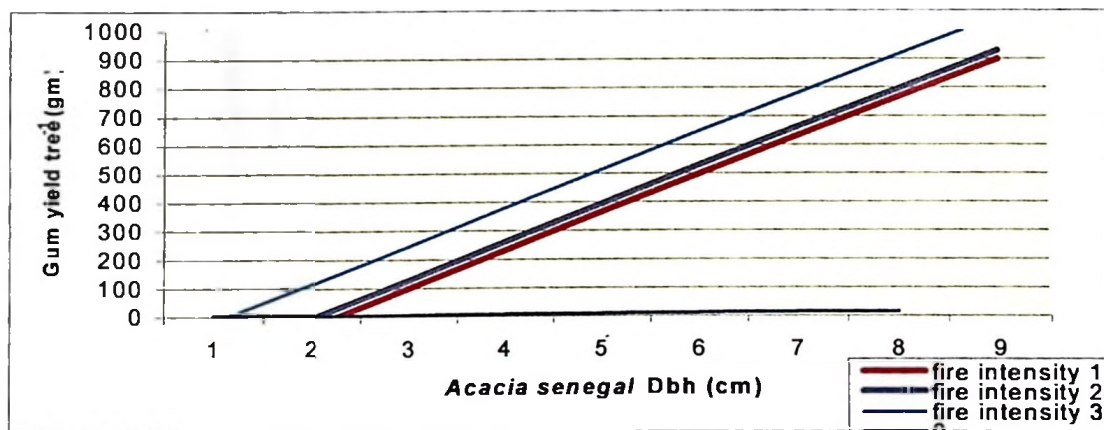


Figure 2.8 Effect of fire on gum arabic yield per tree

According to this study, it can be tentatively concluded that fire intensity 2 has a positive effect on gum yield and it can more firmly be concluded that fire intensity 3 does have a significant positive effect on gum yield.

The effect of fire on inducing higher yield is thought to be two-fold:

- Scorching the tree opens up more, though invisible, wounds in the phloem sub-cambial area, which promotes further gummosis
- The high temperatures caused by the fire trigger gummosis in the same way as high ambient temperatures do, over the short term only.

The effect of fire on gum yield can be viewed in terms of both short and long term effects. In the short term, regression analysis shows that introduction of fire of intensity 3 to a plot will raise gum yield per tree by 36 % (equation 9), from an average of 246 to 386 g, when the climatic conditions are not considered. And equation 12 suggests that when fire of intensity 3 is looked at singly, it is responsible for inducing gum production per tree of any size by 31.5 g. The difference between dummies 0 and 1 is therefore about 26 g tree⁻¹ season⁻¹.

But in a long run, fire has an adverse effect on tree diameter, which in turn negatively affects the gum yield. This is exhibited by introducing Dbh into the gum yield, as displayed in equation 11. The equation suggests that with fire intensity 3, at mean environmental and tree conditions, a tree of Dbh of 5.6 cm will yield 90.6 g of gum. If fire had reduced Dbh to 4.6, 3.6, 2.6 or 1.6 cm today instead of its expected 5.6 cm, the yield would decline from 90.6 to 26.1, 4.4, 0.3 or 0 g respectively.

The AGL (1993) and ISC (2002) suggested that production of gum by trees is due to unhealthy conditions. From this viewpoint, it can therefore be concluded that fire lessens the vitality of the tree thereby improving yields. Nevertheless, the use of fire as a tool for inducing gum production is only a short-term solution as in a long-term, it shortens the tree's life span and sometimes it might cause sudden tree deaths.

Whereas, Toole (1965) noted that fire wounds on surviving trees allow entry of fungi which could cause heart rot decay, Waldrop *et al* (1992) reported that fire could reduce the number of hardwood stems between Dbh of 2.6 and 12.5 cm in Carolina.

Slope of the landscape

From the study, slope of the landscape has direct negative influence on gum yield ($p=0.01$), when considered with all the other assessed factors (equation 10). The influence of slope becomes statistically insignificant, however ($p=0.47, 0.09$ and 0.16), when Dbh and environmental factors except stem crowdedness, all of the assessed factors except climate and only environmental factors are considered, respectively (equations 9, 7 and 13). When considered alone, slope's little effect on gum yield ($p=0.76, R^2 \approx 0$) is apparent.

Terrain has a direct effect on the availability of plant growth resources, particularly the soil moisture and nutrients. The steeper the gradient, the higher the vulnerability of the soils to loss of moisture and nutrients through erosion. This however, does not affect gum yield much. According to NAS (1979), *Acacia senegal* can yield well even where the soil is depleted and unable to support other crops. AGL (1993) added that extreme poorness of the soil with only a trace of salt in it might cause, in some instances, good yields in soils which are unable to further produce other crops.

The above observations attempt to counteract the effect of slope of the landscape on the gum yield therefore, explaining the cause for the poor relationship observed between the two.

2.4.1.3 Explaining gum arabic yield variation from the assessed factors

From Table 2.2, equations 3, 4, 5, 7, 8 and 11 give reasonably high R^2 values. Tree diameter can be seen at a glance as the main component in all of the above equations, the rest (apart from fire intensity 3) being insignificant in terms of their effect on gum yield. Zar (1996) documented that the presence of any variable in multiple regressions, if it has an insignificant influence on the sampled population, may be eliminated without any harm. In equations 4 and 8 therefore, only Dbh was considered.

The above six equations were used in plotting Figure 2.9 below in which it is clearly evident that equation 4 was the best gum arabic yield predictor.

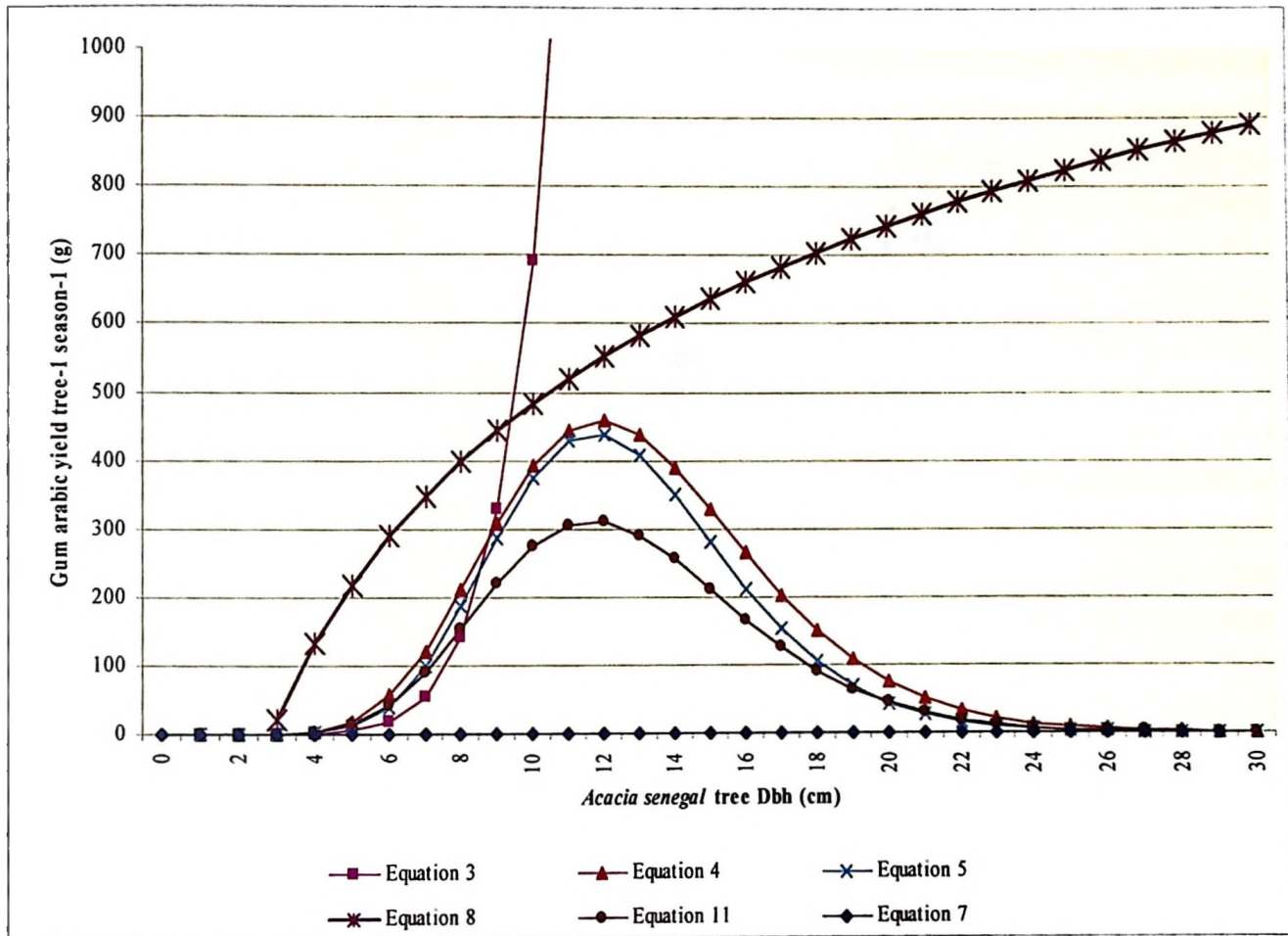


Figure 2.9 Validation of gum arabic yield prediction equations

2.4.1.4 Explaining gum arabic yield variation from effect of district dummy variables

A test of the effect of districts' dummy variables was carried out, taking out the effect of diameter, with Dodoma acting as a base. Results presented in Appendix III, Table 1 show that the districts' dummy variables, with Dbh, could explain the 52 % of the variation in gum yield ($R^2 = 0.52$), and except Igunga, Shinyanga, Maswa, Geita and Iramba, the other districts had significant coefficients ($p = 0.01$). Further observations on the table suggest that except Maswa only, the other districts negatively influenced tree gum yield.

The order of districts' gum yield tree⁻¹ with dummies from the highest to the lowest could be observed as follows (see Appendix III, Figure 1): Maswa, Dodoma, Iramba, Shinyanga, Igunga, Geita, Babati, Bukombe, Singida, Meatu and Kiteto. It can be noted from the order that Maswa, whose dummy variable coefficient is positive, had the highest yield and the districts whose dummy variables had no significant effect on the yield variation were following in a similar order.

2.4.1.5 Assessment of factors controlling probabilities of a tree to yield gum arabic

A logistic regression analysis employing binary logistics was carried out to determine factors, which control a tree to produce or not to produce gum. An Entering Wald method was used, in which the analysis was performed in a single step with a cut value of 0.50 at a percentage correct of 83 (see Appendix II, Table 1).

Results in Table 2.3 show that only Dbh and height were influencing gum production, both with significance levels of $p < 0.001$. Nevertheless, Dbh showed the strongest influence followed by height. Number of branches in a tree was found to influence gum production at 10 % probability level.

Table 2.3 Summarised logistic regression analysis results for factors controlling probabilities of a tree to produce or not to produce gum arabic

Parameter	β	Sampling Error	Wald	Significance level	Exponential of β	Probability
Dbh	0.673	0.067	99.977	0.000	1.960	0.662
Height	-0.436	0.112	15.301	0.000	0.646	0.392
Branches	-0.117	0.064	3.361	0.067	0.889	0.471
Stems	0.000	0.000	0.247	0.619	1.000	0.500
Temperature	0.033	0.035	0.873	0.350	1.034	0.508
Rainfall	0.000	0.001	0.059	0.808	1.000	0.500
Altitude	0.000	0.001	0.227	0.633	1.000	0.500
Slope	-0.950	7.498	0.016	0.899	0.387	0.279
Constant	-1.905	1.358	1.968	0.161	0.149	0.129

The above results also indicate that Dbh has a positive influence on the yield, whereas height shows a negative influence. This could be due to reasons that height picks all the negative influence when a tree becomes taller than its proportionate diameter.

A further logistic regression analysis was conducted to examine the effect of Dbh on the probability of yielding gum, employing yield and Dbh and allowing Dbh as a categorical covariate in a Forward Stepwise (Wald) method. The analysis was performed in a single step, at 82.3 percentage correct (see Appendix II, Table 1.1). Results are shown in Figure 2.10 below in which the model assumes a linear relationship between gum yield and tree Dbh and there is an abrupt stoppage of gum production above Dbh of 23 cm.

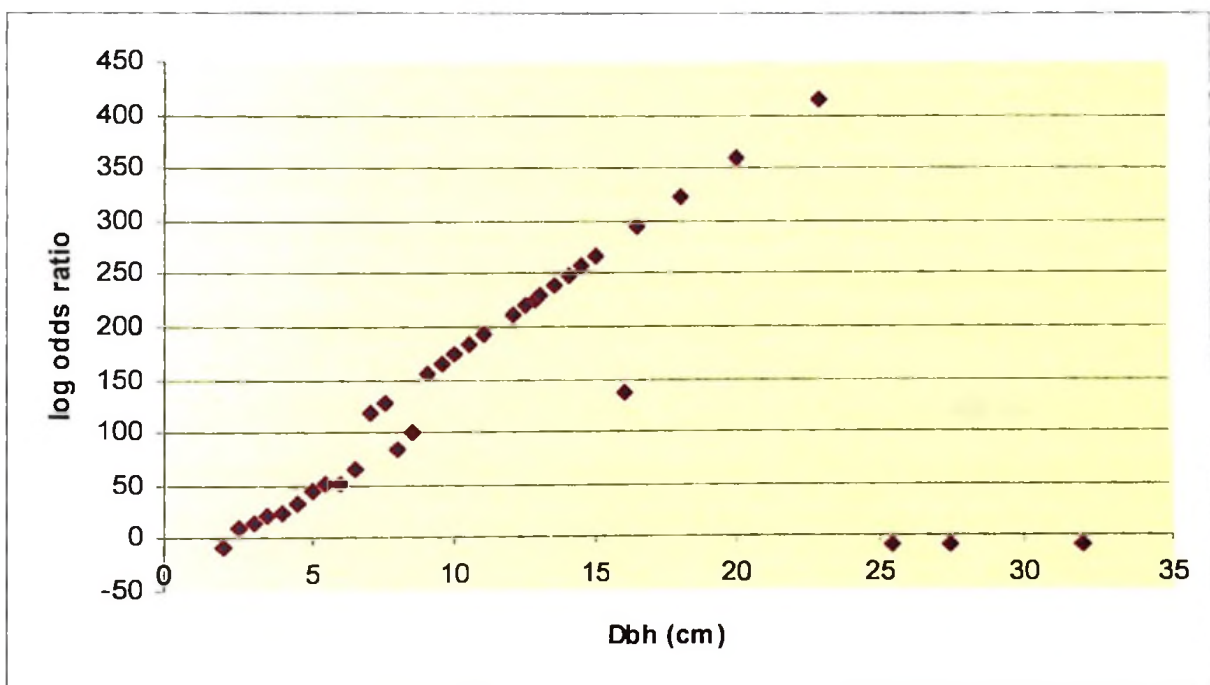


Figure 2.10 Prediction of gum arabic yield from yield log odds ratio and tree Dbh

In order to check for the validity of the above predicted model, the field data were grouped into Dbh classes and the percentages of the yielding trees in each class calculated which were used for computation of the logarithm of odds ratio, as

$$\text{Logarithm of odds ratio} = \ln [P/(1-P)]$$

Where: P = Probability of trees yielding gum in a Dbh class.

The logarithms of odd ratios for the yield were plotted against Dbh classes at their mid points. Results for the plot are depicted in Figure 2.11 below in which the assumption shown by Figure 2.10 above, for linearity is violated.

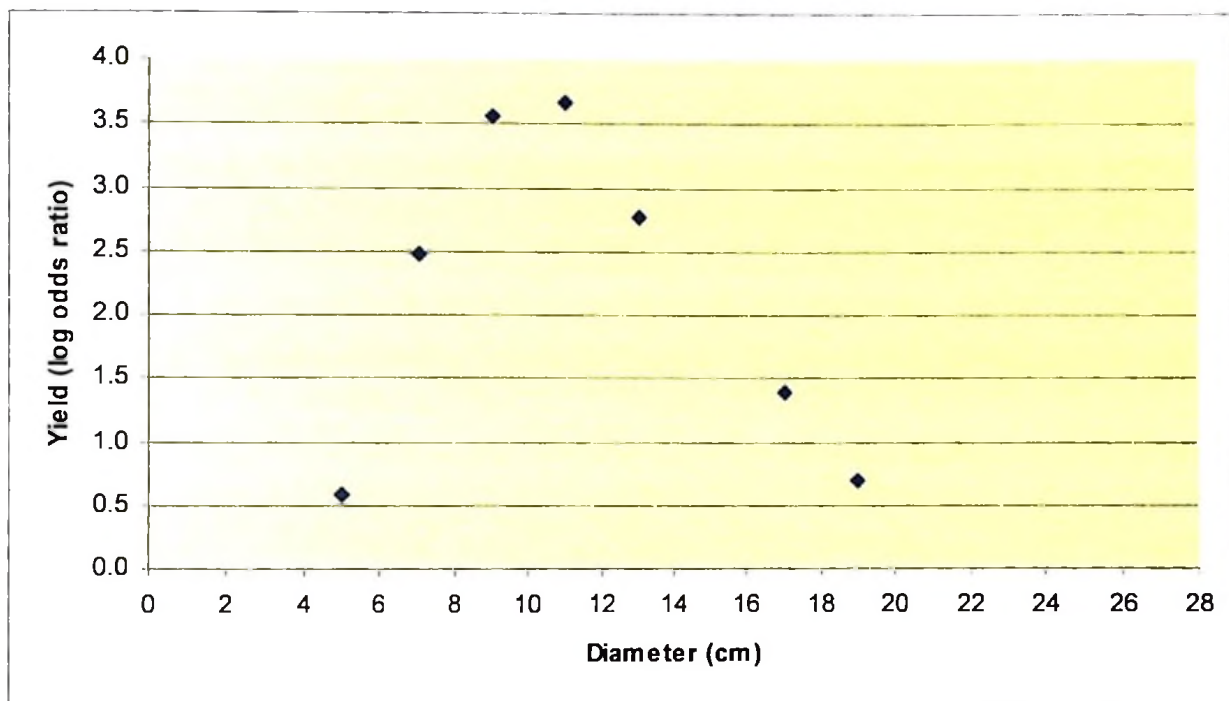


Figure 2.11 Effect of diameter on the probability of a tree to produce gum arabic

In order to tie more closely with Equation 4 in Table 2.3, a further logistic regression analysis employing yield, Dbh, $\ln Dbh$ and exponential of Dbh was conducted by Forward Stepwise (Wald) method allowing categorical covariates. This however, did not have any improvement in the percentage correct and the variables in the equation remained the same.

A similar procedure was used for obtaining the logarithms of odd ratios for the yield and plotting against height and number of branches as shown in Figure 2.12 and Figure 2.13 below. The logistic regression analyses involving height and number of branches are presented in Appendix II, Table 1.2 and 1.3 respectively.

The yield shown in Figure 2.11 followed a similar pattern shown in Figure 2.6 for diameter whereas the number of branches did not clearly show any definite pattern.

2.4.2 *Acacia senegal* resources in Tanzania

2.4.2.1 Resource mapping and stocking density by district

Figure 2.14 shows the general distribution of *Acacia senegal* in Tanzania. To provide a more detailed picture, intensive inventory was carried out using study areas shown in Figure 1.1 to determine the quantity and quality of the growing stock.

Table 2.4 below presents the descriptive statistics for *Acacia senegal* inventory district wise, the populations being assorted into diameter classes. Table 2.5 gives a summary of other species found in association with *A. senegal*. The overall diameter range for the country was from 1 to 32 cm with a mean of 6 cm.

Most of the *A. senegal* trees (63.6 %) were represented in diameter class 0 – 4 cm, 27.5 % in class 4.5 – 8.0 cm and only a minority (7.7 %) were in classes above 8.0 cm. The difference in diameter class density between districts was found not statistically significant ($p = 0.04$).

The highest density for the 0 – 4 cm class was found in Dodoma Rural, Meatu, Shinyanga Rural, Igunga and Iramba districts whereas the 4.5 – 8.0 cm class was recorded in Dodoma Rural, Igunga, Meatu, Kiteto, and Shinyanga Rural districts. Iramba, Igunga, Shinyanga, Maswa and Geita districts had more 8.5 – 12 cm diameter trees than the rest of the districts. For trees with over 12 cm diameter, it is only Dodoma which had the highest stem density of 3 stems ha⁻¹, followed by Singida, Iramba, Geita, Kiteto and Meatu districts each with 1 stem ha⁻¹, Igunga district with 0.3 stems ha⁻¹ and the rest had no trees in that class.

The overall tree mean height was 3.0 ± 1.3 m and the maximum height recorded was 18 m encountered in Dodoma although, nowhere else does it exceed 9 m. Overall, the highest mean height was observed in Iramba district (5.6 ± 1.5 m) whereas the lowest mean height was 3.2 ± 2.7 m characterised by trees of Dodoma Rural district.

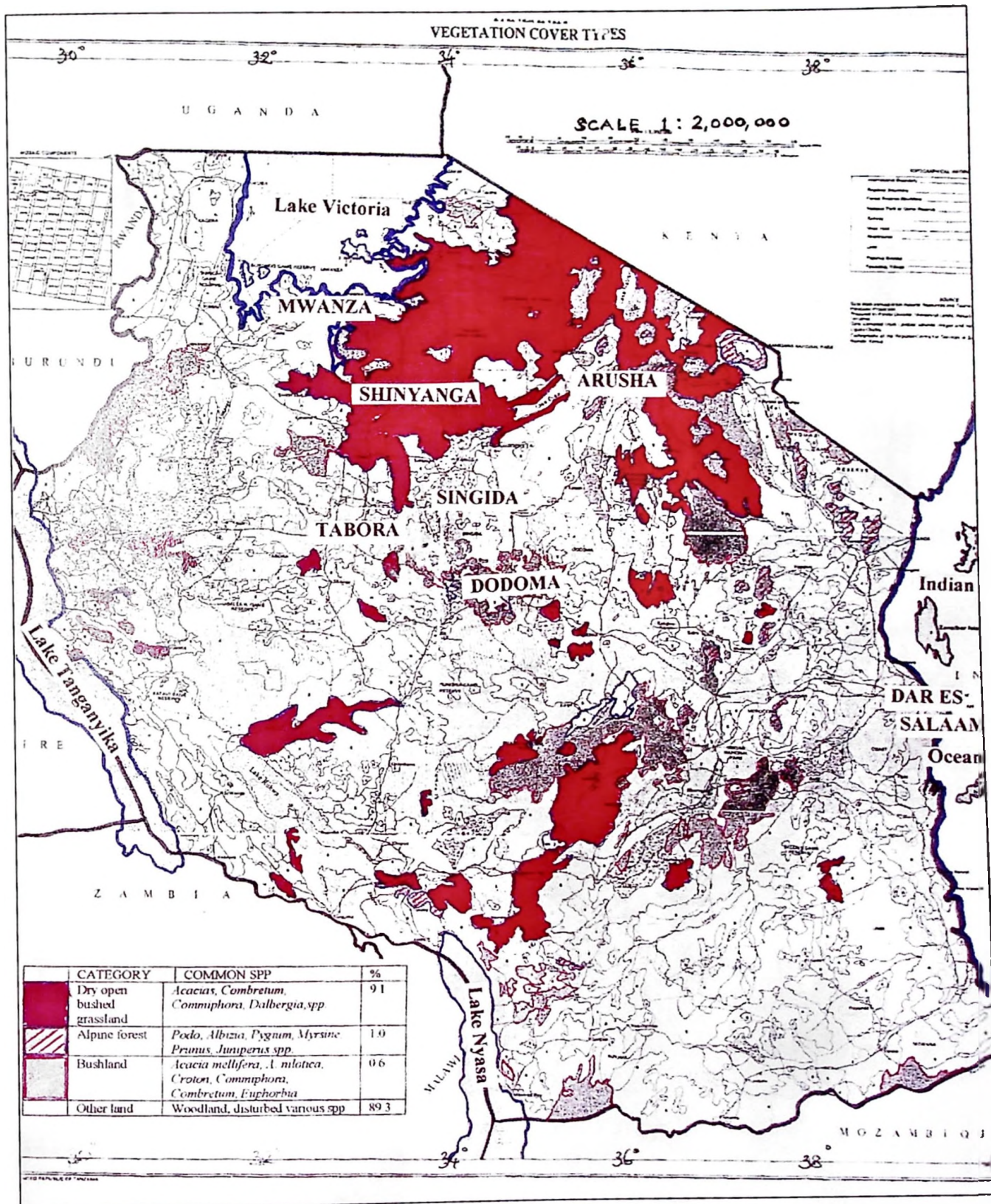


Figure 2.14 Map of Tanzania showing vegetation cover types (Adapted from MNRT, 1984).

The size and distribution of tree diameter classes indicate not only the species' small sized nature but also how much the tree is in demand for its wood.

Due to scarcity of wood in the gum production areas, almost all trees reaching merchantable size are harvested. *A. senegal* and *A. drepanolobium* stems and branches are suitable for fencing kraals as the thorny nature of the trees safeguards the livestock against such predators as lions, hyenas and theft and also deters the livestock from getting out of compounds during the night. In another study conducted in Shinyanga region by Barrow *et al.* (1988), it was noted that the building of kraals forms a significant strain on the regeneration of these species.

Other uses of *A. senegal* trees include woodfuel and building poles. NAS (1980) reported annual yield of $5.0 \text{ m}^3 \text{ ha}^{-1}$ for *A. senegal* in natural forests. The demand for wood in the study areas was higher than the supply. Barrow *et al.* (1988) recorded a per capita consumption of wood of $0.8 \text{ m}^3 \text{ year}^{-1}$ in Shinyanga, necessitating the use of cow dung as an alternative source of fuel in some areas in the region.

In such a situation, trees seem to be cut much earlier suggesting increasing depletion of resources and demand for fuelwood since these earlier reports were written.

Similar observations have been made elsewhere, for example, NAS (1980) and Kaba (1989) noted that the species was in high demand in Mauritius, Senegal and Mauritania for meeting household wood energy demands, brick making, tobacco curing and baking. According to NAS (1980), the wood has an energy value of about 3,500 kcal kg⁻¹. In Burkina Faso, extensive fuelwood plantations have been established around the provincial capital of Dori to replenish the resource and to meet the growing demand for its wood (NAS, 1980). In Kenya, Chikamai (1994) found very few trees exceeding 8 cm when surveying *A.senegal* resources for that country, an indication that no large trees were spared to grow for long.

FAO (1983) reported that the longevity of this species does not seem to exceed 30 – 35 years, but it is rather rare to find trees of such an age in arid and semi-arid areas as they are usually cut down when 20 – 25 years old. In Western Sudan however, Dipierre (1969) found that gum trees were almost entirely 5 – 7 m tall, with an average diameter of 20 – 25 cm.



Plate 2.2 An exceptionally large *Acacia senegal* encountered in Geita district, with dbh of 30 cm and height of 12 m.

Table 2.4 Summary of *Acacia senegal* mean inventory studies in Tanzania

District	<i>A. senegal</i> population density ha ⁻¹											Height (m)				
	Diameter class (cm)											Mean	SD	Mode	Min	Max
	0 - 4	4.5 - 8	8.5 - 12	>12	Total	Mean	SD	Mode	Min	Max						
Dodoma	302 (72.6%)	110 (26.4%)	1 (0.2%)	3 (0.7%)	416	638	0	0	0	3,250	3.2	2.7	2.0	1.5	18.0	
Singida	51 (67.1%)	19 (25.0%)	5 (6.6%)	1 (1.3%)	76	123	0	0	0	380	4.5	1.2	4.0	2.0	8.0	
Iramba	117 (59.1%)	46 (23.2%)	34 (17.2%)	1 (0.5%)	198	222	0	0	0	910	5.6	1.5	6.0	2.0	9.0	
Igunga	151 (53.4%)	100.7 (35.6%)	31 (11.0%)	0.3 (0.1%)	283	289	0	0	0	1,010	5.3	1.5	6.0	2.0	9.0	
Shinyanga	209 (65.1%)	84 (26.2%)	28 (8.7%)	0 (0.0%)	321	373	0	0	0	1,200	5.1	1.4	5.0	2.0	8.0	
Maswa	147 (71.0%)	37 (17.9%)	23 (11.1%)	0 (0.0%)	207	219	0	0	0	680	4.8	1.6	5.0	2.0	8.0	
Meatu	284 (71.4%)	100 (25.1%)	13 (3.3%)	1 (0.3%)	398	365	50	0	0	1,250	3.7	1.0	3.0	2.0	7.0	
Babati	55 (59.8%)	30 (32.6%)	7 (7.6%)	0 (0.0%)	92	145	0	0	0	650	5.3	1.4	5.0	3.0	9.0	
Kiteto	89 (50.0%)	77 (43.3%)	11 (6.2%)	1 (0.6%)	178	178	0	0	0	630	4.6	1.4	4.0	2.0	7.0	
Bukombe	79 (63.7%)	37 (29.8%)	8 (6.5%)	0 (0.0%)	124	109	50	0	0	320	5.3	1.1	6.0	3.0	8.0	
Geita	91 (59.1%)	41 (26.6%)	21 (13.6%)	1 (0.6%)	154	164	40	0	0	590	4.7	1.3	4.0	2.0	8.0	
Overall	143 (63.6%)	62 (27.5%)	17 (7.4%)	0.8 (0.3%)	225	325	0	0	0	3,250	3.0	1.3	3.0	1.5	18.0	

Table 2.5 Summary of population densities of dominant species found in association with *A. senegal* in Tanzania

District	Species population density ha ⁻¹								
	<i>Acacia drepanolobium</i>	<i>Acacia seyal</i>	<i>Acacia nilotica</i>	<i>Acacia tortilis</i>	<i>Dalbergia melanoxylon</i>	<i>Commiphora</i> spp.	<i>Balanites aegyptiaca</i>	<i>Combretum</i> spp.	Others
Dodoma	968	107	88	24	39	468	348	78	700
Singida	1,487	302	59	27	25	607	218	121	1,303
Iramba	2,329	78	27	13	2	327	396	172	873
Igunga	2,489	78	14	679	20	143	94	88	488
Shinyanga	2,556	203	450	64	43	98	154	119	959
Maswa	1,987	102	506	38	58	88	83	132	625
Meatu	2,190	69	103	91	82	125	308	82	823
Babati	1,756	213	148	57	57	134	230	95	1,392
Kiteto	2,560	105	69	8	21	302	162	163	610
Bukombe	1,314	69	43	23	38	211	288	121	2,675
Geita	2,112	423	120	54	503	721	274	125	1,806
Overall	1,977	159	148	98	81	293	232	118	1,114

The overall weighted mean density of *A. senegal* stems was estimated to be 225 ± 325 stems ha^{-1} . The population density varied much between districts, ranging between 76 ± 123 to 416 ± 638 stems ha^{-1} observed in Singida and Dodoma respectively, with a mean of 225 ± 325 stems ha^{-1} for the country. The districts can be differentiated into three *A. senegal* stem density categories as follows;

- High density districts: These are those whose stem densities were well above the overall mean of 225 stems ha^{-1} . These are Dodoma, Meatu, Shinyanga Rural and Igunga,
- Moderate density districts: These had stem densities of about the overall mean. They are Maswa and Iramba,
- Low density districts: These had stem densities well below the overall mean for the country. They are Kiteto, Geita, Bukombe, Babati and Singida.

The differences of mean densities between plots and districts were statistically highly significant ($p < 0.01$). The variation seemed to be related to such environmental factors controlling plant growth as climate, altitude and gradient.



Plate 2.3 Typical *Acacia senegal* stands. Left: dense, Right: moderate populations

Dipierre (1969) found the tree population in Sudan to be fairly regularly distributed ranging from 500 to 2,000 trees ha^{-1} . This density is much higher than the average of 95 trees ha^{-1} found later by Sharawi (1986) and supported by Anderson (1987) and Jamal and Huntisinger (1993). This is a reflection of how fast the natural vegetation cover has been denuded with time.

The more recently reported *Acacia senegal* density of Sudan is much lower than the mean density of 225 stems ha⁻¹ found in this study for Tanzania, although plots in some districts did have much higher densities. However, FAO (1983) recommended a density of 625 stems ha⁻¹ for gum orchards, in the Sahelian zone.

In Tanzania, this study revealed *Acacia senegal* to constitute only about 5 % of the total woody vegetation cover growing in the potential gum areas (225 c.f 4,500 stems ha⁻¹ of others). This species was found to be growing in association with *Acacia drepanolobium* which constituted 45% of the total woody vegetation cover, *Commiphora species* (7 %), *Balanites aegyptiaca* (5 %), *Acacia seyal* (4 %), *A. nilotica* and *Combretum spp.* (3 % each). Others were *Acacia tortilis* and *Dalbergia melanoxylon*, each with 2 % of the woody vegetation cover.

Provisional *Acacia senegal* maps of Kenya showed that 14 %, 20 % and 37 % of Isiolo, South Western Marsabit and Turkana districts were occupied by the resource respectively (Chikamai, 1994; Chikamai *et al.*, 1995).

In Kenya, Chikamai (1994) and Chikamai *et al.* (1995) found the species in association with *A. seyal* and *A. tortilis*, which were suspected as possible contaminants of Kenya's gum arabic. In Somalia, Brenan (1959) reported an association of *A. senegal* with *A. mellifera*, *A. tortilis*, *A. bussei*, *Commiphora spp.* and *Terminalia spp.*

Nour (1999) observed that *A. senegal* in Sudan principally grows in association with *A. seyal* and *Balanites aegyptiaca*. Other species include *Acacia mellifera*, *Dalbergia melanoxylon*, *Adansonia digitata* and *Combretum spp.* These other findings are similar to observations made in the current study.

2.4.2.2 Relationship between stocking density and environmental factors

The environmental factors assessed in this study are rainfall, temperature, altitude and slope of the landscape. Table 2.6 below summarises results of regression analyses of *Acacia senegal* stock density and environmental characteristics. Note, however, that

the temperature and rainfall means were across whole districts so would be unable to explain intra-district variation.

Table 2.6 Summary of regression analyses of gum arabic stocking level and environmental characteristics

No.	Density Term	Coefficients									R ²	
		Constant	Rain	ln.rain	Temp	ln.Temp	Altitude	ln.Alt.	Slope	ln.Slp		
1.	N	11018.90 (1.09) p=0.28	1.90 (0.81) p=0.42	-1843.71 (-1.03) p=0.31)								0.04
2.	N	-520.86 (-0.10) p=0.92			10.75 (0.10) p=0.92	167.80 (0.07) p=0.95						0.02
3.	N	-35942.30 (-1.62) p=0.11					-5.22 (-1.72) p=0.09	5992.14 (1.65) p=0.10				0.02
4.	N	244.62 (0.29) p=0.77							-1451.35 (-0.17) p=0.86	1.06 (0.01) p=1.00		0.00
5.	N	-37970.48 (-1.68) 0.09					-5.58 (-1.78) p=0.07	6419.34 (1.73) p=0.09	-2343.26 (-0.27) p=0.79	12.07 (0.06) p=0.95		0.02
6.	N	-35423.34 (-0.66) p=0.51	3.28 (1.05) p=0.29	-2681.26 (-1.17) p=0.24	574.23 (1.34) p=0.18	-12820.07 (-1.31) p=0.19	-12.11 (-1.14) p=0.25)	12946.45 (1.13) p=0.26	-3579.18 (-0.34) p=0.73	-0.26 (0.00) p=1.00		0.07
7.	ln.N	-117.11 (-0.38) p=0.71					-0.02 (-0.38) p=0.71	19.38 (0.38) p=0.70	-39.44 (-0.33) p=0.74	1.00 (0.39) p=0.70		0.00
8.	ln.N	171.81 (0.25) p=0.81	0.01 (0.13) p=0.90	-3.96 (-0.13) p=0.89	1.54 (0.28) p=0.78	-32.53 (-0.25) p=0.80	0.01 (0.10) p=0.92	-16.82 (-0.11) p=0.91	-18.46 (-0.14) p=0.89	0.76 (0.26) p=0.80		0.02

Figures in parentheses indicate t-statistics, cells in bold are significant at $p < 0.1$

Rainfall

Acacia senegal stocking level was not found to be significantly influenced by rainfall when considered alone ($p=0.42$, equation 1), when considered along with all other environmental factors ($p=0.29$, equation 6) nor when adjusted to natural logarithmic terms and considered along with all other environmental factors ($p=0.90$, equation 8).

Generally, the density of *Acacia senegal* can be observed from the scatter plot presented in Figure 2.15 below, as adversely affected by the amount of rainfall. The amount of the variation in *A. senegal* stocking densities between districts explained by variation in the amount of annual rainfall received was only 4 % although the test for

significance indicated no significant effect of rainfall on the stocking density ($p=0.42$, $p = 0.31$). This could again be caused by insufficient data for climate in the districts as only eight districts formed the sample size.

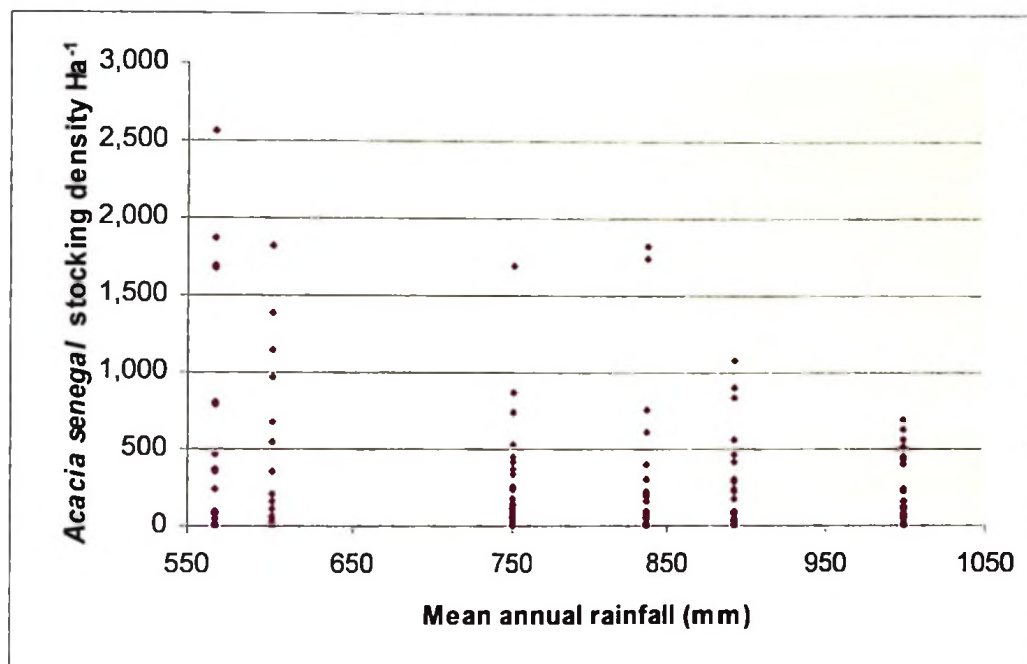


Figure 2.15 A scatter plot of *Acacia senegal* stocking level and mean annual rainfall in Tanzania

Attempting to describe the ecological zones of *A. senegal*, Barnes *et al.* (undated) documented that the distribution is restricted to tropical regions with mean annual rainfall of 200 to 800 mm. Sharawi (1987) noted that *A. senegal* in Sudan is found in more or less pure stands, wild or cultivated and also in varying degrees of mixture with other species from the 200 mm isohyet to 450 mm in sands and 650 mm on the dark cracking clays. This is explained by FAO (1983) that the species cannot withstand an excess of moisture. *A. senegal* is a distinct and peculiar tree species of the semi-arid desert regions with minimal moisture requirement (AGL, 1993). Walter (1971) concluded the rainfall range of 250 to 400 mm as optimal. However, it is apparent that the relationship with rainfall varies with soil types due to differences in texture. Cheema and Qadir (1973) added that the species thrives well on other soils like clay and alluvial where rainfall is not too high to cause water logging and drainage is good.

In the study districts, the mean annual rainfall ranged between 578 – 1,200 mm which is slightly higher than these other findings.

Temperature

The effect of temperature on *A. senegal* density proved to contrast with that of rainfall, being positive. However, the explanatory power of the *A. senegal* stocking level – temperature equation was weaker, with an R^2 of 0.02 and the variables were statistically insignificant ($p = 0.92$, $p = 0.95$, equation 2) when temperature is considered alone and when temperature is considered along with all other environmental factors and when adjusted to natural logarithmic terms and considered along with all other environmental factors respectively ($p = 0.19$ and $p = 0.80$, equation 6 and 8).

In a study in Sudan, Sharawi (1987) noted that high day temperatures are a characteristic of *A. senegal* areas. Barnes *et al.* (undated) and Chikamai (1994) supported the statement by qualifying the species to be native of the hot and dry regions of Africa and parts of the Middle East. According to Ballal (1991), *A. senegal* is found particularly within a mean annual temperature range of 25 to 27⁰ C with extremes of up to 48.3⁰ C in Sudan; Doran *et al.* (1983) documented the same extreme for India. FAO (1983) concluded that, in order for the species to thrive, the mean annual temperatures should be close to 20⁰ C minimum and 37⁰ C maximum. This study supports these others; six of the eight districts for which climatic data were available experienced mean annual temperatures between 22 and 25⁰ C, and the other two were within 5⁰ C of this range, and stocking density tended, if anything to increase with temperature.

Altitude

Although none of the factors assessed proved to be significant at the 95 % level, altitude had the strongest influence on stocking levels of *A. senegal*. Altitude as a determinant of stocking density is statistically barely significant at the 90 % level ($p = 0.09$, $p=0.10$, equation 3) when considered alone and when considered with gradient ($p = 0.07$, $p=0.09$, equation 5). But not at all when considered with other environmental factors.

Again, the relationship between stocking level and altitude is very weak ($R^2 = 0.02$). It should be noted that altitude range was not great, ranging from a minimum of 900 to 1,450 metres above seal level. Figure 2.16 below shows a scatter plot of *A. senegal* stocking density and altitude.

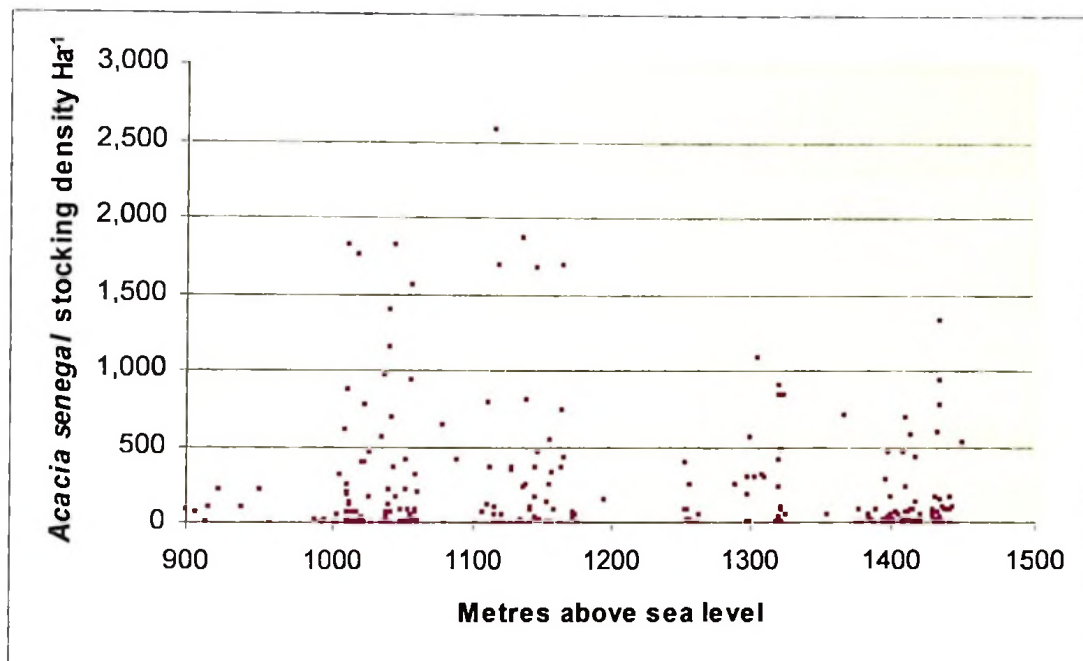


Figure 2.16 A scatter plot of *Acacia senegal* stocking level and altitude in Tanzania

As several authors, such as NAS (1979; 1980), Doran *et al.* (1983), Baumer (1983), Booth and Wickens (1988) and Barnes *et al.* (undated) commented, the distribution of *A. senegal* is restricted to areas between 100 to 1,700 metres above sea level. This could be because this species is intolerant to low temperatures and excessive moistures and since altitude greatly influences the climatic conditions of an area (Tarbuck and Lutgens, 1976), conditions outside this altitude range might be unsuitable.

Slope of the landscape

The population distribution of *A. senegal* was found to be negatively correlated with the slope of the landscape but the relationship was very weak, with an $R^2 < 0.01$ and the influence statistically insignificant ($p=0.86$, equation 4). The poor relationship could be related to the small range between the minimum (0 %) and maximum (6 %) gradient encountered during the study.

All occurrences of this species were recorded in rocky and sandy soils which concur with Chikamai's (1994) findings in Kenya and the report by Barnes *et al.* (undated) that the species colonizes rocky hills, dry sandy flats and dunes, although Cheema and Qadir (1973) also observed good occurrence of the species on other soils, however, where rainfall and drainage was permissible. The rocky and sandy soils are characterized with low water holding capacity (optimum range of 15 – 25 %), high permeability and rich in carbonates (Cheema and Qadir, 1973).

Pandya and Sidha (1985) noted the species on hills in India on soils that are mostly sandy intermixed with stones and pebbles. As Sudan Government Report (1981) and Sharawi (1987) reported, *A. senegal* is dominant on sandy soils where it forms stands known as *A. senegal* savannah. These soils are of low inherent fertility, potential fertility and cation exchange capacity meaning that they have little resistance to drought. Edaphic factors have been described by Cheema and Qadir (1973) as important in influencing the growth and abundance of this species, which is ideal for light rainy season browsing and for forestry.

From this study, the above-tabulated results, as well as the range of conditions in which the species was found to occur, indicate mean annual rainfall, temperature and altitude do influence the population distribution and density of *A. senegal*. However, these factors explain only part of the variation in density, as it would appear that other environmental factors perhaps soils and human influence are also having a big effect.

2.4.3 Potential gum arabic yield

In order to determine the potential gum arabic yield, the gum yields per tree and *Acacia senegal* stocking levels were employed.

The summary presented below in Table 2.7 shows potential gum arabic yield in Tanzania, derived from the weighted means and the potential gum arabic yield from Figure 2.3 and Table 2.4 respectively, using the simple equations shown in Section 2.3.3:

$$\bar{X}_{wt} = \sum[f_i X_i] / \sum f_i \text{ and } \bar{Y}_{wt, gum} * \bar{X}_{wt, stock}$$

Table 2.7 Potential gum arabic yield for Tanzania

District	Sample trees	Mean gum yield tree ⁻¹	Sample plots	Mean <i>A. senegal</i> Stocking level ha ⁻¹	Potential gum arabic yield, kg ha ⁻¹
Dodoma	103	191	58	416	79
Singida	101	275	50	76	21
Iramba	103	170	46	198	34
Igunga	100	374	52	283	106
Shinyanga	100	313	46	321	100
Maswa	100	292	50	207	60
Meatu	99	359	38	398	143
Babati	100	150	48	92	14
Kiteto	102	111	46	178	20
Bukombe	88	175	34	124	22
Geita	110	193	50	154	30
Weighted mean		236		225	53

The potential weighted mean gum yield for the whole study area was estimated at 53 kg ha⁻¹, with variations from 14 (in Babati) to 143 kg ha⁻¹ (in Meatu) with only 3 districts exceeding 80 kg ha⁻¹ which were Meatu, Igunga and Shinyanga Rural. Gum arabic yields in Babati, Singida, Bukombe, Geita and Iramba districts did not reach 35 kg ha⁻¹.

The weighted mean gum yield is within the reported range of 40 to 80 kg ha⁻¹ (FAO, 1978) but less than the yield of 90 kg ha⁻¹ reported by Muthana (1988) for Sudan. Meatu, Igunga and Shinyanga Rural, each had mean gum yield within the range of

100 and 240 kg ha⁻¹ reported by some authors (NAS, 1979; Badi *et al.*, 1989) for Sudan but none of the districts reached the ITC (1972) reported mean yield of between 360 and 800 kg ha⁻¹, also for Sudan. This could be because the reported yields by these authors were based on a density of 400 trees ha⁻¹ for which only Dodoma district could qualify. According to Ballal (1986) the natural stands of *A. senegal* in western Sudan gave a mean gum yield of 44 kg ha⁻¹.

Despite Dodoma's highest stocking level of *A. senegal*, its gum productivity is only about half that of Meatu district whose stocking level is slightly lower. This means therefore that, improving the stocking levels in high yield districts like Meatu, Shinyanga and Igunga, would greatly increase their land's gum productivity. This was also noted in other studies, for example in the North-eastern State of Nigeria, Philip (1975) disclosed that afforestation could be both a means of increasing gum arabic production as well as part of anti-desiccation schemes.

According to MLNRT (1984) the potential gum arabic producing areas in Tanzania cover 9.1 % of the total land area of 89 million hectares which is equivalent to 8 million ha (Figure 2.15). Thus, the area has a biological potential for producing 424,000 tonnes of gum arabic a year if all trees were tapped, calculated as:

$$53 \text{ kg}^{-\text{ha}} \cdot 9.1 \% \text{ of } 89,000,000 \text{ ha} / 1,000 = 424,000 \text{ tonnes (Potential gum arabic yield)}$$

A. senegal in Sudan occurs naturally over the large area known as the gum belt, which covers 40 to 50 % of the total area of Sudan (Seif el Din and Zarroug, 1998). Recent estimates of production potential have indicated that it is possible to double Sudan's current production of about 40,000 tonnes year⁻¹ from existing natural tree stocks through afforestation (Nour, 1999). FAO (1999) reported that a total of 12,500 ha had been planted to act as buffer plantations. Seif el Din and Zarroug (1998) reported further that about 35 % of the annual tree planting programme in Sudan is devoted to *A. senegal*. There are however, no data to quantify the total potential production for Sudan.

2.4.4 Conclusions and recommendations

2.4.4.1 Conclusions

From a biological point of view, it can be concluded that Tanzania is a country with major potential for supplying the international market with gum arabic. The mean gum arabic yield per tree and hectare are within the reported ranges in Sudan, the leading producer in the world.

The gum yield and *A. senegal* stocking level vary significantly between districts and are influenced *inter alia*, by climate and environmental factors although the intra-district variation in yield could not be ascertained for some factors. Gum yield per tree is extremely variable, with most of the trees producing gum below 360 g per tree and 30 % producing nothing at all. Gum yield is greatly influenced by tree size particularly diameter, which in turn can be expected to be influenced by tree age, genetic and environmental factors, the bigger the tree, the higher the yield up to an optimum size beyond which yield decline may occur. The environmental factors of importance to cause gum yield variation are temperature, fire intensity and stem crowdedness. The population density of *A. senegal* is influenced marginally by altitude followed by temperature. The highest densities are expected in areas with average elevations, highest mean annual temperatures and lowest mean annual rainfall.

2.4.4.2 Recommendations

Since not all the sample trees produced gum or produced quantities large enough to be perceived, the exact nature of the mechanisms inducing gum biosynthesis and gummosis still need to be established. Also the optimum levels of soil water and fire intensity and their effects on the production life span of the tree need attention.

Despite addition to the total tree gum yields, tapping cycles should be kept at a minimum as their contribution diminishes with time and they weaken the tree, hence shortening its life span.

In order to manipulate gum production, *A. senegal* stocking levels across the areas need to be improved. The current sparse stocking nature of *A. senegal* may not be economic for tapping. Gum plantations might be established and managed in a manner favourable to gummosis. Such silvicultural techniques as tree breeding, optimum stocking levels, soil moisture and prescribed burning could be used. Furthermore, deliberate efforts geared towards conservation of the existing *A. senegal* resources should be made by individuals and local as well as central government in order to curb their rampant rate of disappearance. If trees are not being allowed to reach optimum diameter and age, then this means a greater potential gum production is missed out. However, this will not happen until people value gum more than early timber or fuelwood use, and communities have control over who fells the trees.

Intensive inventories of *A. senegal* are needed on other parts of the country which were not covered by this study, in order to come up with more conclusive results on the potentialities of Tanzania on gum arabic production. However, the bulk of production potential has probably been covered within the study areas.

Parallel research is needed on the yield of gum arabic from domesticated *A. senegal* trees for making comparisons with the naturally growing ones in their habitats. However, the husbandry and conservation of existing and planted *A. senegal* resources is likely to be closely linked to the marketing and economics of gum production, as well as the livelihoods and tenure systems of those living in *A. senegal* areas, so firmer conclusions cannot be drawn until these aspects are considered.

CHAPTER III

GUM ARABIC ACTUAL PRODUCTION STUDIES FOR TANZANIA

3.1 Introduction

3.1.1 General

Tanzania is endowed with forests of various sorts, estimated by MLNRT (1989), Hunting Technical Services (1999) in FBD (1999) and FAO (2001a) to cover 37 % of the land area. These forest resources continue to contribute to livelihoods by providing such products as wood fuel, building materials, medicines and food and form habitats for wildlife, natural ecosystems and are valuable genetic resources. They create employment opportunities for the Tanzanians: In 1988 MLNRT (1989) reported that 730,000 people (about 3 % of the population) worked in the forest sector out of which 25,000 were engaged in NWFP activities.

Despite the country's large forest endowment, the apparent contribution of forestry to GDP is less than 2.5 % because the importance of non-wood forest products (NWFPs) has generally been under-estimated in relation to local economy and consumption (Makupa, 1995; Makonda and Ishengoma, 1997; Makonda *et al.*, 1998a; 1998b; URT, 1998; 2000). The main focus from forestry has been on timber, yet, only three quarters of the country's forest land is productive (Anon., 1989).

Among the important NWFPs produced and traded in Tanzania, as listed by MLNRT(1989), FBD (1999) and FAO (2001a), are bee products, tannin from black wattle bark (*Acacia mearnsii*), Cinchona bark and gum arabic.

Substantial collection of gum arabic is carried out in Sudan, and in semi-arid areas of a number of other Sahelian countries (Adamson and Bell, 1974; NAS, 1979; FAO, 2001a; b). Sudan produces over 80% of the world's gum requirements (Adamson and Bell, 1974; NAS, 1979; FAO, 1983; 95; Fagg *et al.*, 1997; Timberlake *et al.*, 1999; FAO, 2001a) with reasons given by Adamson and Bell (1974) as ease of collection and grading due to possession of pure stands of *Acacia senegal* in the country. Sudan's average annual production of gum arabic ranges from about 20,000 to 60,000 tonnes while the world total production fluctuates from 25,000 to 70,000 tonnes.

In Tanzania, Chihongo (1992; 1995; 2000) reported an annual production estimate of 1,000 tonnes, out of which 50% was exported. This author concluded that the gum has a great potential for increased production and exports with sufficient economic returns.

3.1.2 Problem statement and justification for this study

There are two key issues for Tanzania to be tackled simultaneously, namely, poverty alleviation and sustainability of the environment. It is crucial for the long term future of the country that Tanzania's natural resources are managed so that production of commercial products is sustainable, and negative externalities are kept to a minimum. Current environmental issues in the country include soil degradation, deforestation, desertification and the recent droughts, which frequently affect marginal agriculture (Amani *et al.*, 1987; MLNRT, 1989; Ashimogo, 1995). ILO (1982) listed Dodoma, Singida, Tabora, Shinyanga and Arusha as among the eight regions of Tanzania, which have been badly affected by these phenomena. These are the areas forming a zone for gum arabic production in the country.

One way of achieving the two goals of development and environmental sustainability is through utilization of NWFPs as their extraction is mostly non-destructive (Stiles 1988; Arnold and Townson 1998) and they may be available even during major stress periods (Scoones *et al.*, 1992).

Scoones *et al.* (1992) and Woon and Lim (1995) explained that conventional agricultural and forestry research has paid too little attention to the wide range of products used by rural people. This is true for Tanzania where there is no mention of NWFPs in the forestry action plan (MLNRT, 1989). Funding for key government agricultural services in Tanzania has been declining in real terms (MLNRT, 1989; World Bank, 1994) and was low compared to 40 other developing countries over the same period (World Bank 1994).

The direct and indirect benefits of these resources are many, however, and accelerated development of these areas, which are too dry to support intensive agriculture, depends partly on the potential that exists in the natural vegetation resources and incorporating it in the development strategy. But this cannot be embarked upon until estimates of yield and potential supply to the industry are gained.

Currently, the figures for gum arabic production in Tanzania show no agreement. Early reports by Adamson and Bell (1974) for example, documented that 2,000 tonnes were being produced annually in the 1950s, between 1966 and 1978 about 350 tonnes were reported by Seif el Din and Zarroug (1998) and Chihongo (1992; 1995; 2000) reported an average production of 1,000 tonnes between 1980s to-date.

3.1.3 Objectives

3.1.3.1 Overall objectives

It is against the above background that this section of the study was carried out, with overall objectives of estimating the annual actual production of gum arabic and its future potential in Tanzania.

3.1.3.2 Specific objectives

The specific objectives of this study were:

- a. To determine the country's actual annual production of gum arabic and its quality
- b. To examine gum arabic harvesting and processing techniques
- c. To examine factors which influence annual gum arabic production
- d. To estimate and characterise the country's gum arabic collectors
- e. To assess the accessibility of rural communities to collection and utilisation of gum arabic
- f. To identify constraints to increased production of gum arabic.

3.2 Literature review

3.2.1 Forestry and environmental issues

Forests and woodlands of Tanzania are estimated to cover 44 million ha, of which, some 29.3 million ha are unreserved forests on public land, 13 million ha are under forest reserves, and 2 million ha are forests and woodlands in national parks (MLNRT 1989). These forests are categorized as follows with their respective areas in hectares:

Closed forest	1,400,000
Mangrove forest	80,000
Miombo woodland	42,891,000
Total	44,371,000

These forests provide goods and services of various sorts including earning foreign exchange for the country. DANIDA (1989) in an environmental profile for Tanzania, commented that 75 % of the forest land is productive since timber is harvestable from this area. The apparently low contribution of forestry to GDP is attributed to the fact that most NWFPs are for subsistence economy of local communities and are therefore not assigned any monetary value and there are indications that official GDP statistics do not capture much of the economic activity, which takes place in the informal sector (World Bank 1994), which largely constitute NWFPs. According to Maliyamkono and Bagachwa (1990), inclusion of this “second economy” would increase total GDP estimates by a minimum of 45% which would give a GDP figure closer to 4 %.

The so-called unproductive forestland which is mostly dry, has the potential for providing greater amounts of resources such as *Acacia* gum, particularly gum arabic, resins and essential oils (Stiles, 1988; Scoones *et al.* 1992) as well as grazing and browsing land. Stiles (1988) lamented shortcomings in research and development for the dry lands of Sub-Saharan Africa as concentration has been on breeding fast growing, drought-resistant food crops, irrigation projects, introduction of more productive livestock and alternative

sources of energy. Forestry projects are also widespread, using mainly exotics which grow faster than most indigenous species. Despite the significant expenditures on these projects, per capita income and food production have been decreasing in almost all African countries since 1970, particularly those with large areas of arid and semi-arid lands. Land continues to be degraded; several authors have documented their concerns on degradative land use in Africa through overgrazing and agricultural activities (FAO, 1983; Oldeman *et al.*, 1990; WRI, 1992; Barbier, 1999; Barbier, 2000; FAO, 2001a). A new approach is needed which will incorporate in the development strategies, recognition of the potential that exists in the natural vegetation resources.

FAO (1995c) noted the importance of conservation, management and utilization of plant gums, resins and essential oils in Africa. One of these products of most importance to the local and national economy is gum arabic. It was recommended by FAO (1995c) that priority be given to undertaking resource surveys in all the countries producing gum arabic, and improving the resource base itself. Nour (1999) pinpointed elements necessary for quantifying the production potential of gum to include current production trends.

3.2.2 Gum arabic

3.2.2.1 Source and production

Chemically, gums are complex polysaccharides (NAS, 1979) whose process of formation is not fully understood (NAS, 1979; Siddig, 1991; Bhausar and Tiwari, 1995).

Throughout the world, there are more than 1,000 species and sub-species of gum exuding acacias. For commercial purposes, only two species are significant sources of gum arabic, namely, *Acacia senegal* and *Acacia seyal* (Adamson and Bell, 1974; FAO, 1990a; 1990b; 1995c; Nour, 1999). However, the authors added that the former is the best and contributes the bulk of world gum.

Gum is produced in sizeable quantities if the trees are wounded either accidentally or deliberately (Joseleau and Ullman, 1990; Dwivedi, 1993; Vassal and Mouret, 1991; Vassal and Dione, 1993; Simpson and Ogorzaly, 1995). Other methods include deliberate injury by stripping away the bark (Obeid and Seif El Din, 1970; FAO, 1983; AGL, 1993; Dwivedi, 1993; Payne, 2001). A viscous secretion of gum takes place in a more or less spherical ball, which hardens little by little and remains stuck to the tree ready for hand picking after 3 to 6 weeks. This takes place during the dry season which is October to June (Payne, 2001; ISC, 2002) in the Northern Hemisphere.

Gum arabic is produced in commercial quantities in Sudan, Nigeria, Chad, Senegal, Mali and Tanzania (Adamson and Bell, 1974; Chikamai, 1997). Other countries listed by Chikamai (1997) include Burkina Faso, Mauritania, Ethiopia, Zimbabwe, Niger and Kenya. It has also been noted by FAO (1995b) that Kenya has emerged as a new supplier of gum arabic to the world market in recent years and countries like Zimbabwe and South Africa produce gum for the local market but not in sufficient quantities to enable exports to be made.

Chikamai (1997) and FAO (2001b) commented that there is wide variation in the scale of production of gum arabic between the countries with Sudan, Nigeria and Chad accounting for the majority of world production and trade (refer Figure 3.1). Sudan is the biggest world producer with average annual exports of 20,300 tonnes year⁻¹ between 1988 and 1993 (FAO, 1995c). Other authors however, (Omer and Wasila, 1993; Jamal, 1994; FAO, 1995a; b; Seif el Din, 1995; Seif el Din and Zarroug 1998) reported an annual average production for Sudan of 45,000 tonnes but with a wide range of between 20,000 and 62,000 tonnes.

Production of gum arabic in Tanzania has been reported to be on a definite downward trend. Adamson and Bell (1974) reported an annual figure of 2,000 tonnes during the 1950s, but the production was halved during the 1960s and in the 1970s the figure averaged only about 500 tonnes. The figures are, however, strongly disputed by Seif el Din and Zarroug (1998) and Chihongo (1992; 1995; 2000). The former cited world gum

arabic production statistics for 1966 – 1978 which indicated that Tanzania had average annual production of 350 tonnes which is 0.7 % of the total, whereas the latter reported an average annual production of 1,000 tonnes out of which 50 % was exported.

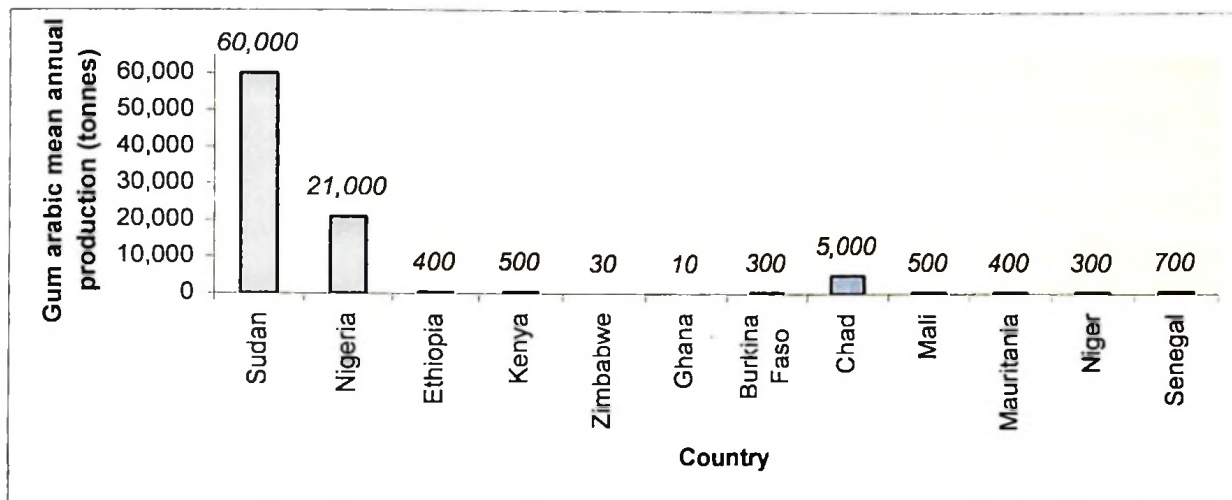


Figure 3.1 Mean annual gum arabic production in 12 selected African countries (FAO, 1995b).

The global market of gum arabic could reportedly absorb a much greater quantity due to its wide variety of uses and lack of close substitutes. The current high price reflects the shortage of supply (Stiles, 1988; Anderson, 1993). Payne (2001) stated that annual production of gum arabic is subject to climatic changes, insect attacks with irregularity of supply and consequently widely fluctuating prices. For Sudan, several authors have concluded that political and civil unrest, pests, low local prices of gum compared with those of other crops, general socioeconomic instability of the gum producing areas and drought influence annual variation in gum arabic production (Omer and Wasila, 1993; Jamal, 1994; FAO, 1995; Seif el Din, 1995; Seif el Din and Zarroug 1998).

3.2.2.2 Quality control

Variations in gum arabic quality exist, and are attributed to the mixed species of *Acacia* trees found in the collection areas, harvesting and post-harvesting treatments and also the soil composition of different regions, together with varying climatic conditions (Payne, 2001; Chikamai and Banks, 1993; Chikamai, 1997).

Similar variations occur in quality of exudates from other plants. Differences in pine resin quality, for instance were noted by Coppen (1995) to even occur between individual trees within a provenance. The differences were also influenced by climatic conditions: high ambient temperatures were found to be conducive to good resin flow while prolonged periods of rainfall were not.

Botanic origin

The market demand is for clean, unbroken gum nodules (Booth and Wickens, 1988). FAO (1995b) describes true gum arabic (from *A. senegal*) as a pale to orange-brown coloured solid, which breaks with a glassy fracture. The best grades are described as those in the form of whole, round tears, orange-brown in colour and with a matt surface texture; in the broken, kibbled state the pieces are much paler and have a glassy appearance. Inferior grades and gum from other than *A. senegal* are often darker in colour and may not have the characteristic tear shape. Seif el Din and Zarroug (1998) stated that Kordofan gum is a term applied to distinguish the gum obtained purely from *Acacia senegal* as opposed to that adulterated with exudations from other trees.

It was reported by Chikamai (1997) that the bulk of gum arabic and *Acacia* gum is derived from natural stands and by natural exudation and Simpson and Ogorzaly (1995) commented that 90 % of the world gum supply is obtained from unattended wild trees that are slashed or punctured to induce a wound reaction. However, Nour (1999) reported that more than 50 % of the gum from Sudan comes from plantations which are owned by private individuals, government or cooperative bodies. Quality control for the gum arabic collected either from tapping or natural exudation is therefore very important.

Gum arabic from Tanzania and Kenya was characterized by Robbins (1987) as dark red in colour rather than amber and this was related to the gum's admixture with gums from other sources or to a high iron content by Chikamai and Banks (1993). In a study on trees and indigenous knowledge in Shinyanga, Kilahama (1994) noted collection of gum from

Acacia senegal and *A. drepanolobium* for sale. Adamson and Bell (1974) further criticised gum arabic from Tanzania as the bulk of it is collected from *A. drepanolobium*.

Harvesting and post-harvesting treatments

Adamson and Bell (1974) stated that gum arabic from Tanzania is collected in a much less systematic nature than elsewhere, depending to a large extent on the progress of the collectors' other crops. This method was disqualified by AGL (1993) as inefficient and having no quality controls at source. Operations are naturally subject to the traditional practice that relies totally on independent, individual, pastoral, nomadic part-time collectors. The collectors' action is an opportunistic reaction to gums on a tree, rather than a well-planned exercise based on a specific time schedule.

In order to achieve the required optimum quality, NAS (1979) and AGL (1993) advocated a drying period of the exudation of at least two to three weeks before it is plucked off the tree. Payne (2001) explained further that the first crop of nodules takes 3 to 6 weeks to harvest, the exact period depending on climatic conditions. In general, the higher the average temperature, the greater the production of gum and the shorter the drying period. Subsequent crops are harvested at shorter intervals of 1 to 2 weeks. Observations made by AGL (1993) indicated that gum arabic collection by nomads in Kenya is not based on a specific time schedule, as it was mostly premature or delayed.

Environmental factors

Soil characteristics may influence the characteristics of gum of the same botanic origin in terms of colour and chemical properties. A high iron content in the soil may impart a dark red colour on the gum arabic rather than amber (Chikamai and Banks, 1993). Other environmental factors include climate. Analytical differences were reported to occur between gum arabic of Kenya and that from Sudan and Nigeria (Chikamai and Banks, 1993), the major reason apparently being the differences in environmental conditions between the three countries.

Because of the variations in the quality of gum arabic and the market demand specification, it is important to grade the gum. Depending on the country, there are different gum grading systems, in Sudan for example there are four main grades (Adamson and Bell, 1974; FAO, 1995b) whereas in Nigeria there are three (Adamson and Bell, 1974; Chikamai, 1994; FAO, 1995b) and in Francophone West Africa there are six grades (Adamson and Bell, 1974).

3.3 Materials and methods

3.3.1 Study sites

This study was undertaken in eight districts in which gum arabic collection and trade are carried out. These are Singida, Iramba, Igunga, Shinyanga Rural, Meatu, Maswa, Babati and Kiteto.

3.3.2 Sampling and data collection

3.3.2.1 Sampling

Data were collected from 630 gum collectors as well as 630 ordinary farmers living in gum producing areas in 64 villages, eight gum middlemen in the areas and three final buyers and exporters of gum in the country. For gum arabic quality assessment, 30 gum sample lots (each sample lot weighed roughly 2 kg) were picked randomly to represent each district. This process was repeated three times to cover the entire gum season, in June, August and October, making a total of 90 observations for each district and 720 for the study.

Also, the following government offices were consulted for secondary data: district and regional forest and natural resources offices in which gum arabic is collected, Tanzania Forest Division Headquarters and the Tanzania Revenue Authority – Customs Statistics Section both, in Dar Es Salaam.

The above listed groups of people and offices formed very important information gathering centres which were discovered during a preliminary survey carried out with assistance from forest officers and village leaders in their respective areas. Sharawi (1987) used a sample size of 38 farmers, and two gum merchants who were interviewed in seven villages in Northern Kordofan and five villages in the Rahad Scheme, in Sudan.

A very general guide given by Wong (2001) is that more than 30 observations is good and less than 5 is probably inadequate which suggests that the district sample sizes are sufficiently large.

Gum collectors

Trading centres, which are under the charge of gum middlemen, were used as centres for collecting data from gum collectors. A total of 630 gum collectors were sampled in the study, 15 people each from Babati and Kiteto, owing to a relatively small scale collection in the two districts and 100 people in each of the rest of the districts. These people were sampled and interviewed upon their arrival to the gum middlemen in the respective areas. Since the gum middlemen knew the identity of the informants, there was no danger of repetition of the interviewing process with the same persons.

Villages

All villages in which people engage in gum collection activities were objectively sampled. Information on these villages was gathered with the help of vegetation maps specific to each area (MNRT 1996a; b; c; d; e; f; g; h; i; j; k; l; m; n; o; p), and interviews with gum middlemen, gum collectors and other local people knowledgeable in gum arabic sources including forest officers and local leaders. A list of the villages is presented in Table 3.2.

Ordinary farmers

After obtaining the full list of villages forming a base for gum collection activities, 100 ordinary farmers (non-collectors of gum) from each district, but 15 each from Babati and Kiteto, were randomly sampled. In the sample areas, village registers were used as a framework through which sample households were picked using random numbers. As recommended by Casley and Lury (1987), households provided the main information through structured questionnaires. A summary of sampling layout is presented in Table 3.1 below.

Gum middlemen

There were eight gum arabic middlemen identified in Tanzania, being recognised by the gum final buyers and exporters, gum collectors and licensed by the district councils' forest offices. They were also all sampled in this study. These intermediaries were situated in the main gum trading centres with various branches in the gum producing areas.

Final buyers and exporters of gum

The final buyers and exporters of gum formed the starting point from which information on the gum producing districts was obtained. There were three companies in this group, namely Mohamed Enterprises Company Limited, Fidahusseini Company Limited and Export Trading Company Limited, all based in Dar Es Salaam, and all were sampled. Preliminary investigations suggested that there were four exporters of gum arabic in the country, but during this study the fourth company, Masukh Company Limited, was found to have long since closed this operation down.

Table 3.1 Sampling for estimation of actual gum arabic production in Tanzania

District	Sample gum villages	% sample gum villages	Sample gum collectors	% of sample collectors	Sample ordinary farmers	Sample trading centres	% of trading centres	No. of sample middlemen	% of middlemen
Singida	8	100	100	2.5	100	3	100	2	100
Iramba	7	100	100	2.4	100	3	100	1	100
Igunga	17	100	100	2.6	100	2	100	5	100
Shinyanga	8	100	100	3.4	100	3	100	3	100
Meatu	12	100	100	2.0	100	4	100	3	100
Maswa	6	100	100	4.0	100	4	100	3	100
Babati	4	100	15	7.7	15	1	100	2	100
Kiteto	2	100	15	8.3	15	1	100	1	100
Total	64	100	630	2.8	630	8	100	8	100

3.3.2.2 Data collection

A multi-disciplinary approach entailing both social survey and resource assessment methods was employed in data collection. The social survey methods employed Participatory Rural Appraisal (PRA), well documented by Gorden (1975), Chambers (1992) and Martin (1995). The methods were successfully applied by several researchers such as Brokensha and Riley (1980) in Kenya, Kajembe (1994), Kilahama (1994) and Kikula (1996) in Tanzania, Bishop and Scoones (1994) in Botswana, Fujisaka *et al.* (1994) in Thailand and Campbell *et al.* (1995) in Zimbabwe.

These methods were divided into two categories namely, interviews with individuals (i.e gum and non-gum collectors, gum middlemen, buyers and exporters of gum) and government officials and group discussions. Unprompted questionnaires of three kinds were used to guide interviews for: gum arabic key informants (gum collectors and middlemen, local leaders and foresters), gum final buyers and exporters and ordinary informants (Appendices IV, V and VI respectively). Questionnaires in Appendices IV and VI were pre-tested on ten households and revised accordingly prior to the interview process. Employment of group discussions encouraged a collective response and identification of differences of opinion as well as areas of consensus within the group, as advocated by Nichols (1991) and Pratt and Loizos (1992). Resource assessment methods encompassed field observations and ethno-botanical surveys to obtain such information as identity of species used for gum collection and their ranks.

Actual annual production of gum arabic and its quality

The quantities of gum collected and sold to internal and external markets were elicited using questionnaires shown in Appendix IV (Section B 3 and 20) and Appendix V (Section B 2 and 3) for the collectors and middlemen and the final buyers and exporters respectively.

The quality of the gum arabic produced was assessed by grading the sample contents and determining the proportion of each grade by weight. This was achieved through group discussions in which the gum middlemen were encouraged to demonstrate gum grading using the operational systems. These people and some gum collectors assisted in identifying gums from other botanic sources. Several authors, for instance Conway (1989), Gupta (1989), Bell and Hardiman (1989), Pretty and Scoones (1989) and Lightfoot *et al.* (1989), have emphasized encouragement of use of illustrations by farmers for making their points clearer to researchers.

A second method used involved weighing to determine the proportion by weight, of gum from different botanic origins constituting the samples. In so doing all other gum producing plants which are the possible contaminants of Tanzania's gum arabic were recorded using vernacular and where possible scientific names. Identification using scientific names was carried out by consulting Burt (1940), Eggeling (1940), Dale and Greenway (1961), Blundell (1987), Hines and Eckman (1993), Mbuya *et al.* (1994) and Timberlake *et al.* (1999).

Harvesting and processing techniques

Collection of data concerning harvesting and processing techniques of gum arabic was made using questionnaires (Appendix IV, Section B 11, 13, 14, 20) for the collectors and middlemen and (Appendix V, Section B 10, 12 and 13) for the final buyers and exporters.

Factors influencing annual gum production

The same questionnaires were used in collecting the information on the factors that influence annual production of gum arabic in the country. In Appendix IV, section B was used (questions 3, 4, 7, 8, 9 and 13) for the collectors and middlemen and in Appendix V, section B (2, 3 and 7) for the final buyers and exporters.

Estimation and characterisation of gum arabic collectors

In order to estimate and characterise the gum arabic collectors in the country, the Appendix IV questionnaire and group discussions were used. In the appendix, Section A, B 2, 6 and 18 and C were employed, while, in the group discussions the gum collectors and the middlemen were involved in giving the information.

Accessibility to collection and utilization of gum arabic

Collection of the information on accessibility to collection and utilization of gum arabic was done using another section of the questionnaire (Appendix IV, Section A and B 12 and 15 and Appendix V, Section B 9 and 13) and group discussions with rural communities in the gum collection villages.

Constraints to increased production of gum arabic

The constraints to the increased gum production in the country were registered using the questionnaires: Appendix IV (Section B 3, 4, 6, 7, 8 and 9), Appendix V (Section 2, 3, 5, 6, 7 and 16), and Appendix VI (Section B 12 and 13), and group discussions with the gum collectors.

McCracken *et al.* (1988) documented how Subhadhira and Apichatvullop (1987) attempted analytical games, components of PRA, to rank priorities and develop labour calendars in an agroforestry study in Thailand. Use of this method in the present study yielded information on gum grades, ranking priorities and constraints to increased production of gum and seasonal calendars of activities.

3.3.3 Data analysis

Data analysis was carried out using the Microsoft Excel package of Microsoft Office 98 and 2000. Descriptive statistics facilitated determination of means, standard deviations, modes and minimum and maximum values. One-way statistical analysis of variance (ANOVA) was used to determine the least significant difference between means.

Annual gum arabic production was estimated for each district as the product of the estimated annual production per individual collector for a four-year period (1998 - 2001) and collectors' population in each district.

The following formula was employed in calculating the gum arabic production for the country:

$$P = \sum_{\delta=1}^8 (G_{\delta} / S_{\delta} * 1,000) * C_{\delta}$$

Where, P = annual gum arabic production for the country in metric tonnes,
δ = district,
G = annual gum arabic production by sample population in district δ,
S = sample population of gum collectors in district δ,
C = gum collectors population in district δ.

The population of gum arabic collectors was estimated by summing the collectors populations for each gum-producing village.

Regression analysis was used (using Excel and SPSS) to assess relationships between quantitative data. These were:

- Influence of stocking levels of *Acacia senegal* and *A. drepanolobium*, gum price and mean yields per tree on quantities of gum collected in each district,
- Influence of environmental factors (rainfall, temperature and altitude) on gum grade.

- Influence of household size, household farm size, income, duration of residence in a particular area, gender and age on the engagement of gum collection activities. This analysis used a logistic regression employing binary logistics with a Wald Forward Stepwise entering method and a cut value of 0.50, in SPSS version 11.

The strengths of the above relationships on the simple regressions were measured employing R^2 and t-statistics and probability levels 0.05 and 0.01. Several equations for regressed parameters were derived and tried and the best fits were short-listed basing on R^2 , t-statistics and probability levels. For the logistic regression, the strength was measured using Percentage Correct, β , Wald, t-statistics and probability levels.

Qualitative data were analysed through categorisation and content analysis and presented in graphical or tabular form. Prioritisation of the following information was conducted employing percentage of total frequency cited in order to obtain ranks of importance:

- Factors influencing annual gum production variation,
- Constraints to gum arabic production expansion in the country,
- Improvements thought important to gum arabic production in the country.

3.4 Results and discussion

3.4.1 Gum arabic production in Tanzania

3.4.1.1 Mean annual production

Table 3.2 below summarises results for this study's statistics on gum arabic production in the different gum producing areas of Tanzania.

The mean annual production of gum arabic estimated for the four-year period was found to be $4,030 \pm 15$ tonnes, produced exclusively by haphazard picking from naturally and/or accidentally exuding trees by peasants. Ninety two percent of the gum collectors solely use a forked stick while 8 %, exclusively females, combine the forked stick with a machete. The stick is applied for hooking down branches and even small and flexible *Acacia* stems which have harvestable gum tears.

In Sudan, Anderson (1993) and Nour (1999) reported that gum arabic from *Acacia senegal* (gum hashab) is collected by tapping using a traditional axe or Vidal-Hall equipment which is a spear like instrument. Further, all gum from *A. seyal* (gum talha) is collected as a result of natural exudation (refer Table 4.8). An average of 250 to 300 metric tonnes of gum is harvested in Kenya, the whole amount based completely on livestock herders' collection (AGL, 1993).

Gum arabic picking in Tanzania takes place during the dry season, which commences in June and ends in October. In Sudan which is in the Northern Hemisphere, the dry period, which also forms the gum season, is between October and June (Payne, 2001; ISC, 2002). According to ISC (2002) no gum is formed during the rainy season since the trees are in full bloom. However, Dwivedi (1993) pointed out that gum babul (from *Acacia nilotica*) tapping is suitably done during the summer season, and when carried out in rain, a tin shade should be fitted at the top of the wound.

The researched mean annual gum production figure for Tanzania however, exceeds by four times the documented figures for the country.

This new production figure also suggests that Tanzania would be the fourth largest gum producer in the world, after Sudan, Nigeria and Chad (see Figure 3.1).

The Tanzania Revenue Authority (TRA) was established in 1996/97 under the Authority Act of 1995 with the responsibility among others of monitoring imports and exports. No figures for gum exports beyond 1998 were made available, as there were problems in the data management. According to the TRA statistics reported by URT (2001a), gum arabic annual exports from Tanzania were 943.24, 869.96, 910.23 and 246.75 tonnes for years 1998 to 2001 respectively, although data for year 2001 was available only for the period January – May.

A more reliable source of data on gum production should be district and regional forest office records and the final buyers and exporters' statistics. Disappointingly, however, there were very poor recording and record keeping systems at a district level (see Table 3.3 below). From the table, it is only in Igunga and Singida Rural districts where gum arabic production records are at least available, although comparison with Table 3.2 suggests that they are unreliable. No records on gum arabic production were available at regional levels. Moreover, the final gum buyers and exporters kept their records as confidential; only one reported a yearly export of only 30, tonnes which again could not be relied upon.

In a regional and national overview on NWFPs, FAO (2001b) concluded that country statistical data for most NWFPs in Africa is incomplete and the available information is often unclear, inconsistent and contradictory.

The discrepancy in the gum arabic production figures, between the field and the recorded statistics suggests that the bulk of gum from Tanzania is traded in unrecorded transactions. The domestic market for gum within the country is less than a tonne (Mohamed Enterprises Company Ltd; Export Trading Company Ltd and Fidahusseini Company Ltd, personal communication); the trade therefore is export oriented. There were indications that Tanzania's gum arabic was in demand in the neighbouring countries. In 1998 for example, URT (2001a) reported that Kenya and the Democratic Republic of Congo were supplied with 3 and 2.3 tonnes of gum

respectively. The observations made above concur with claims of Chihongo (2000) that exportation of Tanzania's gum arabic is in an informal manner. Maliyamkono and Bagachwa (1990) considered illegal exports of Tanzania's products to be quite substantial. They lamented that illegal trans-border trade had been rampant along the Tanzania borders, with major trading centres along the Tanzania/Kenya border at Tarime, Suna, Namanga and Lungalunga. These authors noted that most illegal exports were agricultural produce, livestock and foreign currencies.

If gums were bought and exported by a quasi-government marketing board (which is not the case here) then this problem could be associated with the pricing policy as documented by Ellis (1982), Odegaard (1985), Skarstein and Wangwe (1986), Amani and Ndulu (1987), Lundahl and Ndulu (1987), Maliyamkono and Bagachwa (1993) and Ashimogo (1995) that official prices for agricultural commodities in Tanzania were low compared to the unofficial prices. Smuggling usually occurs to get a better price, usually because of relative taxes or exchange rates, so if Tanzania has either some form of export duty/tax and or over-valued exchange rate compared to another country, then smuggling might occur.

Similar situations have been cited elsewhere: for instance, Barbier (2000) lamented a recent increase in smuggling of Sudan's gum arabic to neighbouring countries. FAO (1995b) observed that a significant proportion of the gum exported from Chad as well as from the Central African Republic is believed to originate in Sudan and enter the neighbouring countries through illegal cross-border trade. Also, some gum from Cameroon originates in Chad. The 1,000 tonnes import of gum arabic into the EEC from the former USSR in 1988 is regarded by FAO (1995b) as re-exports of bartered gum from Sudan. Omer and Wasila (1993) had noted earlier that some of the Sudan's gum production is smuggled outside the country especially through Chad and Ethiopia where the international prices are higher than what is paid to the merchants in the country. Other countries which were listed as recipients of the smuggled gum arabic from Sudan were Nigeria, Uganda and Kenya.

Table 3.2 Summary of gum arabic production statistics in the gum producing areas of Tanzania

District	Gum gatherers' villages	Gum collection centres	Collectors' population	Annual gum arabic production (metric tonnes)				Mean
				1998	1999	2000	2001	
Singida Rural	Mdoguuyu, Mwaru, Mwanduigembe, Magi, Lwandai, Malingila, Kisengi, Kitinku	Mtekenete, Ndago, Singida	3,940 (30) p=0.06	789.97 (3.15) p=0.16	709.20 (3.03) p=0.15	592.97 (2.57) p=0.13	520.08 (2.32) p=0.12	653.06 (119.97) p=0.50
				839.51 (4.48) p=0.23	812.49 (4.05) p=0.20	681.58 (3.77) p=0.18	650.41 (3.94) p=0.19	746.00 (93.88) p=0.70
Iramba	Ijungu, Mtekenete, Ndago, Malamala, Mahenge, Usure, Mwansabi	Mtekenete, Ndago, Singida	4,156 (34) p=0.07	783.56 (4.71) p=0.24	719.55 (4.30) p=0.21	601.25 (3.80) p=0.19	557.61 (3.42) p=0.18	665.48 (104.31) p=0.80
				557.26 (2.89) p=0.20	522.99 (2.98) p=0.20	455.94 (2.65) p=0.18	406.77 (2.37) p=0.16	485.74 (67.41) p=0.70
Shinyanga	Masanga, Ukenyenge, Magalata, Ikonda, Isagara, Kasaji, Mwangongo, Mwamagembe	Shinyanga, Igunga, Igurubi	2,980 (20) p=0.04	1,110.53 (5.27) p=0.21	1027.61 (5.04) p=0.20	917.06 (5.07) p=0.20	866.81 (4.86) p=0.20	980.53 (109.64) p=0.75
				491.68 (2.29) p=0.18	464.02 (2.33) p=0.18	394.85 (2.20) p=0.17	354.62 (1.92) p=0.15	426.54 (62.77) p=0.63
Maswa	Luguru ya mbuga, Kimbago, Shishiyu, Ipililo, Banyu, Likenjejo	Maswa, Shinyanga, Igunga, Igurubi	2,515 (19) p=0.04	29.25 (1.03) p=0.45	30.55 (1.01) p=0.42	24.70 (0.73) p=0.31	24.05 (0.77) p=0.33	39.94 (3.25) p=0.64
				36.60 (1.14) p=0.55	35.40 (0.86) p=0.40	31.20 (0.81) p=0.38	31.20 (0.81) p=0.38	33.60 (2.82) p=1.00
Babati	Labai, Ufana, Laghranbeg, Guswe	Singida	195 (6) p=0.03	4,577.63 (3.67) p=0.08	4,278.14 (3.49) p=0.08	3,655.57 (3.22) p=0.07	3,364.25 (3.03) p=0.07	4,030.89 (15.34) p=0.28
				22,870 (29) p=0.02	22,870 (29) p=0.02	22,870 (29) p=0.02	22,870 (29) p=0.02	22,870 (29) p=0.02
Kiteto	Wakama, Makami	Singida	180 (6) p=0.03	36.60 (1.14) p=0.55	35.40 (0.86) p=0.40	31.20 (0.81) p=0.38	31.20 (0.81) p=0.38	33.60 (2.82) p=1.00
				36.60 (1.14) p=0.55	35.40 (0.86) p=0.40	31.20 (0.81) p=0.38	31.20 (0.81) p=0.38	33.60 (2.82) p=1.00
Total	64		22,870 (29) p=0.02	4,577.63 (3.67) p=0.08	4,278.14 (3.49) p=0.08	3,655.57 (3.22) p=0.07	3,364.25 (3.03) p=0.07	4,030.89 (15.34) p=0.28
				22,870 (29) p=0.02	22,870 (29) p=0.02	22,870 (29) p=0.02	22,870 (29) p=0.02	22,870 (29) p=0.02

Figures in parentheses indicate standard deviation, cells in bold indicate significance at $p = 0.05$

Table 3.3 Annual district gum arabic productions in Tanzania

District	Annual gum arabic production (metric tonnes)						
	1994	1995	1996	1997	1998	1999	2000
Singida Rural	n.a	n.a	n.a	n.a	0.10	0.15	1.47
Iramba	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Igunga	3.80	2.50	5.20	4.90	1.50	2.49	2.00
Shinyanga	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Meatu	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Maswa	n.a	n.a	n.a	n.a	n.a	n.a	n.a
Total	Incomplete	Incomplete	Incomplete	Incomplete	Incomplete	Incomplete	Incomplete

n.a = Data not available.

Source: Respective District Councils (2001).

3.4.1.2 Gum yield per tree

Figure 3.2 below shows the mean gum yields per tree perceived by collectors in the different gum producing districts of Tanzania (see Appendix IV, section B13). The overall mean yield per tree was 390 ± 153 g; this can be compared with the figure of 246 ± 333 g found in the gum tapping experiments (see Chapter II). There are two explanations for the apparent higher yields in naturally exuding trees than in tapped trees:

- Over-estimation of gum weights by the collectors during this study, due to not being conversant with the weight units used. In contrast, all gum samples in the tapping experiments were physically weighed, using standard methods.
- Adulteration of gum arabic with other different *Acacia* gums greatly improves calculated means for yield per tree. In Tanzania, over 60 % of the gum was found to be constituted by *A. drepanolobium* gum whose yield per tree is over 500 g per season (Nkupa, personal communication). In contrast, all gum samples in the tapping experiments were collected from *A. senegal*.
- The mean yield in the tapped trees was calculated including even those trees which did not yield any gum at all. If these non-yielding trees are excluded, the average becomes about 340 g.
- The narrower range between districts' mean yield per tree perceived by collectors compared with that for tapping figures.

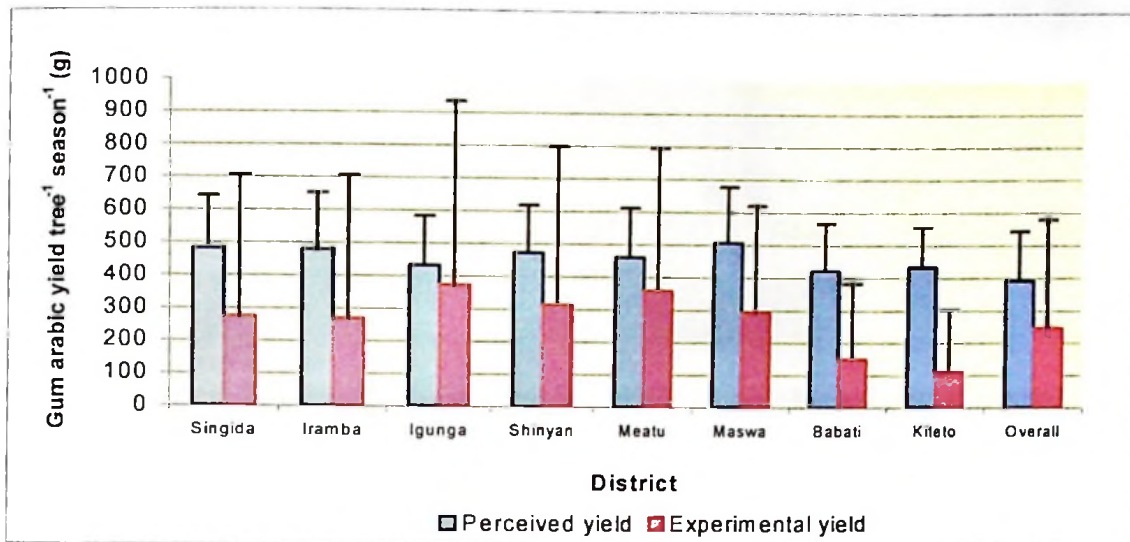


Figure 3.2 Mean gum arabic yield per tree in Tanzania
 Note: lines atop the bars indicate positive standard deviations

The gum yield ranged from 100 to 1,000 g, with 40 % of the observations made on gum production of between 300 and 500 g per tree (see Figure 3.3). One-way analysis of variance indicated statistical significance in the results observed between the collectors ($p < 0.01$). The mean figures and the variations depicted in Figure 3.2 and Figure 3.3 are within the range of gum yield per tree reported by several authors who gave a range of from a few grammes to extremes of 10,000 g (ITC, 1972; FAO, 1978; 1983; 1995; NAS, 1979; Mulinge and Abdille, 1988; ISC, 2002). However, according to Badi *et al.* (1989) yields of above 300 g are quite exceptionally high.

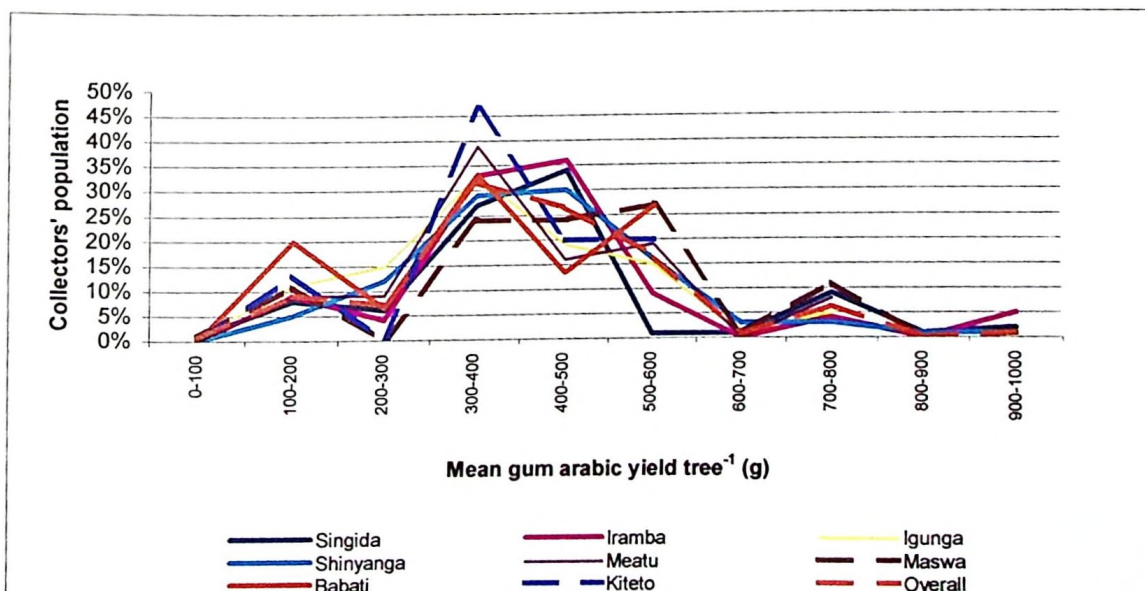


Figure 3.3 Gum arabic mean yield per tree distributions by collectors in Tanzania

3.4.1.3 Variations in gum arabic production

Between collectors

The overall amounts of gum collected per head throughout the country during the study period ranged between 50 and 600 kg with an average of 177.3 ± 88.3 kg season⁻¹ (see Figure 3.4). Further analysis showed that 14 % of the collectors gathered an average amount below 100 kg in a year, 38 % had between 100 - 200 kg, 28 % between 200 - 300 kg, whereas 8 % and 2 % had between 300 – 400 and over 400 kg respectively.

Collectors in Meatu district had the highest average collection per head (200 kg), followed by Kiteto (192 kg), Iramba (186 kg) and Igunga and Maswa (each with 173 kg). Others were Shinyanga rural and Singida (each with 168 kg) and Babati (143 kg).

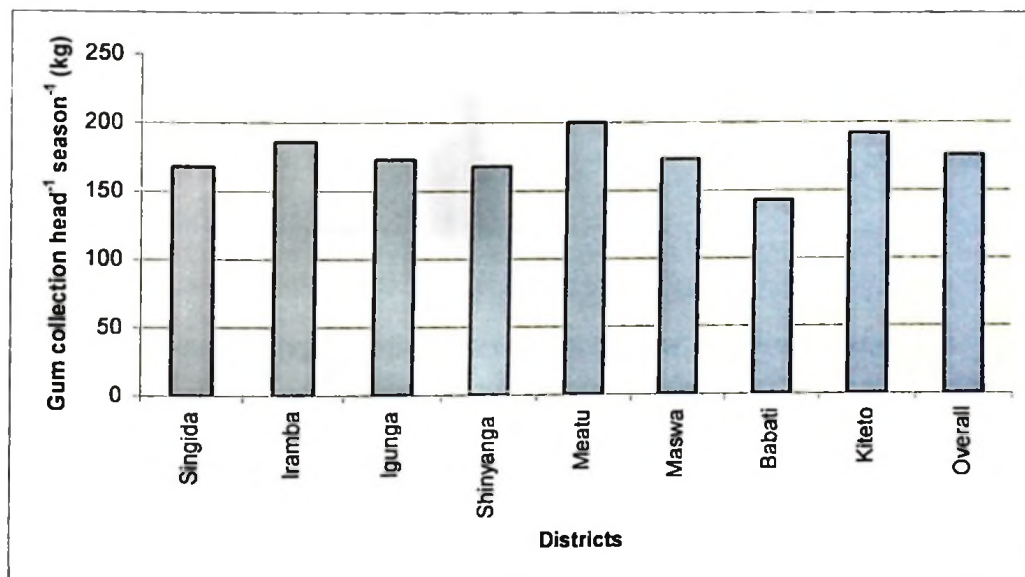


Figure 3.4 Gum arabic mean collection per head per season in Tanzania

There were no great range between the districts averages ($p = 0.19$) however, these amounts were statistically different between years $p < 0.01$. This might be an indication of the weather effect in the districts. Regression analysis of gum production per head and prices across districts did not show any strong relationship ($R^2 = 0.03$) and the influence of price was statistically insignificant ($p = 0.69$).

Further to the above observations, the *Acacia* stocking density, the mean yield per tree, the household mean annual income and the per capita incomes for the collectors across districts showed no statistically significant influence on the amount of gum collected per head ($p = 0.58$, $p = 0.71$, $p = 0.86$ and $p = 0.52$ respectively).

It might therefore be concluded that the amount of gum collected per head was more influenced by other factors such as availability of alternative work, rather than the above.

Between districts

There was a high statistical significant difference in gum production observed between districts ($p < 0.01$, Table 3.2), Meatu leading with 980.53 ± 109.64 tonnes, followed by Iramba (746 ± 93.88), Igunga (665.48 ± 104.31), Singida Rural (653.06 ± 119.97), Shinyanga (485.74 ± 67.41) and Maswa (426.54 ± 62.77). Babati and Kiteto had the least production (39.94 ± 3.25 and 33.60 ± 2.82 tonnes respectively).

This however, is not an accurate reflection of districts' production capacities as there were inter-district movements of gum observed. In Iramba for example, the middleman in the area also buys gum from collectors of Igunga district and in Igunga the middlemen travelled as far as Meatu, Maswa and Shinyanga Rural where they had gum buying centres. Also, the gum collectors did not have political boundaries and would therefore collect a mixture of gums in terms of locality, particularly where the gum resources cut across the districts.

The relationship between district gum production level and yield (collectors' figures), differences in gum price, *Acacia senegal* and *A. drepanolobium* stocking levels, mean gum yield per tree, weather conditions (rainfall and temperature) and altitude were tested. The results are summarized and presented in Table 3.4 below which is based on average values for each of the eight districts studied.

Gum price

From Table 3.4 above, the districts' annual gum production did not correlate strongly with the gum prices ($R^2 = 0.03$) and the influence of the price on the amount of gum collected was negative but statistically insignificant ($p < 0.69$). However, this result should not be too surprising. Although quantity supplied would be expected to be positively influenced by price, in this market, where the price lead is likely to come from the exporters, the local price may only vary between districts according to differential costs of reaching the capital.

Therefore, the relationship might be expected to be very weak. Furthermore, insofar as the relationship is negative, this might be due to plentiful supply in the well endowed areas seeming to push down the price.

Stocking levels of Acacia senegal and A. drepanolobium

Another determinant of variation between the districts is the gum resource abundance and availability. The *Acacia senegal* inventory reported in the gum arabic production potentials part of this study indicated Shinyanga and Igunga zones as dominant. Regression analysis between gum production and stocking levels of *A. senegal* and *A. drepanolobium* indicated a fairly strong relationship ($R^2 = 0.46$) with the former species positively influencing production ($p < 0.01$) but the latter having a negative effect ($p < 0.01$, refer Table 3.4). These results are unexpected since the bulk of gum from Tanzania is collected from *A. drepanolobium*. The disagreement observed could be due to the effect of counteraction of differences in the population of gum collectors between districts as already explained above. The effect of stocking level was also statistically significant for both species ($p < 0.01$) when considered along with both altitude and yield per tree ($p < 0.01$).

Table 3.4 Summary of regression analysis between gum arabic production and the assessed influencing factors

Equation No.	Coefficients										R ²		
	Constant	Gum price between districts	Stocking level		Mean gum yield tree ⁻¹	Weather		Altitude					
			<i>A. senegal</i>	<i>A. drepanolob.</i>		Experimental	Perceived		Rainfall	Temper.			
1.	214.54 (93.50) p = 0.06	-0.123 (0.29) p = 0.69										0.03	
2.	985.46 (10.85) p < 0.01		2.40 (13.18) p < 0.01	-0.45 (-8.64) p < 0.01								0.45	
3.	-93.10 (-0.74) p = 0.46										0.56 (5.35) p < 0.01	0.12	
4.	-583.14 (-13.32) p < 0.01		4.12 (47.60) p < 0.01	-0.57 (-33.58) p < 0.01	-0.65 (-8.99) p < 0.01						1.36 (50.84) p < 0.01	0.96	
5.	-588.51 (-1.79) p = 0.08								2.49 (3.53) p < 0.01			0.06	
6.	49.55 (0.96) p < 0.34				1.91 (10.59) p < 0.01							0.35	
7.	1,461.11 (8.99) p < 0.01									-1.16 (-5.52) p < 0.01		0.19	
8.	213.36 (0.76) p = 0.45										14.85 (1.28) p = 0.20	0.01	
9.	-298.12 (-1.76) 0.08									-3.39 (-15.68) p < 0.01	162.18 (11.23) p < 0.01	-0.41 (-2.27) p = 0.02	0.66

The production term is Y, figures in parentheses indicate standard deviations, cells in bold indicate significance at p = 0.05

Mean gum yield per tree

Two sets of gum yield were used in establishing the relationship namely, the experimental yield and the collectors' perceived yield (Table 3.4). Regression analyses showed that the collectors' perceived yield could explain only 6 % of the variation in production while the experimental yield explained 35 %. The results partly confirm the hypothesis that the perceived yields per tree are not very reliable. Both yields positively influenced gum production significantly ($p < 0.01$).

The fact that collectors' yield estimates have positive coefficients may be because their estimates are influenced by *Acacia drepanolobium* yield, whereas for experimental yields there may be multicollinearity (correlation with *Acacia senegal* stocking) or again, influence of some other (non-included) factors.

Weather

Rainfall had a negative influence on gum production, with a weak value of $R^2 = 0.19$ ($p < 0.01$). This was in line with findings reported elsewhere (AGL, 1993; Autoon, personal communication). High mean annual rainfall gives lower productivity and perhaps lower stocking for the gum resources. Also high rainfall provides higher opportunity cost for collectors.

Again as commented upon by NAS (1979), AGL (1993), Coppen (1995) and ISC (2002) temperature positively influenced gum production but the relationship is very weak ($R^2 = 0.01$) and statistically insignificant ($p = 0.203$). High temperature gives higher yield, influences higher stocking for the gum resources and perhaps less opportunity costs for collectors.

Altitude

Analysis of regression of gum production and the districts' mean altitude revealed a relationship with an R^2 of 0.12 and a positive and statistically significant relationship ($p < 0.01$).

From Table 3.4, it can be concluded that the stocking levels of *Acacia senegal* and *A. drepanolobium* command the most influence on annual gum production, followed by the gum yield tree⁻¹, rainfall and altitude.

Between years

The general trend of gum production shown in Table 3.2 indicates a decline in gum arabic production from year to year. The analysis of variance however, indicated no significant difference between amounts of gum arabic annual production for different years between 1998 and 2001 ($p = 0.79$). This complies with some information given by one of the final buyers and exporters (Fidahusseini, personal communication) that there is not much variation in gum production in Tanzania between years when compared to that of Sudan.

Albeit statistically insignificant, the observed variations might be explained by one or a combination of the following:

- Influence of weather conditions that affect gum yield per tree and collection by the gatherers.
- Declining gum resources due to haphazard land clearing for agriculture and wood and other requirements
- Inaccurate estimation of gum weights by the collectors
- Poor memories in retrieving data for past years by the gum collectors since none of them keeps written records for gum collections.

Hunting Technical Services (1964) and Coppen (1995) acknowledged the role of climatic changes on irregularity of gum and resin supply respectively. High ambient temperatures are conducive for good exudation as opposed to prolonged periods of rainfall. So one would expect production to be influenced by annual weather conditions, but perhaps this is being hidden by inaccuracy in the figures supplied by the collectors, and by an inexorable depletion of resources.

3.4.1.4 Gum arabic collectors

Population, gender and economic activities

From the study, it is estimated that Tanzania had a gum arabic gatherer population reaching $22,870 \pm 1,812$ in 2000 which is composed of 7,369 (32 %) males and 15,501 (68 %) females.

Table 3.2 above indicates that Meatu has the highest population of gum collectors ($5,025 \pm 25$), followed by Iramba ($4,156 \pm 34$), Singida Rural ($3,940 \pm 30$), Igunga ($3,879 \pm 35$), Shinyanga ($2,980 \pm 20$) and Maswa ($2,515 \pm 19$). Babati and Kiteto had the smallest populations with 195 ± 6 and 180 ± 6 respectively.

Gum collectors in Singida ranged from 5 to 200 per site, with an average of 40 which was not significantly different between the district's sites ($p=5.91$). An almost identical number of collectors was observed in Iramba, with an average of 42 and a range of 6 to 200, also not significantly different between sites ($p=6.79$). For Babati and Kiteto, the collectors' population was 5 to 20 per site with an average of 13 and 12 respectively, and for the rest of the districts, the population of gum collectors per site was between 10 and 100 with an average of 36. The difference in means for the gum collectors' population were statistically significant when compared between sites within these latter districts ($p<0.05$).

The above-observed pattern could be explained by the economic activities of gum collectors within the gum producing areas. According to the 1984 livestock census cited by Barrow *et al.* (1988), Shinyanga region had 3.25 million head, mostly found in Meatu district, which is the largest concentration of livestock in Tanzania. However, the livestock populations of Iramba and Singida Rural do not exceed that of Igunga, Shinyanga Rural or Maswa districts. Analysis of economic activities presented in Table 3.5 reveals that there are few farming activities during the gum-picking season in Iramba and Singida Rural districts apart from harvesting sunflower and cereals and land preparation towards the end of the season. In contrast, in Igunga, Shinyanga Rural and Maswa districts during the period, there are harvesting activities

for cereals and cassava and harvesting, processing and selling rice and cotton which are the most important cash crops in the area. Also, there are open livestock auctions before land preparation starts, marking the end of the gum season.

There are more adult females engaged in gum arabic collection than adult males, and children outnumber the latter ($p = 0.05$). This could be explained by the fact that it is women and children who fetch firewood, an activity that is usually accompanied by gum gathering from trees. This explains why the use of machetes is solely by women since their primary concern is firewood and gum is secondary. Kilahama (1994) reported that women in Shinyanga region spend 4 to 5 hours a day (almost 50 % of the daytime) on collection of firewood.

Another possible explanation for this was given by Eriksson (1993), that women play the most important role in agricultural production as peasants. Men however, generally control the household incomes accruing from these primary activities, the women and children would therefore engage themselves in secondary economies.

Lastly, it is a responsibility of children and to some extent women to herd the livestock. Kilahama (1994) for example, found that the responsibility of herding cattle was 11 % to men, 84 % to children and 6 % to women, whereas in goats, the responsibility was 0 % to men, 79 % to children and 21 % to women. The herding activities also take place in the gum resource areas.

Table 3.5a Seasonal calendar of activities : Singida and Iramba districts

Activities	Activity duration											
	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1 Sowing: maize, sorghum, millet	_____											
2 Weeding: maize, sorghum, millet			_____									
3 Sowing: sesame, sunflower				_____								
4 Weeding: sesame, sunflower					_____							
5 Gum picking						_____						
6 Harvesting: sunflower							_____					
7 Harvesting: maize, millet, sorghum, onion						_____						
8 Land preparation: slashing, burning, tilling									_____			

Period (Months)

Table 3.5b Seasonal calendar of activities Shinyanga, meatu and Maswa districts

Activities	Activity duration											
	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1 Sowing: maize, rice, cotton, millet, peas	_____											
2 Planting: cassava, s/potatoes	_____											_____
3 Weeding: rice, maize, millet, peas			_____									
4 Weeding: cotton			_____		_____							
5 Chemical spraying: cotton				_____								
6 Gum picking						_____						
7 Harvesting: cassava, s/potatoes						_____						
8 Harvesting: maize, rice, sorghum, millet, peas						_____						
9 Harvesting: Cotton							_____					
10 Trade in livestock							_____					
11 Land preparation: slashing, burning, tilling	_____								_____			

Period (Months)

Table 3.5c Seasonal calendar of activities Igunga district

Activities	Activity duration											
1 Sowing: maize, millet, sorghum	_____											
2 Sowing: cotton	_____											
3 Sowing: sesame, sunflower			_____									
4 Weeding: maize, rice, sesame, sunflower			_____									
5 Weeding: cotton			_____									
6 Chemical spraying: cotton			_____									
7 Gum picking					_____							
8 Harvesting: sesame, sunflower, cotton						_____						
9 Harvesting: maize, rice, millet, sorghum						_____						
10 Trade in livestock							_____					
11 Land preparation: slashing, burning, tilling									_____			
	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec

Period (Months)

Table 3.5d Seasonal calendar of activities Babati and Kiteto districts

Activities	Activity duration											
1 Sowing: maize, sorghum, millet, beans, peas	_____											
2 Weeding: maize, sorghum, millet, beans, peas			_____									
3 Gum picking						_____						
4 Harvesting: maize, sorghum, millet, beans, peas						_____						
5 Land preparation: slashing, burning, tilling										_____		
	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec

Period (Months)

In Vietnam, Ciesla (1998) observed that resin tapping is often a women's enterprise and this provides an incentive not to over-exploit the resource for fuel wood which is a scarce commodity.

The analysis in Figure 3.5 which is presented in detail by Table 3.6 below shows that gum collection is more important to women and children in the Shinyanga and Igunga zone than Singida Rural and Iramba in which the importance is shared even by men.

The most common practice (41 % of occasions) is for collection to be carried by all three groups, whereas women are by far the largest category when collection is a sole responsibility. In general, it can be concluded that gum gathering is an occupation of women (44%) and children (30.5%). Men constitute 25.5% of the gatherers and livestock keepers.

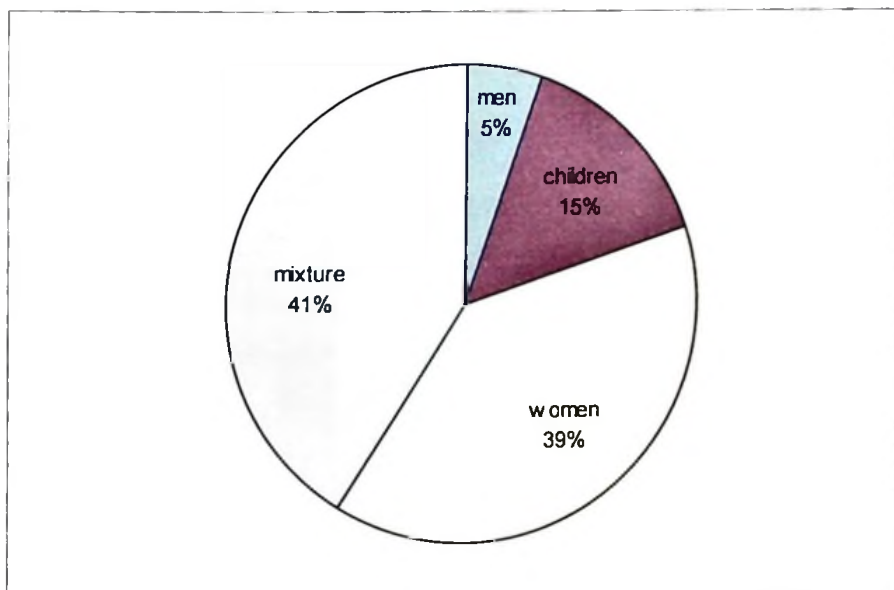


Figure 3.5 Characterization of gum arabic collectors of Tanzania

Table 3.6 Characterization of gum arabic collectors of Tanzania

Gum collectors' category	District	Frequency cited solely	Frequency cited jointly	Total frequency	Percentage cited in district
Men	Singida Rural	8	29	37	13.0
	Iramba	10	26	36	12.0
	Igunga	4	32	36	12.0
	Shinyanga	3	57	60	21.0
	Meatu	4	52	56	19.0
	Maswa	3	47	50	17.0
	Babati	1	5	6	2.0
	Kiteto	0	9	9	3.0
	Total		33	257	290
Children	Singida Rural	16	29	45	13.0
	Iramba	20	26	46	13.1
	Igunga	28	32	60	17.2
	Shinyanga	9	57	66	19.0
	Meatu	10	52	62	17.8
	Maswa	5	47	52	15.0
	Babati	2	5	7	2.0
	Kiteto	1	9	10	2.9
	Total		91	257	348
Women	Singida Rural	42	29	71	14.0
	Iramba	38	26	64	13.0
	Igunga	42	32	74	15.0
	Shinyanga	30	57	87	17.0
	Meatu	35	52	87	17.0
	Maswa	45	47	92	18.0
	Babati	8	5	13	3.0
	Kiteto	4	9	13	3.0
	Total		244	257	501
Overall				1,139	100

Analysis of factors influencing engagement in the gum collection activities

Table 3.7 below gives a summary of key features of gum arabic collecting households in comparison with the non collecting households.

Table 3.7 Key features of gum arabic collecting/non collecting households

Feature	Households		
	Collecting	Non collecting	
Annual income (TShs)	386,198	565,204	
Farm size (Ha)	3.8	4.1	
Household size and composition	Men	2.0	1.5
	Women	3.2	3.1
	Children	4.8	4.0
	Total	10.0	8.6
Occupation (%)	Agriculture	54	73
	Agro-pastoralism	46	24
	Small business	0	3
	Civil service	0	<1
Education (%)	Non-formal	38	34
	Primary	62	66
	Secondary	0	<0
Residence duration (%)	0 – 10 years	51	6
	10 – 20 years	30	28
	>20 years	19	66

From the table, it can be observed that gum collecting households had lower incomes, smaller farms, larger household sizes, more involvement with livestock, lower formal education and were more recent migrants than the non collecting households.

A logistic regression analysis employing binary logistics (collecting/not collecting) was carried out to determine factors that encourage engagement of people in gum collecting activities. The hypothesis was that income, household size, farm size, residence duration and gender influenced gum collecting activities. A Wald Forward Stepwise entering method was used, in which the analysis was performed in five steps with a cut value of 0.50 at a percentage correct of 84.1 (see Appendix VII, Table 1).

Results in Table 3.8 show that all the factors considered in the analysis were strongly influencing engagement in gum collection ($p < 0.05$). Nevertheless, household size was the strongest followed by farm size, household income, duration of residence in a particular area and lastly, gender.

Table 3.8 Summarized logistic analysis results for factors controlling engagement in gum arabic collection activities

Parameter	β	Sampling Error	Wald	Significance level	Exponential of β	Probability
Gender	-2.11	0.19	119.40	0.000	0.12	0.11
Household size	0.64	0.05	148.43	0.000	1.89	0.65
Residence duration	-0.41	0.13	9.79	0.002	0.66	0.40
Income	0.00	0.00	202.83	0.000	1.00	0.50
Farm size	0.36	0.08	21.91	0.000	1.43	0.59
Constant	-1.24	0.63	3.91	0.048	0.29	0.22

Checking for the validity of the above predicted model was done by grouping the field data on the parameters, into classes and the percentages of the gum collectors in each class calculated, and used for computation of the logarithm of odds ratio, as

$$\text{Logarithm of odds ratio } (\beta) = \ln [P/(1-P)]$$

The probabilities were computed from the logarithm of odd ratios for the collectors as

$$P = e^{\beta} / (1 + e^{\beta})$$

Where: P = Probability of a person collecting gum in a particular parameter class.

The probabilities were then plotted against the parameter classes at their mid points. Results for the plots are depicted in Figure 3.6, 3.7, 3.8 and 3.9 below for farm size, per capita income, duration of residence and gender and age, respectively.

Household size

The probability of the influence of household size in gum collection was 65 % which shows a strong positive relationship.

For a given income, the larger the household size, the lower the income per head. Poorer households are more likely to look for alternative income sources to supplement their income (Ellis, 2001). And, for a given farm size, the larger the household, the lower the marginal productivity of labour.

Farm size

The predicted relationship shown in Table 3.8 suggests that increase in farm size would increase the probability of the occupier being a gum collector. However, results in Figure 3.6 show that most of the gum collectors could be found in households with an average farm size of 1 ha, and there was a sharp fall in the collectors' population for larger holdings, with none having a farm greater than 7 ha.

It might be expected, as Figure 3.6 depicts, that large holdings provide greater incomes and greater demand for labour, which should, therefore, produce a negative, rather than a positive coefficient. The result in Table 3.8 is puzzling, unless greater farm size is linked to poorer farm productivity. Also, the β value in Table 3.8 may be influenced by multicollinearity.

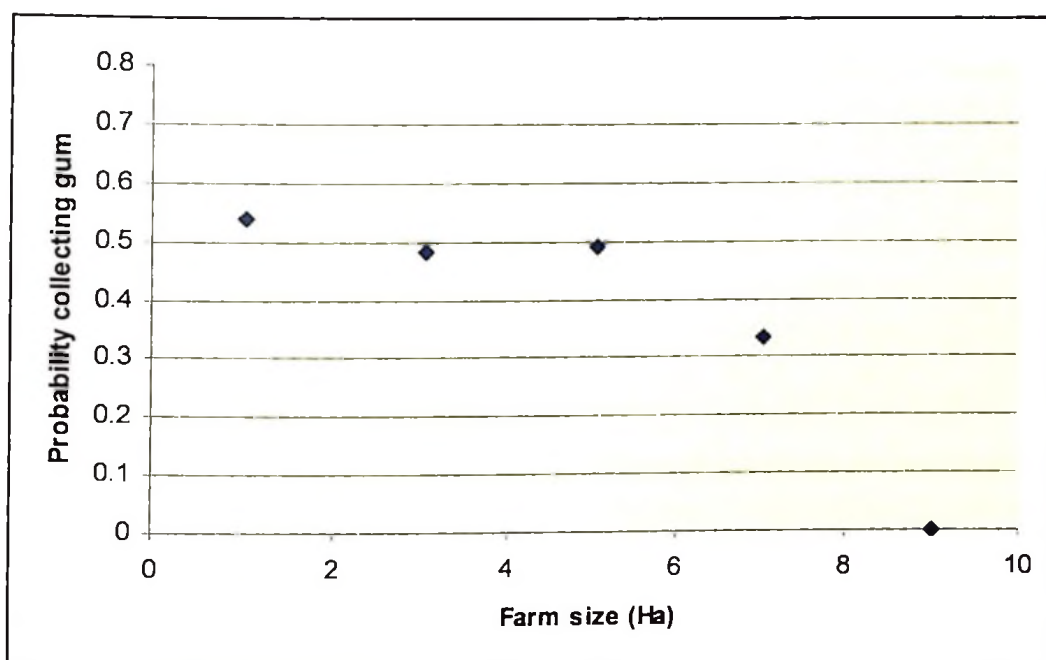


Figure 3.6 Effect of household farm size on the probability of a person collecting gum arabic

Income

Table 3.8 suggests that household income has no effect on the probability of a household member collecting gum or not. However, if per capita income is considered, there is a negative relationship (Figure 3.7). The figure suggests that gum collectors had per capita incomes of less than TShs 150,000 per year.

Since gum collection has been branded labourious and tedious (NAS 1979; FAO, 1983; Sharawi, 1987; Booth and Wickens, 1988; AGL, 1993; Clamens *et al.*, 2000) once enough income is earned from the primary economic activities, gum collection is considered too inferior to undertake (AGL, 1993), and is only likely to be adopted if income is low.

Duration of residence in a particular area

The logistic analysis results in Table 3.8 predict a negative relationship between the residence duration and the probability of being a gum collector. This is strongly supported by observations in Figure 3.8 in which it was uncommon to encounter a gum collector with a duration of over 15 years in the same residence.

This is a good measure of how gum collectors are composed of a large proportion of semi-nomadic people whose primary economic activity is livestock rearing. These people would therefore, keep on shifting in search of better pastures and watering sources and if they had only relatively recently migrated into an area would be likely to have less access to land.

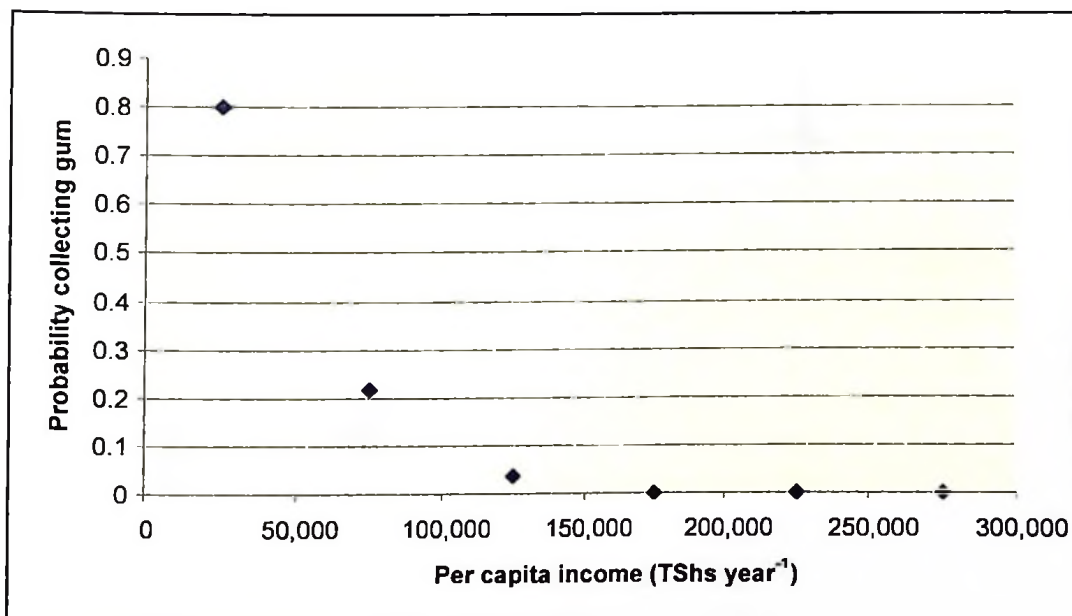


Figure 3.7 Effect of per capita income on the probability of a person collecting gum arabic

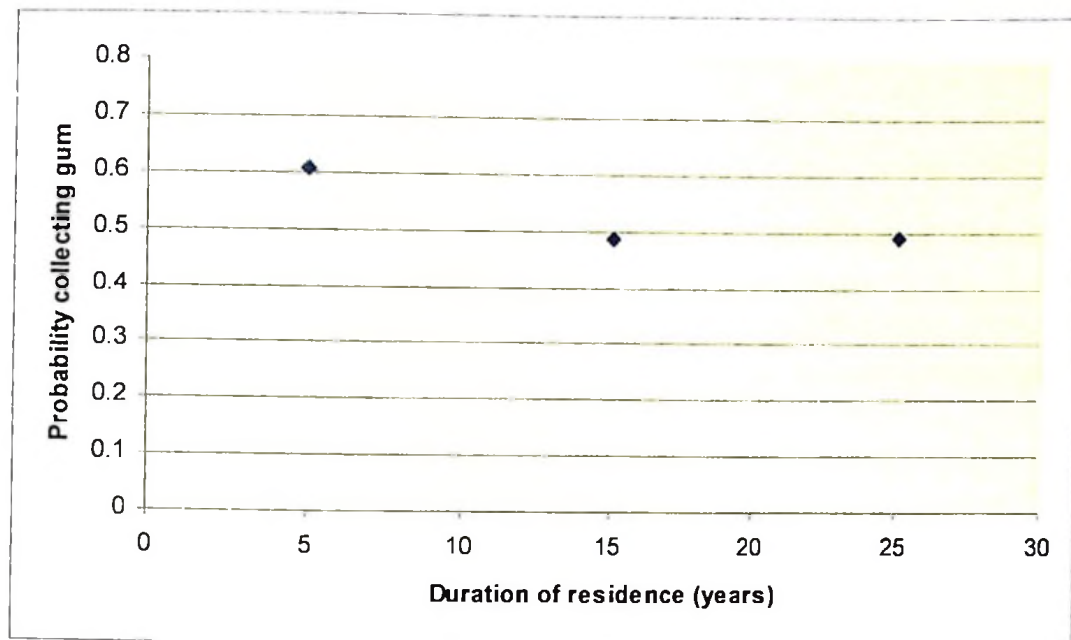


Figure 3.8 Effect of duration of residence on the probability of a person collecting gum arabic

Gender

Table 3.8 suggests that the probability of a male to be a gum collector is 10 % and the influence of the male gender is negative. The observations made from the table concur with those presented in Figure 3.9 below. In general, it is more probable to encounter females in the gum collection activities than males, for the reasons given in Section 3.4.1.4 above.

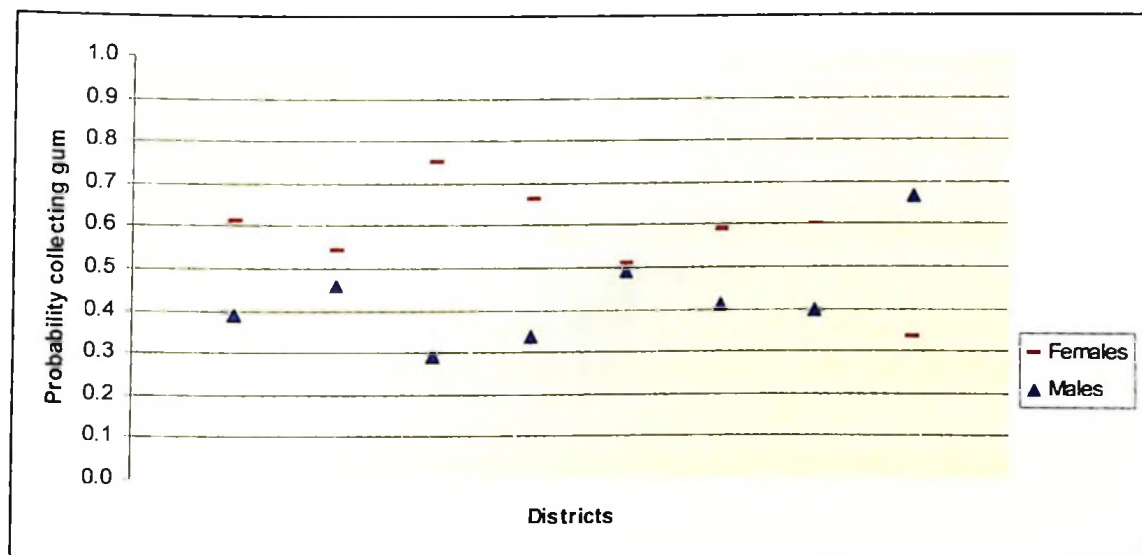


Figure 3.9 Effect of gender on the probability of a person collecting gum arabic.

3.4.1.5 Factors influencing annual variation in gum arabic production

The factors that influence annual variation in the amount of gum arabic collected in the production areas of Tanzania were gleaned from three sets of human groups namely, the gum collectors, gum middlemen and the final gum buyers and exporters.

Results from the gum collectors are presented in Table 3.9 below.

Table 3.9 Factors considered influencing annual variation in gum arabic production by gum collectors

Factor considered responsible	Frequency cited solely	Frequency cited jointly	Total frequency	% of total frequency
1. Variation in weather	2	123	125	10.42
2. Gum price fluctuations	78	448	526	43.83
3. Availability of gum trees	82	467	549	45.75
Total	162	1,038	1,200	100.00

From the analysis of these results, availability of gum producing trees i.e. *Acacia senegal* and *A. drepanolobium* is considered by the collectors to most influence gum collection (46 %) closely followed by instabilities in the gum price given by the middlemen (44 %) and with variation in weather a minor factor (10 %).

Perception of the gum collectors

Availability of gum trees

Most of the woodlands in Tanzania, estimated by Mgeni (1985) to cover 70 % of the forest land, do not have any legal status but are simply common lands forming uncontrolled wood harvesting and charcoaling areas (Mnzava, 1991). About 40 % of the land in Tanzania is in rough grazing areas (Shao *et al.*, 1990). Gum collection is carried out in natural stands scattered in open access areas in this land category. Since there is an ever-growing demand for wood of *Acacia senegal* and *A. drepanolobium*

for cattle kraals by the pastoral communities, particularly the Sukuma who are semi-nomadic, and for fuel, the gum resources are being scrambled over. The wood of these two species however, was noted to be perishable, with only about three months natural durability, this together with the frequent movement of pastoralists pose a threat to the gum resource stocking.

Table 3.12 indicates that gum collectors think conservation of the resources is second only to improvement of gum price in importance. The role of *Acacia senegal* as a resource for gum arabic has been appreciated by the Sukuma for many decades: Malcolm (1953), for example, was documented by Barrow *et al.* (1992) as reporting the socio-economic importance of this tree species in the, then, Sukumaland. Despite its importance, very little has been done to either conserve or replant the tree. There has been an increasing demand for the seeds of *Acacia senegal* in Tanzania by individual farmers and institutions. In 1999, the National Tree Seed Project (personal communication) sold 6.25 kg of seeds, whose demand tripled to 16.27 kg in 2000 and during this study 3.25 kg had been purchased. There was also an order for 100 kg of seeds for Australia in 1999, which was never picked up by the clients. The centre had seeds in stock averaging 120 kg year⁻¹.

The reluctance in conserving or planting the tree species has been largely attributable to the heritage of land tenure insecurity created by the villagization ('*vijiji*') and communal farming ('*ujamaa*') reforms during 1967 – 1974 as described by Hyden (1980), Hedlund and Lundahl (1989), Shao *et al.* (1990) and van Cranenburgh (1990). Also, by the high mobility of herdsmen who are the major beneficiaries of the species.

Booth and Wickens (1988) noted a similar situation in Sudan where the decline in the gum fallow period has meant longer distances to be travelled by harvesters in finding productive trees. Booth and Wickens (1988) and Stiles (1988) recommended that increasing appreciation of *Acacia senegal* in an agroforestry system should lead to an increase in well managed gum gardens. Natural regeneration of *Acacia senegal* is very easy in favourable environments (Cheema and Qadir, 1973; FAO, 1983) as seed viability is good and germination excellent (Doran *et al.*, 1983; the National Tree Seed Project, personal communication) however, young plants are susceptible to damage by fire and grazing animals (NAS, 1980; Doran *et al.*, 1983).

Nour (1999) applauded Sudan for embarking on a steady *Acacia senegal* planting programme with an annual average of 25,200 ha which is above 50 % of the annual afforestation programmes for the country. With a recommended spacing of 4 m x 4 m, Booth and Wickens (1988) estimated that the entire annual production of the Sudan which is estimated to be 45,000 tons (FAO, 1995b; Seif el Din and Zarroug, 1998) could be obtained from a plantation of 55 km². In such a situation, a person may tap up to 100 trees a day and deal with about 30 ha a season, producing 200 to 300 kg of gum (Hunting Technical Services, 1964).

Perhaps the two keys to conservation of *A. senegal* lie in the resource ownership and the value of gum arabic: Firstly, under the current common property ownership of the *Acacia* resources, if one does not chop a tree, someone else will. Secondly, the short term values in the use of the resource as fuel or other forms of wood may overwhelm long term gum value and, besides, different people might benefit from wood use and gum produce.

Gum price fluctuations

Gum price variations presented great discouragement to gum collection, as they could not be predicted. Out of the total sampled gum collectors' population, 99.2 % did not know the cause for gum price fluctuations while the balance indicated that it was due to gum quality. Recognizing the influence of declining prices of gum as compared to those of other crops, Seif el Din and Zarroug (1998) and Nour (1999) observed that *Acacia* forest cover in Sudan was reduced for extensive agricultural crop production. This was explained by FAO (1983) as strategies to improve the living standard and food security of the population whose 1980's agricultural production per capita had declined compared to that of the 1960's.

Annual variation in weather conditions

The influence of weather trickles down to a number of factors affecting gum arabic availability either directly or indirectly including, the gum yield per tree, manpower availability and gum pest (mice) outbreak.

It was noted that good gum yield follows plentiful rainfall received in the area since yield is improved as a short-term effect. This is in agreement with earlier reports by Hunting Technical Services (1964), Hain (1970), Booth and Wickens (1988), Wolf (1991), Jamal (1994) and Payne (2001).

It was again noted however, that good weather conditions for agricultural crops result in low labour engagement for gum collection in the same and the following year. This could be explained by Autoon's report (personal communication) in a study on agro-economic strategy development for Shinyanga and Maswa that this is evidence that the gum prices are not attractive enough to engage in the collection exercise unless it is very necessary for livelihood support.

Observations made by Coppen (1995) in Somalia revealed that drought conditions affect production of *Boswellia* and *Commiphora* resins as watering and livestock grazing places need to be sought more actively and there may be less time devoted to resin tapping.

During this study it had been foreseen that there would be a lower gum crop than in the previous year due to inadequate rain and mice infestation. Attacks by mice negatively affect gum production as they consume the product on trees making its availability to gatherers insufficient. Mouse influx is largely controlled by weather, whereby a decrease in soil moisture content favours rapid multiplication of the pests. Jamal (1994) noted a tremendous decline in gum production in Kordofan during the period 1979 – 84 incriminated by long drought and insect attacks.

Perception of the gum middlemen and exporters

The gum middlemen and exporters expressed concerns regarding market demand, weather and the ever-increasing distances to the sites where the gum collectors supply their collections.

Annual variation in the gum market demand

The amount of gum purchased by the final buyers and exporters from the middlemen and subsequently the collectors was found to be controlled solely by the world market supply. Payne (2001) acknowledged that gum arabic is irregular in terms of supply to the world market and consequently it experiences widely fluctuating prices.

Anderson (1993) reported a steady decrease in gum arabic and other water-soluble tree exudates sold annually over the past 15 – 20 years due to a number of identifiable factors. However, there still remained some commercial demand for gums meeting international market specifications and whose annual availability and prices were steady.

Gum arabic being a minor but important and hard-to-substitute input for many industrial products would face a largely inelastic demand on the world market (see Figure 3.10). It would not tend to shift a great deal, but might show a rising or falling trend (rising with incomes, falling as substitutes).

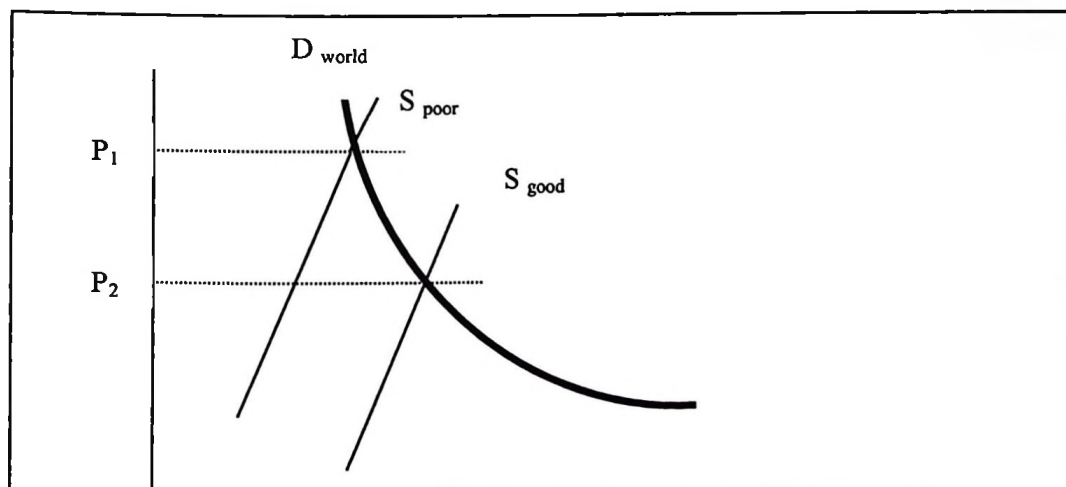


Figure 3.10 Hypothetical gum arabic world market Demand – Supply schedule.
P = Price, D = Demand and S = Supply.

Therefore, what determines variation in price is exchange rates and supply variation from year to year which would be relatively fixed (inelastic) in the short term. So price fluctuates due to Supply fluctuations with inelastic Demand. As far as Tanzania is concerned, being a small supplier is a “price taker” so it would seem (apparent

completely elastic) Demand is determining price since their Supply does not influence it.

Annual variation in weather conditions

The effect of weather, according to the middlemen and exporters was two fold: in accessibility for and availability of gum collectors. The gum collection sites are situated in remote areas where there are no proper motorable tracks. In years of heavy rainfall these areas become difficult to access, as they become cut-off from communication, forcing an increase in walking distances by the gum collectors to the middlemen, and some decide not to sell their harvest at all during the year.

Secondly, gum collection is an occupation that is volatile, depending on the economic performance of the gatherers. During good harvests of agricultural crops there is little gum offered to the buyers. A similar trend was stated by AGL (1993) for Kenya, who observed that the ideal harvesting season of gum arabic does not match the pattern of the pastoral nomads' ecology-adapted schedule of their life style. This is because the season is within the span of the wet rainy season which happens to be the bountiful season with the least economic incentive for the nomads to engage in activities outside their traditional, core lifestyle of livestock rearing, particularly if other conditions are good.

Variation in travelling distances

There were variations in distance traveled ($p < 0.01$) by the middlemen and final buyers and exporters of gum between years, because of the mobility of gum collectors in search of greener pastures for their livestock. Elsewhere, AGL (1993) and Barbier (2000) described the gum collectors as mostly pastoral nomads, highly mobile with their livestock and constantly on the move in search of water and greener pastures.

3.4.1.6 Drawbacks to gum arabic production expansion in Tanzania

As a natural product of versatile application, sought by many industries around the world, one would have expected gum arabic production in the country to be thriving. In contrast, the business has actually been stumbling from year to year (Adamson and Bell, 1974).

A survey of the factors that negatively affect gum arabic production expansion was conducted on three sets of actors, namely gum collectors and ordinary farmers in the producing areas, gum middlemen and final gum buyers and exporters.

The survey conducted on gum collectors and non-collectors living in the gum producing areas revealed the results in Tables 3.10.

As Table 3.10 shows, low returns from gum collection activities was cited as the most important limiting factor for the gum arabic industry in Tanzania, by both the collectors and non-collectors with 46.0 % and 44.0 % respectively.

The second factor, namely the view that collection is labourious and tedious, was more common amongst the collectors whereas deeming collection as an inferior undertaking was more common amongst non-collectors.

Further analysis indicated that out of all the non-collectors interviewed, 14.0 % had carried out collection activities in their lifetime and the rest 86.0 % had never done so due to either one or combinations of the above listed factors.

Results from the survey of gum middlemen presented in Table 3.11 indicate that the costs involved affect the business most (25.0 %), followed by low prices and market uncertainties (18.8 % each) and the distance travelled (15.6 %).

Table 3.10 Factors considered hampering gum arabic production expansion in Tanzania by gum collectors and non-collectors

Factor thought most limiting	Frequency cited solely	Frequency cited jointly	Total frequency	% of total frequency
1. Low returns	56 ^a	447	503	46.0
	191 ^b	239	430	44.4
2. Labourious and tedious	52 ^a	447	499	45.7
	177 ^b	109	286	29.5
3. Inferior undertaking	8 ^a	83	91	8.3
	23 ^b	230	253	26.1
	116 ^a	977	1,093	100.0
Total	391 ^b	578	969	100.0

Rows with ^a indicate data from gum collectors, ^b data from non-collectors

Low returns

The costs incurred in the gum business by the middlemen can be broken down into the following items: licence, registration fee for forest products, income tax, transport costs, loading and unloading, processing, packaging, weighing, buying and selling.

According to URT (2001b), the fee rate payable as a license on non-plantation forest produce and where the produce is cut and removed by the licensee, which applies to gums and resins is TShs 150 kg⁻¹. This is almost 50 % of the gum price, and was being complained of by the middlemen to the Tanzania Chamber of Commerce, Industry and Agriculture, requesting that 5 – 10 % of the price be used as a fee instead. However, the figures of amounts produced recorded by local governments suggest that almost 100 % of the tax is being evaded.

Table 3.11 Factors considered hampering gum arabic production expansion in Tanzania by gum middlemen

Factor thought most limiting	Frequency cited solely	Frequency cited jointly	Total frequency	% of total frequency
1. Costs involved	1	7	8	25.0
2. Decline in gum areas	0	4	4	12.5
3. Low prices by the buyers	0	6	6	18.8
4. Labourious	0	3	3	9.4
5. Distance travelled in collection	0	5	5	15.6
6. Market	0	6	6	18.8
Total	1	31	32	100.0

Table 3.12 Factors thought important in boosting gum arabic production in Tanzania by gum collectors

Improvement thought important	Frequency cited solely	Frequency cited jointly	Total frequency	% of total frequency
1. Gum trees conservation	64	415	479	43.4
2. Establishment of gum plantations	1	38	39	3.5
3. Gum price improvement	150	408	558	50.6
4. Gum harvesting technology	0	27	27	2.5
Total	215	888	1,103	100.0

The registration fee that is to be paid in order to engage in business in any forest products was TShs 30,000 per year. Income tax has to be paid depending upon the sales, at an average rate of 20 %. Again, it appears that little of these charges are actually being paid, despite the merchants' protestations.

Apart from these, transport cost was about TShs 40.00 kg⁻¹ to Dar Es Salaam without considering costs for gathering gum from the collectors, processing and packaging, loading and unloading.

The most important factor influencing expansion of the gum business considered by the final buyers and exporters of gum from Tanzania is the Government's policies on taxation of the product. These were hindering the growth in production because of the height and quantity of levies and taxes involved and the poor infrastructure causing high transportation costs, all resulting in low returns to the capital invested in the gum business.

Labourious and tedious task

There are several reasons for the gum collection activities to be labourious and tedious, which concur with reports by other authors.

Firstly, it is due to its high level of manpower requirements involving random walking in search of trees with harvestable gum exudes. From the annual production and gum collectors' statistics, it is estimated that an individual collects 0.177 tonnes year⁻¹.

As presented in section 3.4.1.2 and 3.4.1.3 above, the mean gum production tree⁻¹ season⁻¹ is 390 g. It can be estimated that, in order to fill a 10 tonne cargo truck, annual collection of gum from 57 collectors must be involved, going around 25,642 trees in total which is an average of 450 trees person⁻¹. Similarly, for pine resin the same cargo would need 30,000 – 50,000 trees (Coppen, 1995).

This occupation is also acknowledged by NAS (1979) as labour intensive since gum-tears need to be hand picked, and, where grading is practised, every tear is colour sorted entirely by hand. A similar observation was made for pine resin tapping by Coppen and Hone (1995) and Ciesla (1998).

In Table 3.12 it can be noted that 2.5 % of the gum collectors wished there were simpler methods invented for facilitation of gum collection activities. Gum tapping and the use of Vidal-Hall tapping tool as advocated by (Booth and Wickens, 1988) would be of great help.

Secondly, the gum trees' tendency to form thorny thickets whose spines are uncinata and become attached to the skin and clothes make the harvesting of the gum in dense groves very difficult. This hindrance was also noted by Sudan Forest Department (1954; 1959; 1960; 1962; 1971), FAO (1983) and Booth and Wickens (1988).

Thirdly, the harsh environment of hot and dry weather and the sun-reflecting ground that characterizes the commercial gum production areas as also noted by other workers (AGL, 1993; Clamens *et al.*, 2000), poses hardship in gum collection. Gum collection was observed to be concentrated in early and late hours of the day during which the atmosphere is cool and the sun is at an acute angle. It was also noted that this environment is favourable for vermin particularly black ants, which are notorious for their stings, and venomous snakes.

As concluded by Arnold and Townson (1998), much of the involvement in labour intensive low return activities by the rural poor is to provide an income safety net but declines once better alternatives become available.

Inferior undertaking

Some people in the gum areas considered the gum collection activities as inferior. This is more important to the non-collectors (26 %) than the gum collectors (8 %). This is another explanation for higher participation rates by women and children in the gum collection business since these are groups with a low profile in the society.

Elsewhere, gum production is still largely a peasant occupation, which is dirty and uncomfortable. In Sudan, for example, despite the introduction of the Vidal-Hall tapping tool which has made the task less unpleasant (Booth and Wickens, 1988), the nomads have no interest in gum production as they own either camels or cattle (Sharawi, 1987). And FAO (1983) observed that, in spite of farmers' interest in harvesting gum, which earns them an important income, they are becoming increasingly reluctant to convert their marginal land into gum orchards or to plant millet and sorghum fallows with gum trees.

This outlook is not only experienced in gum: in pine resin production, for instance, Ciesla (1998) noted that in the developed countries labour has become more expensive as fewer workers will undertake the activities. Production of resin has therefore declined in these countries and the centres of production have shifted. In the 1960's, for instance, the author cited USA and the former USSR as leading countries in resin production. Today these have greatly been overtaken by China and Indonesia. According to Coppen and Hone (1995), tapping of pine resin remains essentially a manual operation as attempts to introduce mechanization for some of the tasks have met with little success.

In the Philippines however, in the 1980's, Conelly (1985) noted that the Tagbanua people were abandoning their farming activities to engage in tapping resin from *Agathis spp.*, an activity that was paying much more than farming.

AGL (1993) concluded that since the habitat of the *Acacia senegal* tree is the arid and semi-arid lands where pastoral nomads predominate, the task of gum collection is largely performed by pastoralist communities who perceive any activity outside their chief function of livestock rearing as of a secondary nature. The almost total dependency on pastoral nomads' collection of gum is a serious shortcoming that depresses actual production in the context of a vast potential of untapped, gum-producing trees.

Gum market uncertainties

Finding ideal markets for gum was a problem expressed by all gum middlemen (and also the collectors although this was presented as low pay from the business) as the three final buyers and exporters of gum dictated all the trade in the country. During the period between 1991 and 1994 for example, gum arabic production was carried out in Kongwa and Nondwa areas in Dodoma district. However, the business collapsed after the dealer who requested collection of the product failed to turn up (Dodoma District Forest Officer, pers. comm).

The gum market uncertainties were blamed upon the dissolution of the rural cooperative system and expropriation of its assets in the mid-1970s as explained by

Eriksson (1993), World Bank (1994) and Ashimogo (1995). Among the reasons put forward for the dissolution decision were:

- Loss of farmers' confidence in the organ due to its inability to pay them promptly,
- Embezzlement by the management leading to heavy indebtedness and bankruptcy,
- Inadequate procurement arrangements,
- Poor stock control leading to losses and low quality control.

The whole exercise resulted in a set back to the development of a burgeoning rural institution capable of responding commercially to farmers' needs in the remotest villages.

Dwindling gum resources

This was a problem felt by all the parties concerned in the gum business, as partly described in section 3.4.1.5 above. According to one middleman, for example, in the 1950's a 10-ton truck could be filled with gum arabic in a single day, with big balls of gum up to 10 cm diameter. By the time of this study, the duration had increased to a couple of days and the average gum ball diameter had fallen to 2 cm. The longer duration is partly due to the decline in the *Acacia senegal* stocking level, meaning more time for gum gathering, and partly due to the pressure on the available trees for gum, meaning premature (earlier than the necessary 2 weeks gestation period) collection of smaller diameter gum balls.

As noted by FAO (2001b), the use of wood negatively affects the provision of NWFPs. Conelly (1985) reported that productive *Agathis spp* which bear Manila copal resin were becoming difficult to locate in the Philippines where in the 1980s, 4 to 5 hours were being spent walking compared to 1 to 3 hours in previous years.

It has been noted by Shao *et al.* (1990), Eriksson (1993) and World Bank (1994) that the villagization policy in Tanzania, which attempted to collectivize agriculture, (as fully explained by Proctor, 1975) separated farmers from their perennial crops and

known cropland. This added to costs and forced the exploitation, often beyond sustainable levels, of the land close to the new settlements.

Tanzania has about 8,000 villages of which only 900 (11.3 %) have been surveyed and land titles issued (World Bank, 1994). Tenure insecurity has not only reduced investment in land and conservation of soil fertility but has also gone further into instigating conflicts. One aspect of traditional land-use rights which has not been included in village-based tenure, has been grazing and access to water rights of the nomadic groups in semi-arid and arid areas.

This omission, coupled with the expansion of cultivation into more marginal agricultural areas, has caused sharp conflict between agriculturists and pastoralists, and has generated most tenure-related disputes in recent years (World Bank, 1994). During this study, for instance, over 20 agriculturists had been massacred by Maasai pastoralists in a fierce land conflict in Kilosa district, in Morogoro.

Elsewhere, the trend in production of gum arabic seems to vary: in Mali and Senegal, the production is declining while it is increasing in Chad and Niger (FAO, 2001b).

Gum arabic quality

The final gum buyers and exporters considered the quality of the product as a limitation. They disclosed that if the quality of gum arabic was to be upgraded the demand and price for gum from the country would obviously improve. However, they gave nothing to the collectors or the middlemen as an incentive for improving the collections. Thus, the gum price did not take into account, the gum grades and was therefore not encouraging improvement in the quality of the gum collected.

According to Meer (1980), the international demand for gum arabic is for clean, unbroken gum nodules. The gum traders of Tanzania might appear to have little or no control over this quality to the world market as everything is taken care of by the gum collectors' communities back in the gum sites. This makes the scheduling and planning of procurement to meet export orders rather haphazard and erratic, a situation which was also noted by AGL (1993) in Kenya.

Nevertheless, two factors would suggest that the exporters could exercise much greater control. Firstly, if a pricing structure was used which gave premium for higher quality grades, collectors and merchants could be encouraged to deliver better quality gum. Secondly, more sorting and grading could be carried out.

That neither of these currently seem to be exercised suggests that exporters are, for some reason, content with the *status quo*. As the export statistics show (see later in Chapter V), most sales are into relatively low price markets and may be that these markets do not discern between gum qualities. In this case, it would not be cost effective to incur sorting costs or adopt a different price structure.

Comparing the results of this study with those of Nour (2001) for Sudan, it can be concluded that gum production in the latter is a more well-established activity with more favourable policies, legislation, institutions, resource management and development and quality control than in Tanzania where it is solely left to a few private individual final buyers and exporters who are reliant on opportunistic collectors.

3.4.2 Source of commercial *Acacia* gum of Tanzania

Table 3.13 below summarises findings on the plant species from which commercial gums are collected and traded under the name of gum arabic in Tanzania, according to the collectors.

Table 3.13 Survey of plant species regarded as sources of commercial gum in Tanzania

Gum tree species	Frequency cited solely	Frequency cited jointly	Total frequency	% of total frequency
1. <i>Acacia senegal</i>	0	604	604	46.9
2. <i>Acacia drepanolobium</i>	26	604	630	49.0
3. <i>Acacia seyal</i>	0	37	37	2.9
4. <i>Acacia tortilis</i>	0	10	10	0.8
5. <i>Commiphora sp.</i>	0	5	5	0.4
6. <i>Acacia nilotica</i>	0	1	1	0.1
Total	26	1,261	1,287	100.0

The most important gum tree species in Tanzania was found to be *Acacia drepanolobium* with a score of 49.0 %, followed by *A. senegal* (46.9 %) and *A. seyal* (2.9 %). Others whose scores were below 1.0 % are *Acacia tortilis*, *A. nilotica* and *Commiphora sp.* By far (90 %), the most common practice appears to be collection from the two species *Acacia drepanolobium* and *A. senegal*, however, *A. senegal* was never collected alone whereas *A. drepanolobium* the only species collected solely (in small number of cases).

The findings marry with earlier reports by Adamson and Bell (1974) and Autoon (personal communication) which suggest that the bulk of gum arabic from Tanzania comes from *Acacia drepanolobium*, and is therefore likely to be accorded a lower grade and hence a lower price on international markets than material from *Acacia senegal*. Chikamai (1997) and Payne (2001) were strongly convinced that variations

in gum arabic quality exist mainly due to adulteration of gum from *Acacia senegal* (true gum arabic) with other gums of different botanic origin found in the collection areas.

Acacia nilotica also known as gum babul is an important gum tree in India, with its bark containing 12 % tannins. Though considered inferior to true gum arabic, Dwivedi (1993) believes that if proper care is given in collection and grading, the gum obtained would conform to the commercial requirements, except with regard to the optical rotation. The areas of this species in Tanzania were found to have an average density of 148 stems ha⁻¹ which is fairly high for commercial production of babul gum. Yet, only one collector (0.2 %) reported exploiting this species.

It was reported by Autoon (personal communication) that gum from *Commiphora sp.*, which has a strong smell was being traded mainly to people of Asian origin in Shinyanga region, to be used as frankincense. However, there are indications that this commodity is being secretively exported. For example, it is documented by FAO (2001b) that Tanzania exported 421 tonnes of myrrh, a resin from *Commiphora myrrha* in 1979 and 200 and 800 tonnes of Olibanum, resins from *Boswellia carteri*, and *B. freeriana* in 1987 and 1988 respectively. Again, however only a tiny proportion of collectors (<1.0 %) reported using the species.

In a project on gum arabic in 12 countries in Africa, funded by FAO, Chikamai (1997) reported that 17 species were identified as sources of *Acacia* gum collected by the local communities (see Table 3.14). From the table it can be noted that *Acacia senegal*, *A. seyal* and *A. laeta* have widespread distribution within the gum belt whereas the other species have limited regional distribution. *Acacia drepanolobium* and *A. paoli* for example, are confined to East Africa and the Horn of Africa, *A. karroo* to Southern Africa and *A. late* and *A. dudgeoni* to West Africa.

Analysing this table, the following conclusions can be drawn regarding the source of commercial *Acacia* gum in Africa:

- All countries produce a mixture of *Acacia* gum, with Senegal having the highest gum heterogeneity,
- According to the FAO (1990) specifications, Zimbabwe and Ghana do not produce gum arabic,
- Almost 60 % of the countries combine the management of the gum resources in plantations and natural stands,
- All countries which manage the gum resource in plantations, grow solely *Acacia senegal* except Mali which combines this species with *A. laeta*,
- Seventy five percent of the countries produce gum by combining both methods of tapping and picking natural exudates from the trees.

Table 3.14 Survey of source of commercial *Acacia* gum in twelve African gum producing countries

Country	Commercial <i>Acacia</i> gum producing species	Source of bulk gum produced		Methods of obtaining gum	
		Plantations	Natural stands	Tapping	Natural
Burkina Faso	<i>A. senegal</i>	**	**		**
	<i>A. laeta</i>		**		**
	<i>A. seyal</i>		**		**
	<i>A. gourmaensis</i>		**		**
	<i>A. dudgeoni</i>		**		**
	<i>A. raddiana</i>		**		**
Mali	<i>A. senegal</i>	**	**	**	**
	<i>A. laeta</i>	**	**	**	**
	<i>A. seyal</i>		**		**
	<i>A. polyacantha</i>		**		**
	<i>A. raddiana</i>		**		**
Mauritania	<i>A. senegal</i>	**	**	**	**
	<i>A. laeta</i>		**		**
	<i>A. seyal</i>		**		**
	<i>A. macrostachya</i>		**		**
Senegal	<i>A. senegal</i>	**	**	**	**
	<i>A. ehrenbergiana</i>		**	**	**
	<i>A. laeta</i>		**		**
	<i>A. macrostachya</i>		**		**
	<i>A. macrothyrsa</i>		**		**
	<i>A. nilotica</i>		**		**
	<i>A. polyacantha</i>		**		**
	<i>A. sieberana</i>		**		**
Sudan	<i>A. senegal</i> var. <i>senegal</i>	**	**	**	
	<i>A. seyal</i> var. <i>seyal</i>		**		**
Ethiopia	<i>A. senegal</i> var. <i>senegal</i>	**	**	**	**
	<i>A. senegal</i> var. <i>kerensis</i>		**		**
	<i>A. seyal</i> var. <i>seyal</i>		**		**
	<i>A. seyal</i> var. <i>fistula</i>		**		**
	<i>A. polyacantha</i>		**		**
	<i>A. drepanolobium</i>		**		**
Kenya	<i>A. senegal</i> var. <i>kerensis</i>		**		**
	<i>A. paoli</i>		**		**
Zimbabwe	<i>A. karroo</i>		**	**	**
Nigeria	<i>A. senegal</i> var. <i>senegal</i>		**	**	**
	<i>A. seyal</i> var. <i>seyal</i>		**		**
	<i>A. nilotica</i>		**		**
Ghana	<i>A. sieberana</i>		**		**
	<i>A. polyacantha</i>		**		**
Chad	<i>A. senegal</i> var. <i>senegal</i>		**	**	**
	<i>A. laeta</i>		**	**	**
	<i>A. seyal</i>		**		**
	<i>A. polyacantha</i>		**		**
Niger	<i>A. senegal</i>	**	**	**	**
	<i>A. seyal</i>		**		**
	<i>A. raddiana</i>		**		**
	<i>A. tortilis</i>		**		**
	<i>A. polyacantha</i>		**		**

Source: Chikamai (1997).

3.4.3 Gum arabic quality and control in Tanzania

3.4.3.1 Grading

The gum quality was assessed by picking 30 random gum samples from each gum collection centre, representing each district. This process was repeated three times to cover the entire gum season, in June, August and October, making 90 observations for each of the districts. The quality of gum arabic from Tanzania was assessed by exposing the gum samples to two kinds of analyses namely, grades (purity) using the operational grading system of the country and identity by determining the level of adulteration of gum arabic with gum from other botanic sources (see Section 3.3.2.2).

It was found that gum arabic from Tanzania was not graded any more whereas it reportedly used to be before the abolition of cooperative unions (Nkupa, personal communication). This was said to be a result of the undifferentiated price given by the final buyers and exporters to the middlemen. As a consequence, the middlemen are not motivated to incur the additional costs on sorting the gum into grades. Elsewhere, Copen (1995) noted that sorting and grading of resin in Somalia was done by local merchants to whom it is sold, rather than by the collector.

According to the information given during this survey, there were four grades (see Table 3.15 and Plates 3.1 a-d, below) when grading of the gum was in operation until 1970's (Nkupa; Rashoud; Suleiman; Salum, Abdallah, personal communication). The table attempts to compare the gum arabic grading system of Tanzania with other systems in selected *Acacia* gum producing countries in Africa. It is shown that gum from Sudan and Francophone West Africa is much more refined than that from Tanzania. However, gum from Nigeria shows much similarity with that from Tanzania, the only contrast being that the Nigerian gum grade I comes purely from *Acacia senegal* whereas that from Tanzania is a mixture with gum from other botanic sources.

Table 3.15 Gum arabic grading system in Tanzania compared to other systems in selected *Acacia* gum producing countries in Africa

Grade	Description			
	Tanzania ^a	Sudan ^b	Nigeria ^c	Francophone W. African countries ^d
I	Clean, large pieces of gum above 2 cm in diameter	<i>Kibbled</i> – Hand picked selected and kibble processed <i>A. senegal</i> gum, cleanest, most expensive	<i>Falli/Kolkol</i> – Gum from <i>Acacia senegal</i> , comparable to the Kordofan HPS	<i>Gomme Blanche</i> – Colourless and comparable to Kordofan HPS
II	Small pieces of clean gum, less than 2 cm but not in dust form	<i>HPS</i> – Hand picked selected <i>Acacia senegal</i> gum of high quality	<i>Other Acacias Gum</i> - Gum from a mixture of other <i>Acacia</i> species, darker in colour than I	<i>Gomme Petit Blanche</i> – Small pieces of the same I
III	Same gum as in II but fragmented to a fine dust form	<i>Clear Amber Sorts</i> – Cleaned low quality gum in II, light to dark amber colour	<i>General</i> - Gum from a further mixture, including <i>Combretum</i> and <i>Albizia</i> , much darker than II	<i>Gomme Blonde</i> – A darker colour
IV	Dirty form of gum, usually dark, dark brown and ashy, in mixture with bark and other impurities	<i>Siftings</i> – Sifted Clear amber sort gums with a proportion of sand, dirt and bark	-	<i>Gomme Petit Blonde</i> – Small pieces of the same III
V	-	<i>Dust</i> - <i>Acacia senegal</i> gum in dusty form together with sand and dirt	-	<i>Gomme Vermicelle</i> – A whitish to pale yellow gum
VI	-	-	-	<i>Gomme Fabrique</i> – Rejected pieces of gum because of their dark colour

Source: ^a This study, ^b Adamson and Bell (1974), FAO (1995b), Islam *et al.*, (1997), ^c Adamson and Bell (1974), Chikamai (1994), FAO (1995b), ^d Adamson and Bell (1974).



(a) Grade I



(b) Grade II



(c) Grade III



(d) Grade IV

Plates 3.1 (a – d) Gum arabic grades in Tanzania

Results of gum quality grading are presented in Figure 3.11 below. These results indicate that the major proportion of the gum (50 %) is in grade I and almost the same proportion is in grade II. Grades III and IV together constitute only about 5 %.

Analysis of variation showed that statistically, there were significant differences in the proportions of gum collected between districts for grades I, II and IV ($p < 0.01$) but the amount for grade III did not vary much between these districts ($p = 0.09$). The results suggest that Meatu, Igunga and Maswa districts produce the best gum grades followed by Shinyanga and Singida, Kiteto, Iramba and Babati in that order. Also, there were high variations observed in the proportions of gum collected, between the grades ($p < 0.01$).

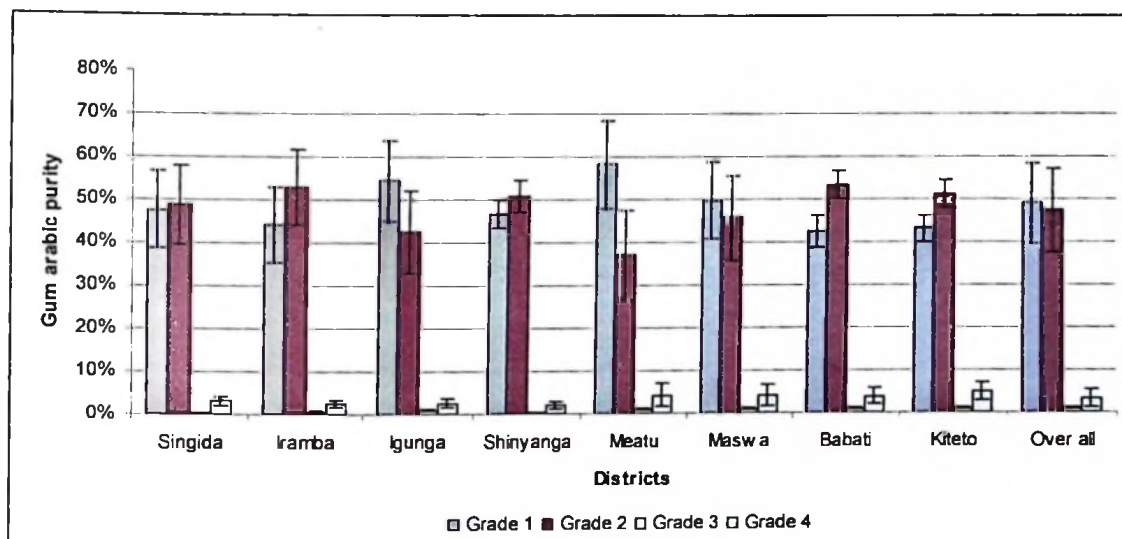


Figure 3.11 Gum arabic quality grading by purity in gum producing areas of Tanzania

When the second gum analysis method is used, the sample suggests that only about 34 % of the gum from Tanzania is the true gum arabic (refer Figure 3.12). The majority of the gum (65 %) is collected from *Acacia drepanolobium* and traces come from *A. seyal*, *A. tortillis*, *A. nilotica* and *Commiphora spp.* and the admixture of these is traded together as gum arabic. These results are in agreement with findings on the species from which commercial gums are collected and traded according to the gum collectors, as presented in Table 3.13 above.

According to Anderson (1993), species falling under Bentham's series 4 (*A. seyal*, *A. tortillis* and *A. nilotica*) together with *A. drepanolobium* among other species, produce

gum with trade names 'white Mali gum', 'East African gum' and 'Nigerian No. 2 gum' which are always in over-supply and command low prices.

FAO (1995c) recommended the term gum arabic to be revised to include *Acacia senegal*, *A. seyal* and those species whose chemometric analyses closely relate to the former two. Studies on properties of some *Acacia* gum of Tanzania have been conducted; on chemical properties in which, Mhinzi and Mosha (1996) discovered that the solubility of *A. drepanolobium* gum was similar to that of Sudanese cleaned grade gum arabic although its viscosity and alkaline-earth metal content were lower. Menzies *et al.* (1996) found the physicochemical and immunological properties of Tanzanian *Acacia seyal* var. *seyal* gum and Sudanese gum arabic to be consistent to the FAO (1990a) specifications for *Acacia senegal* gum.

3.4.4 Factors influencing variation in gum arabic quality

3.4.4.1 Adulteration of gum arabic with other gums

Figure 3.12 below presents results for the adulteration levels of gum arabic of Tanzania for the different gum producing areas in the country. The figure reveals that Shinyanga and Maswa have the best gum arabic in terms of least adulteration (36 % each), followed by Igunga and Meatu (35 % each), Kiteto (33 %), Iramba (32 %), Babati (31 %) and Singida (30 %), the worst.

The above results agree with some earlier information reported by Robbins (1987) indicating that gum arabic from Tanzania and Kenya is dark red in colour rather than amber. This was either related to the gum's admixture with gums from other sources as revealed by Anderson, (1993) or high iron content (Chikamai and Banks (1993; Payne 2001). From this study, it can be concluded that the low gum grade of Tanzania is much more strongly attributable to the former than the latter.

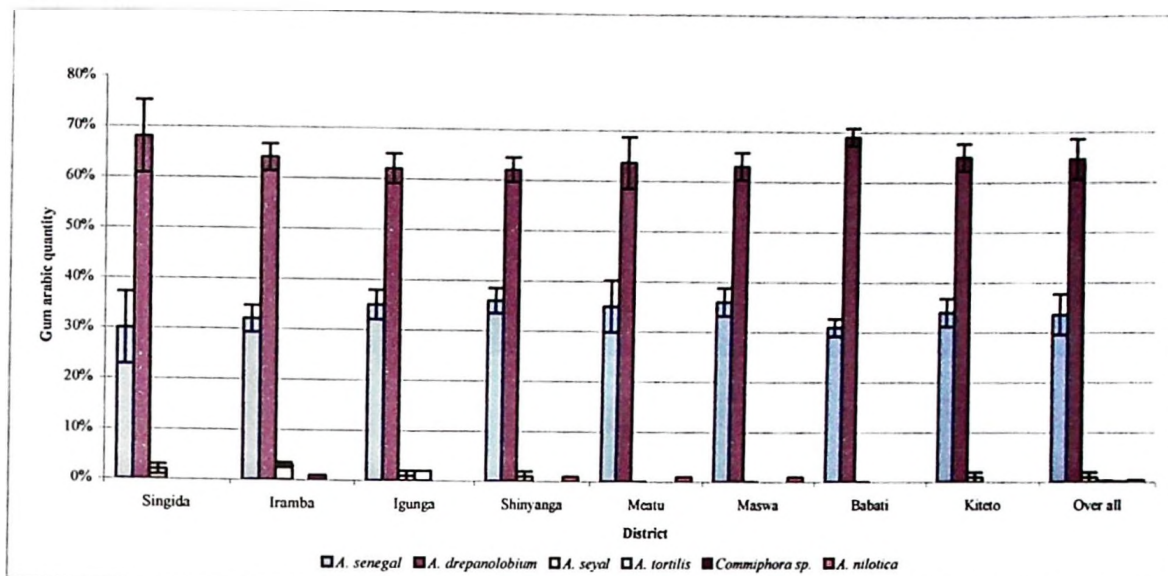


Figure 3.12 Gum arabic quality grading by botanic identity in gum producing areas of Tanzania

The preference of gum arabic sources by exporters in Tanzania was found to be in the order of Shinyanga districts (Shinyanga Rural, Maswa and Meatu), Igunga, Singida and Iramba. Gum from Babati and Kiteto was being sold as a mixed cargo with that of Singida and Iramba. Shinyanga was being favoured partly because of its relatively superior gum quantity and even quality and partly because it is connected to the central railway line, which reduces transport bottlenecks.

Chikamai (1997) reported that up to 95 % of the total gum entering the international market comprises *A. senegal* and *A. seyal*, and that 70 % is purely from *A. senegal*. Anderson (1993) and FAO (1995a; b) documented that gum arabic from Sudan which is highly sought after and valued in the international market, is produced, marketed and separated in both national statistics and trade as “hashab” (from *Acacia senegal*) and “talha” (from *A. seyal*). In order for the Tanzania’s gum to get international attention in terms of value, efforts should be devoted to meeting international specifications as advocated by Robbins (1987) and Anderson (1993).

3.4.4.2 Climatic factors

The mean annual rainfall and temperature data for the eight districts were used in the analysis. The results are presented in Table 3.16 below.

Table 3.16 Regression analysis of factors influencing variation in gum arabic quality

Grade	Constant	Coefficient			R ²
		Climate		Altitude	
		Rainfall	Temperature		
I	0.35 (6.52) p < 0.01	0.00 (2.39) p = 0.02			0.04
	0.05 (0.61) p = 0.54		0.02 (5.57) p < 0.01		0.19
	0.22 (5.31) p < 0.01			0.00 (6.49) p < 0.01	0.17
	0.01 (0.11) p = 0.91	0.00 (-2.56) p = 0.01	0.03 (4.34) p < 0.01	0.00 (-0.33) p = 0.74	0.23
II	0.60 (10.94) p < 0.01	0.00 (-1.98) p = 0.05			0.03
	0.91 (11.52) p < 0.01		-0.02 (-5.32) p < 0.01		0.18
	0.77 (17.78) p < 0.01			0.00 (-7.00) p < 0.01	0.19
	0.95 (12.18) p < 0.01	0.00 (3.00) p < 0.01	-0.03 (-4.48) p < 0.01	0.00 (0.31) p = 0.76	0.23
III	0.00 (4.78) p < 0.01	0.00 (0.06) p = 0.95			0.00
	0.01 (4.56) p < 0.01		0.00 (-1.46) p = 0.15		0.02
	0.01 (8.25) p < 0.01			0.00 (-2.17) p = 0.03	0.02
	0.05 (6.30) p < 0.01	0.00 (-2.70) p < 0.01			0.05
IV	0.04 (3.11) p = 0.01		0.00 (-0.86) p = 0.39		0.01
	0.01 (0.50) p = 0.62			0.00 (3.26) p < 0.01	0.05

Figures in parentheses indicate standard deviation and in bold indicate significance at p = 0.05.

The regression analysis done had rainfall commanding 4.2 % of the variation in gum grade I, positively and significantly ($p=0.02$), 2.8 % of grade II, negatively and significantly ($p=0.05$), none of grade III, positively but insignificantly ($p=0.95$) and 5.2 % of grade IV, negatively and significantly ($p<0.01$).

The effect of temperature on gum grade could be explained by $R^2 = 0.19, 0.18, 0.02$ and 0.006 only for grades I, II, III and IV respectively. The effect is positive and significant ($p<0.01$) for grade I, negative and significant ($p<0.01$) for grade II and negative and insignificant ($p=0.147$ and 0.392) for grade III and IV respectively. The results indicate the importance of high ambient temperatures on the production of quality gum.

3.4.4.3 Altitude

The analysis done on the regression between gum grade production and altitude revealed that altitude has a positive effect on gum grade expressed by $R^2 = 0.17, 0.19, 0.02$ and 0.05 for grade I, II, III and IV respectively and statistically significant ($p<0.01$) for all (see Table 3.16).

The multiple regression analysis of gum grades production with the climatic factors (rainfall considered together with temperature) and altitude commanded $R^2 = 0.23$ of the observed influence on all of the gum grades production and whose influence is statistically significant at $p<0.01$. Other factors likely to explain variation in gum arabic grades ($R^2 = 0.77$) should come from the tree and environmental conditions which could not be assessed in this study. These include tree age, soil characteristics and gum handling conditions.

3.4.4.4 Tree age

Unfortunately, it was not possible to assess this parameter since all gum was being collected from wild trees of different and unknown ages. Several authors have reported the influence of tree age on the quality of gum. Siddig (1991) for example, observed that gum production can begin when the trees are 3 years old. However, the quality and yield are consistent only after 5 years, and old crop gum arabic has a

better viscosity than new crop gum. Joseleau and Ullmann (1990) attempted to explain this effect as a cause of competition between gum biosynthesis and tree growth in the young crop. Idris *et al.* (1998) however, observed no obvious trends with age or source of trees when studying gum arabic from Kordofan region in Sudan.

Yields and quality of frankincense were noted by Coppen (1995) to decline during each tapping season as well as over the longer term, particularly in prolonged periods of drought.

3.4.4.5 Soil characteristics

The worst gum, black in colour and brittle, which was not attracting buyers, was observed in Iramba district, originating from Ndago area. The soils of this area could be hypothesized as the cause for this poor gum quality.

Soil composition of different regions together with varying climatic conditions and tree age, as noted by Payne (2001), could also bring about regional differences in gum quality. Analytical differences occurred between gum arabic of Kenya and that from Sudan and Nigeria (Chikamai and Banks, 1993).

3.4.4.6 Gum arabic handling conditions

Low grade gum might have been a contribution of haphazard picking from trees, poor storage and rough handling while on transit which result in high proportion of gum in the dust form.

Other reasons as put forward by AGL (1993) for the inordinately high incidence of sub-standard quality of gum arabic from Kenya included premature or delayed collection of gum by the pastoral nomadic collectors. This concurred with Chikamai (1997) who added that harvest and post-harvest treatments also, influence gum quality.

3.4.5 Conclusions and recommendations

3.4.5.1 Conclusions

The annual gum 'arabic' production in Tanzania stands at 4,000 tonnes a figure which is four times higher than the national statistics and earlier published reports. Gum production is carried out by collecting exudates from trees in natural stands and not by tapping as it is in Sudan and some other gum producing countries. This is because the gum resources in Tanzania are neither public nor privately owned.

Gum collection is highly labour-intensive since, apart from the actual picking, it involves searching for collectable gum balls by inspecting each individual tree. In so doing, great distances are covered and a lot of time is wasted.

The variation in gum production between districts is largely influenced by the collectors' population who are composed mainly of women, children and male livestock herders. Gum collection is considered secondary as it is carried out while executing other activities perceived to be more important namely firewood collection and livestock rearing.

From this study, it is evident that the gum from Tanzania does not qualify for the name gum arabic rather than gum talha as it is mixed with gum from other *Acacia* species, the bulk being from *Acacia drepanolobium*. This gum is traded in admixture and does not get attention for grading at all.

Constraints to gum production expansion for the country include low prices offered, negative attitude by the would-be collectors, market uncertainties and the dwindling gum resources. These could however, be curbed as there is little annual variation in quantities and the country is politically stable.

3.4.5.2 Recommendations

From this study, the following recommendations can be made:

- More research into the causes and physiology of gum production is needed. This will facilitate manipulation of conditions favourable for optimum gum production.
- More research is also needed on soil characteristics of the gum producing areas in order to determine their influence on gum quality.
- There is need to find out whether there is a market for gum from *Acacia nilotica* (gum babul) as there is enough growing stock of *A. nilotica* trees in many of the gum-producing areas.
- It is of crucial importance to collect, process and trade gum by identity of the source rather than the current haphazard collection of any exudates that would increase the gum weight and therefore payments. In order to emphasize this, an organ to control the business should immediately be formulated with a mandate of quality control and seeking markets.
- Tapping of trees to ensure constant quality of gum as this method also gives a more consistent and better-formed gum than collection from wounds caused by insect borers or other injuries. This method would also greatly reduce the walking distances in search of collectable gum from individual trees.
- The collection and trade in gum should be closely monitored in order to have reliable local and national statistics and appropriate returns through taxation and duties.
- Deliberate efforts geared towards conservation of the existing *A. senegal* resources should be made by all stakeholders in order to curb their rampant rate of disappearance.
- In order to manipulate gum production, *A. senegal* stocking levels across the areas need to be improved. Such silvicultural techniques as tree breeding, optimum stocking levels and soil moisture could be used. Incentives for this can be derived at, through improvements in the pricing and taxing structure, hence prices received by collectors.

CHAPTER IV

ECONOMIC IMPORTANCE OF GUM ARABIC IN TANZANIA

4.1 Introduction

4.1.1 General

Tanzania is one of the poorest countries in the world, with a Gross National Income (GNI) of less than US\$ 500 per capita (World Bank 1994; Booth *et al.* 1998; World Bank 2001; 2002). Agriculture is the backbone of Tanzania's economy employing about 84 % of the population (Eriksson 1993; World Bank 1994) and contributing 61% of the Gross Domestic Product (GDP) (World Bank 1994; 2000; 2002). The growth in the economy from the mid 1970's to early 1990's however, was below the population growth rate of 3.6% (El-Namaki 1979; Eriksson 1993; Ashimogo 1995; de Valk 1996) although this improved after the mid 1990's (World Bank 2000; 2002).

The country is also endowed with forests of various sorts, estimated by MLNRT (1989), Hunting Technical Services (1999) in FBD (1999) and FAO (2001a) to cover 37 % of the land area. Despite the country's large forest endowment, the apparent contribution of forestry to GDP is less than 2.5 % (MLNRT 1989) partly because the importance of NWFPs has generally been underestimated in relation to the local economy and consumption. As in many developing countries, the main focus concerning forestry has been on timber and other major income-generating activities, but takes little account of concurrent subsistence use of many of the same products (Arnold and Townson, 1998).

Activities in NWFPs make a substantial contribution to the secondary economy (Scoones *et al.*, 1992; Arnold and Townson, 1998). It was estimated by Kowero and O'king'ati (1990) that the value of NWFPs in Tanzania far exceeds that of timber. This statement is strongly supported by Woon and Lim (1995) for Malaysian forestry. Tanzania's honey exports, for example, accounted for nearly £800,000 in 1988, and wattle exports for

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£4,000,000 (MLNRT, 1989) whereas wood products in total, accounted for about £2,872,000 during 2001 (FAO, 2002). According to the World Bank (1994) non-traditional exports, which include NWFPs, earn Tanzania about £45 million a year.

It has been estimated by Maliyamkono and Bagachwa (1990) that a minimum of 30 % of Tanzania's total GDP arises within the so-called "second economy" in which there is production and sale of goods and services from the informal sector, yet these are hardly captured by accounting and taxation systems. This point is also supported by de Valk (1996), although no figures for its extent have been given. According to Maliyamkono and Bagachwa (1990), inclusion of this "second economy" would increase total GDP estimates by a minimum of 45 %.

With very few exceptions, the socio-economic importance of NWFPs in Tanzania has not been studied in depth. Many authors, including Okafor (1985), Appasamy (1993), Chandrasekharan (1993), Adger *et al.* (1995), Bourobou and Posso (1995), Lintu (1995) and Arnold and Townson (1998), have reported a similar shortage around Africa. This has been because the value of NWFPs, which are mostly for the subsistence economy of the very poor, is not assigned any monetary value at all.

Forest resources continue to contribute to the livelihood of humankind by providing such products as woodfuel, building materials, medicines and food, and form habitats for wildlife, natural ecosystems and contain valuable genetic resources. It was reported by Arnold and Townson (1998) that large numbers of rural households in Africa continue to generate some of their income from forest product activities. Forests provided employment for 730,000 Tanzanians in 1988 of whom 25,000 people were engaged in NWFP activities (MLNRT 1989).

Among the marketable NWFPs of most importance in Tanzania, is gum arabic (MNRT, 1989; FBD, 1999; FAO, 2001a). This product is tapped from *Acacia senegal* (L.) Willd. trees. Philip (1975), Muthana (1988), FAO (1991), Hanson (1992) and Hanson *et al.* (1992) reported that gum arabic was among the NWFPs that fuelled trade inside and

outside Africa after the abolition of the slave trade. This product contributes 10 – 15 % of Sudan's total export value (Barbier 1990; Timberlake *et al.* 1999), and in 1987 the value reached 18 %, exceeded only by cotton and groundnuts (FAO 1983; Nour, 1999). Barnes *et al.* (undated) documented that more than a million people in Sudan get their principal cash income from gum arabic. Gum arabic is of economic importance not only to farmers but also to the producing countries as well (NAS 1979; Barbier 1990; Siddig 1991). Many thousands of subsistence farmers in Sudan depend on income from gum arabic to supplement their poor harvests (Fagg *et al.* 1997). The producing species makes a major contribution economically, socially and environmentally.

4.1.2 Problem statement and justification for this study

Forests provide goods and services of various sorts including earning foreign exchange for the country. There are, however, indications that official GDP statistics do not capture much of the economic activity, which takes place in the informal sector (World Bank 1994), of which NWFPs mostly form a part.

The present direct and indirect benefits of these resources are many, however, accelerated development of these areas lies in recognising the potential that exists in the natural vegetation resources and incorporating it in the development strategy. The focus of the current study is gum arabic.

The average annual production of gum arabic in Tanzania was estimated to be 1,000 tonnes for the period between the 1980s to-date, out of which 50 % is exported (Chihongo, 1992; 1995; 2000). No account has been taken of the domestic utilization of the remaining 50 %, or of the importance of this resource to the local communities in the producing areas. As Timberlake *et al.* (1999) concluded, this product has a great potential for increased production and exports with sufficient economic returns for many more resource-poor farmers in Africa and other beneficiaries.

4.1.3 Objectives

4.1.3.1 Overall objectives

The overall objective of this study was to assess the role played by gum arabic in the livelihood of rural communities of Tanzania and to the economy of the country at large.

4.1.3.2 Specific objectives

The specific objectives were:

- a. To assess the local utilisation of gum arabic.
- b. To assess the actual and potential contribution of gum arabic to the economy at both local and national levels.
- c. To compare the income levels of gum collectors and ordinary farmers living in the same localities producing gum arabic and to elucidate the factors influencing the decision to collect.
- d. To conduct an economic analysis to determine the profitability of establishing and managing *Acacia senegal* plantation for gum arabic production.

4.2 Literature review

4.2.1 Tanzania

4.2.1.1 Economic performance

General

Tanzania is one of the poorest countries in the world with about 50 % of her population living below the poverty line (World Bank 2000; 2002). The country's population is estimated at 33 million people out of whom about 51 % are women and about 46 % are under age 15. The per capita Gross National Product (GNP) is estimated at US \$ 246. The GDP recorded an average real growth rate of 4.0 % per annum during 1996-1999. Given that the annual population growth rate was 2.8 %, the real per capita GDP growth rate was around 1.2 %.

According to the World Bank (2002), the composition of GDP is such that, the agricultural sector accounts for around 50 %, followed by the trade sector which accounts for around 16 %. The economy of Tanzania is thus, largely dependent on agriculture through poor smallholder farmers (World Bank 1994). The recent Poverty Profile for Tanzania indicated that the poor are overwhelmingly rural, accounting for about 85 % of the total country's population (World Bank 2002). Moreover, the variation in rural incomes is much greater than in urban areas with significantly more concentration, indicated by a rural Gini-coefficient of 0.60, compared to an urban coefficient of 0.48 (World Bank, 1993).

Setbacks

Over a long period, the Tanzanian economy has suffered several shocks with severe destabilizing effects. They include the oil shocks, collapse of commodity prices, drought, break-up of the East African Community and the Uganda War. These shocks, coupled

with a poor policy regime, culminated in a severe economic crisis in the early 1980s. Several adjustment measures have been implemented since 1981, but by mid-1990's fiscal instability was still severe. To date, however, inflation has been controlled from more than 30 % in 1995 to 6.6 % in early 2000 (Tanzania National Website, 2002).

Tanzania has been reliant on a few major agricultural export crops. In the late 1970's the real value of Tanzania's exports decreased due to an increase in the price of oil and a decline in prices for coffee, cotton and tea (Eriksson 1993; World Bank 1994; de Valk 1996).

The overvaluation of the exchange rate further slowed agricultural exports, reduced international competitiveness and caused severe shortages of foreign exchange (Eriksson 1993; Ashimogo 1995; de Valk 1996).

The dissolution of the rural cooperative system and expropriation of its assets in the mid-1970s has been explained by Eriksson (1993), World Bank (1994) and Ashimogo (1995) as a setback to the development of a burgeoning rural institution capable of responding commercially to farmers' needs in the remotest villages.

It has been noted by Eriksson (1993) and the World Bank (1994) that 'villagization' and attempts to collectivize agriculture, as fully explained by Proctor (1975), separated farmers from their perennial crops and known cropland, adding to costs, decreasing production and forcing the exploitation, often beyond sustainable levels, of the land close to the new settlements.

In order to maintain high rates of agricultural output growth, the World Bank (1994) recommended that Tanzania focus, in the short run, on export products, where world markets can absorb the increased production without affecting prices. Among these products is gum arabic, a commodity that fuelled trade in interior Africa and figured in world trade from the earliest times (Adamson and Bell 1974; FAO 1983; Lewington 1990; Fagg *et al.* 1997; Timberlake *et al.* 1999).

4.2.2 Gum arabic

4.2.2.1 General properties

Gum arabic consists mainly of high molecular weight polysaccharides and their calcium, magnesium and potassium salts. On hydrolysis, the gum yields neutral sugars (arabinose, galactose and rhamnose), acids (glucuronic acid and 4-methoxyglucuronic acid) and the salts. Its complex structure is still not completely known, however Leung (1980) found that the gum's backbone chain consists of D-galactose units, and its side chains are composed of D-glucuronic acid units with l-rhamnose or l-arabinose as end units. The molecular weight has been reported to be between 200,000 to 300,000 and as high as 600,000 (Leung, 1980).

ISC (2002) identified three principal fractions in the gum namely:

- Arabinogalactan – 88 % of the molecule and approximately 15 % of the polypeptide fraction
- Arabinogalactan-protein complex – 10 % of the molecule and nearly 50 % of the polypeptide
- Glycoprotein – 1 % of the molecule and again nearly half of the polypeptide fraction.

Gum arabic is truly soluble in cold water, yielding solutions up to 55 % concentration (Fennema, 1996). One gramme, for example, dissolves in 2 ml of water forming a solution, which is laevorotatory, flows readily as 20 % of its aqueous solution will give less than 100 cps, i.e. gum arabic is not very viscous at such concentrations. High viscosity is obtained only at concentrations of 40 % - 50 %. The solution obtained is acid to litmus. Other gums are either insoluble in cold water or form colloidal suspensions. Gum arabic is, however, insoluble in ethanol.

The gum is also reputed for being colourless for the top quality and for giving no off-taste; the colour and taste of products containing the gum are therefore not affected or dulled by gum arabic as the carrier.

4.2.2.2 Utilization of gum arabic

According to NAS (1979), the commercial value of gum arabic is evident from the wealth of uses to which it is put. These include the following:

Traditional

Traditionally, gum arabic is an important food for pastoralists, peasants and hunter-gatherers (FAO, 1989; Lewington, 1990; Walters and Hamilton, 1993; Fagg and Stewart, 1994; Wang and Anderson, 1994; Soni 1995; Wickens *et al.*, 1995) and sometimes children (Wickens 1976). It is reported by Sen and Bansal (1979) that in India, ground gum mixed with fried wheat flour and sugar is fed to women after childbirth. The same authors reported further that small pieces of gum fried in fat could either be used as puffs or food.

Gum arabic also finds uses in local medicines, which include treatments of local inflammations, catarrh, colds, coughs, diarrhoea, dysentery, as expectorants, gonorrhoea, haemorrhage and sore throat. Others are typhoid, urinary tract infections and it is used to cover inflamed or burnt skin, sore nipples and nodular leprosy (Dalziel, 1937; Watt and Breyer-Brandwijk, 1962; Lust, 1974; NAS, 1979; Duke and Wain, 1981; Kloss and Moffet, 1990; Murphey, 1993; The British Pharmacopoeia, 1993, in Wickens *et al.*, 1995; Wickens *et al.*, 1995).

Industrial

Gum arabic is described as one of the safest natural ingredients suitable in a variety of industrial products (Siddig 1991; Wang and Anderson 1994). These include food, pharmaceutical, cosmetic, epoxy resin and coatings industries, which are increasingly searching for natural products from plants (NAS 1979; Barbier 1990; Timberlake *et al.* 1999).

Food

For use in food, it has been strongly recommended by FAO (1999) that such extraneous materials that may be contained in the gum as sand and bark residues, be removed. The bulk of the world production of gum arabic is used as an additive in a variety of food products (FAO, 1999; Payne, 2001). The advantage for food applications of gum arabic is because it is tasteless, acid stable, odourless and non-toxic, and it is generally recognised as safe and has unobjectionable taste (Fennema, 1996; Payne, 2001; TCI, 2001). The three basic functional uses of gum arabic in food were hinted out by FAO (1999) as emulsifier, stabilizer and thickener due to the combination of its high solubility in water and low viscosity. Nutritional experts regard gum arabic as 95 % 'Soluble Fibre', according to the latest evidence reported by TCI (2001).

Leung (1980) attempted to account for the use levels of gum arabic in different food products and found that gum arabic was practically used in all categories of processed foods. There was a wide range of use levels from less than 0.004 % (40 ppm) in soups and milk products, 0.7 to 2.9 % in non-alcoholic beverages, imitation dairy, and snack foods, to as high as 45 % in confections.

The gum is used in the food industry to fix flavouring agents due to its viscosity and adhesive properties (Wickens *et al.*, 1995; TCI, 2001). It is also used as an emulsifier of fats, colours and sugar to prevent the crystallization and settling of these ingredients in winemaking, soft drinks and confectionary products. In bakery products, it has been

documented by NAS (1979) that the gum imparts smoothness and stability and lengthens their shelf life. Another use is as stabiliser in frozen dairy products, stabiliser of foam and clouding agent in beer, to provide the long-lasting head found in some brands, and moistener. The gum is employed in high-quality ice creams to provide the ultra-smooth consistency (NAS, 1979).

Others uses are surface finish coating, flavour particles, agent and thickener (Simpson and Ogorzaly 1995; Fennema, 1996; Timberlake *et al.*, 1999; TCI, 2001). The gum is also used directly in sweets. In Europe, the food additive number of gum arabic is E414 (FAO, 1995b; 1999)

Pharmaceutical

Duke (1983) stated that gum arabic is used extensively in pharmaceutical preparations. The gum is used as a stabiliser for emulsions in the pharmaceutical industry, a binder and coating for tablets, an emollient and demulcent for cough drops and syrups and is used intravenously for nephritic oedema (Duke, 1983; Booth and Wickens 1988, Wickens *et al.*, 1995). Studies by the American Society for Clinical Nutrition (1996) revealed that supplementation with gum arabic increases faecal nitrogen excretion and lowers serum urea nitrogen concentration in chronic renal failure patients consuming a low-protein diet.

Cosmetic

In the cosmetics industry, gum arabic finds applications as an adhesive for facial masks and face powder, and gives a smooth feel to lotions and protective creams (NAS, 1979; Booth and Wickens 1988; Wickens *et al.* 1995). It is also used as an emulsifier for hand lotions, ointments and liquid soaps (NAS, 1979).

Technical

Since the gum is water soluble, it is used industrially as a major components of adhesive for example the glue in postage stamps (NAS, 1979), as a sizing agent for fabrics and paper, an ingredient of lithographic inks, paints and dye, as a granulating agent in fertilizers, as a binder in explosives and a range of additional industrial products. ISC (2002) reported that the uses of gum arabic date back about 5000 years to the time of ancient Egyptians and among its many ancient applications the gum was used as an agent in the mummification process.

NAS (1979) documented that the gum is a vital ingredient in float-processing minerals and in assaying minerals, foundry sands and ceramic glazes. Cossalter (1991) added that gum arabic is also used in the manufacture of matches and ceramic pottery.

The gums containing tannins and whose solutions are dextro-rotatory, from species such as *Acacia seyal*, *A. xanthophloea*, *A. karroo* and *A. nilotica*, are excluded from use in food, as the presence of tannin is considered carcinogenic (Anderson, 1993).

4.3 Materials and methods

4.3.1 Study sites

This study was conducted in eight districts in which gum arabic collection and trade are carried out. These are Singida, Iramba, Igunga, Shinyanga Rural, Meatu, Maswa, Babati and Kiteto.

4.3.2 Sampling and data collection

4.3.2.1 Sampling

Data were collected from 630 gum-collectors as well as 630 non-collectors living in gum producing areas in 64 villages, eight gum middlemen in the areas and three final buyers and exporters of gum in the country. Also, the following government offices were consulted for secondary data survey: District and regional forest and natural resources offices in which gum arabic is collected, Tanzania Forest Division Headquarters and the Tanzania Revenue Authority – Customs Statistics Section, both in Dar Es Salaam.

The above listed groups and offices were sampled following information gathered in a preliminary survey, with great assistance from forest officers and village leaders in their respective areas.

In addition, Tanzania Railways Corporation provided information on transport costs, and Tanzania Breweries Limited and Kibo Breweries Limited were included to assess the raw material requirements for the brewing process.

Gum collectors

Trading centres which are under the charge of gum middlemen were used as centres for collecting data from gum collectors. A total number of 630 gum collectors was sampled

in the study, 15 people each from Babati and Kiteto and 100 people in each of the rest of the districts. These people were sampled and interviewed upon their arrival to the gum middlemen in the respective areas, with lots of gum for sale. Since the gum middlemen knew the identity of the informants, there was no problem of repetition of the interviewing process with the same persons.

Villages

All villages in which people engage in gum collection activities were sampled. Information on these villages was gathered with the help of vegetation maps specific for each area (MNRT 1996a; b; c; d; e; f; g; h; i; j; k; l; m; n; o; p), gum middlemen, gum collectors and other local people knowledgeable in gum arabic sources, including forest officers and local leaders. A list of these villages is presented in Table 4.1.

Ordinary farmers

After getting the full list of villages forming a base for gum collection activities, 100 ordinary farmers (non-collectors of gum) from each district, but 15 each from Babati and Kiteto, were randomly sampled. In the sample areas, village registers were used as a framework through which sample households were picked using random numbers. As recommended by Casley and Lury (1987), households provided the main information through unprompted questionnaires (Appendix IV).

Gum middlemen

There were eight gum arabic middlemen identified in Tanzania, being recognised by the gum final buyers and exporters and gum collectors and licensed by the relevant district council's forest offices. They were, also, all sampled in this study. These were situated in the main gum trading centres with various branches in the gum producing areas.

Final buyers and exporters of gum

The final buyers and exporters of gum formed the starting point from which information on the gum producing districts was obtained. There were three companies in this group, namely Mohamed Enterprises Company Limited, Fida Hussein Company Limited and Export Trading Company Limited all based in Dar Es Salaam, and all were sampled. Preliminary investigations had it that there were four exporters of gum arabic in the country; however during this study the fourth company, Masukh Company Limited had long since it closed the business down.

Sharawi (1987) used a sample size of 38 farmers, and two gum merchants who were interviewed in seven villages in Northern Kordofan and five villages in the Rahad scheme area, in Sudan. Maliyamkono and Bagachwa (1990) used 385 households in eight regions when studying second economy of Tanzania.

A very general guide given by Wong (2001) is that more than 30 observations is good and less than 5 is probably inadequate.

4.3.2.2 Data collection

Social survey methods were employed in data collection, conducted using the tools of Participatory Rural Appraisal (PRA) which were documented by Chambers (1992) and put into use by Brokensha and Riley (1980), Kajembe (1994), Kilahama (1994), Bishop and Scoones (1994), Fujisaka *et al.* (1994), Campbell *et al.* (1995) and Kikula (1996).

The social survey methods were divided into two categories, namely, interviews with individuals, i.e gum collectors, gum middlemen and final buyers and exporters of gum and non gum collectors (Appendices IV, V and VI respectively) and group discussions. Questionnaires in Appendices IV and VI were pre-tested on ten households and revised accordingly prior to the interview process. Government and public offices, including the Forestry and Beekeeping Division Headquarters, Tanzania Revenue Authority, Tanzania

Railways Corporation, Tanzania Breweries Limited, Kibo Breweries Limited, Regional and District Forest Offices provided useful recorded data either on gum arabic, general costs or raw material requirements. Such information as quantities collected and sold to internal and external markets, revenues collected, costs involved, indigenous knowledge and utilization of gum arabic were made available by this method. In addition, an attempt to estimate the number of people employed in this field and the benefits obtained could be made.

The output of group discussions in the study helped collection of such information as gum uses and their ranks, gum collectors' population and general constraints on the gum business. The detailed data collection methodology is summarised below:

Assessment of the local utilisation of gum arabic

Collection of this information was made possible with Appendix IV (Section B 19), Appendix V (Section B 15) and Appendix VI (Section B 14).

Assessment of actual and potential contribution of the gum to the economy

The information concerning actual and potential contribution of gum arabic to the economy at both local and national levels was collected using Appendix IV (Section B 2 and 16) and Appendix V (Section B 1 and 14).

Comparison of the economy of gum collectors and ordinary farmers

The use of Appendix IV (Section A and Section B 2, 3, 6, 7, 8, 11, 13, 14, 16 and 18) and Appendix VI (Section A and Section B 1, 2, 3, 4, 5, 6, 11, 12, 14 and 15) facilitated collection of data concerning income levels of gum and non gum collectors in the gum arabic producing areas in Tanzania.

Economic analysis of a gum arabic plantation

The data for economic analysis of establishing and managing a gum arabic plantation were collected from several sources: The National Tree Seed Centre in Morogoro, Tanzania, gum collectors and non-collectors, Appendix IV (Section B 11, 14 and 16 and Section C, Appendix VI (Section B 5, 8 and 16) and several studies reported elsewhere.

4.3.3 Data analysis

Data analysis was carried out using the Microsoft Excel package of Microsoft Office 98 and 2000. Descriptive statistics facilitated determination of such important information as means, standard deviations, modes and minimum and maximum values. One-way statistical analysis of variance (ANOVA) was important in determining the least significant difference between means.

Qualitative data were analysed through categorisation and content analysis and presented in graphical or tabular form. Prioritisation of the following information was conducted, employing percentage of total frequency cited in order to obtain ranks of importance:

- Local uses of gum arabic,
- Characteristics of gum collectors and ordinary farmers in the gum areas,
- Contribution of gum arabic to the total income of collectors in the different gum areas of the country

The economic analysis of a gum arabic plantation was conducted using a simple developed model, for a period of 50 years employing a discount rate of 10 %. In this model, the Land Expectation Value (LEV), Internal Rate of Return (IRR) and Net Present Value (NPV) were calculated to obtain the optimum rotation age. A sensitivity analysis was also employed by varying prices for the products and the discount rates.

An exchange rate of TShs 670, TShs 725, TShs 805 and TShs 950 US\$⁻¹ was used for 1998, 1999, 2000 and 2001 respectively (Fx Converter, 2003). All costs and incomes were adjusted to constant 2001 employing an inflation rate of 12.8, 7.9, 5.9 and 5.1 % for 1998, 1999, 2000 and 2001 respectively (BoT, 2002) using the following equation (Selvavinayagam, 1991; Price, 1993; Bradley and Patton, 1999):

$$P_t = P_0 (1 + f)$$

Where: P_t = Constant value, referring to year 2001,

P_0 = Earlier value to be inflated to year 2001,

f = Inflation rate between the year under consideration and 2001.

4.4 Results and discussion

4.4.1 Importance of gum arabic

Gum arabic was found to be locally useful in various ways, supporting the early statement by NAS (1979) that the wealth of uses to which this commodity is put is evidence of its commercial value. Its usefulness could be categorised into three main groups, namely,

- Subsistence economy of the rural folk through traditional use
- Economy of the stakeholders through collection and sale
- Employment opportunities provided by the gum activities.

4.4.1.1 Subsistence economy of the rural folk through traditional use

Table 4.1 below summarises findings on the local uses of gum arabic in Tanzania, ranked according to their respective frequency of use. Analysing the table, it can be concluded that gum was mostly used for dietary purposes (74.9 %), followed by medicinal uses (19.7 %) and lastly as glue (5.4 %). Dietary was the sole use cited in Kiteto and assumed the greatest importance (over 80 %) in Singida, Babati, Maswa and Iramba. On the other hand, medicinal use was relatively important (about 20 %) in Igunga, Singida and Meatu.

Dietary use

The gum was eaten raw in the field, mostly by livestock herders and firewood collectors as chewing gum. The preference was for pure *Acacia senegal* gum as gum from other species, particularly *A. drepanolobium*, was said to be objectionably acidic or tasted unpleasant. This comes from the fact that many hours were being spent in the field each day without meals. For the herders, the ordinary setting off time was 09.00 hours and they would continuously graze the livestock until around sundown, at 18.00 hours.

Barrow *et al.* (1988) estimated that in Shinyanga, 1 to 4 hours were being spent in each trip for firewood collection.

It was also found that the Asian community in Tanzania was using the high-grade gum arabic for special traditional food, mixing it with ghee. This tradition might have been imported directly from India as Sen and Bansal (1979) documented the same practice in that country.

The dietary use of gum has been reported elsewhere, for example in South Africa and in desert areas in North Africa by the Hottentots and the Moors respectively (Grieve, 1931 cited in Wickens *et al.*, 1995), in Oman (Fagg and Stewart, 1994) and in the Kalahari Desert by the Bushmen (Story, 1958 cited in Wickens *et al.*, 1995). FAO (1989), Lewington (1990), Walters and Hamilton (1993), Fagg and Stewart (1994), Wang and Anderson (1994), Soni (1995) and Wickens *et al.* (1995) concluded that traditionally, gum arabic is an important food for pastoralists, peasants and hunter-gatherers.

Several scientists have studied the nutritional properties of gum arabic. Leung (1980), for instance, found that the gum's digestibility by rats is up to 71 %, guinea pigs and rabbits also seemed to utilize the gum for energy, as does man to a certain extent. The calorific value officially recognized in the USA is under 1 Kcal gm⁻¹ (The American Society for Clinical Nutrition, 1996) however, recent research points to values of 3 - 4 Kcal gm⁻¹, the value assigned by the joint FAO/WHO Expert Committee since its inauguration (FAO, 1990).

Table 4.1 Local uses of gum arabic in Tanzania

District	Local use of gum	Frequency cited solely	Frequency cited jointly	Total frequency	% of total frequency
Singida	Medicinal	0	13	13	11.5
	Dietary	87	13	100	88.5
	Glue	0	0	0	0.0
	Total	87	26	113	100.0
Iramba	Medicinal	0	20	20	16.5
	Dietary	80	20	100	82.6
	Glue	0	1	1	0.8
	Total	80	41	121	100.0
Igunga	Medicinal	0	57	57	31.7
	Dietary	35	62	97	53.9
	Glue	2	24	26	14.4
	Total	37	143	180	100.0
Shinyanga	Medicinal	0	28	28	20.1
	Dietary	64	35	99	71.2
	Glue	1	11	12	8.6
	Total	65	74	139	100.0
Meatu	Medicinal	0	27	27	20.5
	Dietary	71	29	100	75.8
	Glue	0	5	5	3.8
	Total	71	61	132	100.0
Maswa	Medicinal	0	18	18	15.1
	Dietary	82	18	100	84.0
	Glue	0	1	1	0.8
	Total	82	37	119	100.0
Babati	Medicinal	0	2	2	11.8
	Dietary	13	2	15	88.2
	Glue	0	0	0	0.0
	Total	13	4	17	100.0
Kiteto	Medicinal	0	0	0	0.0
	Dietary	15	0	15	100.0
	Glue	0	0	0	0.0
	Total	15	0	15	100.0
Overall	Medicinal	0	165	165	19.7
	Dietary	447	179	626	74.9
	Glue	3	42	45	5.4
	Total	450	386	836	100.00

Medicinal use

WHO estimated that four billion people (about $\frac{2}{3}$ of the world population) depend on traditional medicine for their primary health care needs (Michael *et al.*, 1996). A large part of traditional therapy involves the use of the medicinal plants or their extracts and active compounds. Medicinal plants are a source of inexpensive medicine used by the under-served populations of the world (WHO, 1978; Ayensu, 1981; Mann, 1992; Michael *et al.* 1996; FAO, 1997a).

A similar situation exists in Tanzania since an estimated 80 % of the Tanzanian rural population still depends on traditional healers and medicinal plants for primary health care (Dery *et al.*, 1998; FBD, 1999). This has been triggered by an extremely low number of doctors, costs involved in hospitals, little funds allocated to the health sector and difficulties in curing some of the diseases using conventional treatments. The ratio of doctors to patients for Tanzania is 1:26,000 while for Zambia and Uganda it is 1:11,000 and 1:8,000 respectively (COSTECH, 1999). On the other hand, the ratio of traditional healers to patients in Tanzania was given by Cunningham (1996) and Cunningham *et al.*(undated) as 1:400.

On government expenditure, COSTECH (1999) noted that Tanzania was using an average of US\$ 6 year⁻¹ person⁻¹ on health services, an amount that was extremely low compared to US\$ 300 for South Africa and US\$ 3,000 for the United States of America.

In this study, it was found that gum arabic was being used by the majority of respondents throughout the areas to treat diarrhoea and dysentery as a purgative and also as a stomachache treatment. This was of particular importance since the gum areas are arid and therefore lack of availability of clean and safe water posed severe health problems. In such areas epidemics of the above-mentioned ailments are prevalent.

In Igunga, some respondents indicated that the gum could also be used as an antidote for snake or scorpion bites. The technical function of gum arabic here could be explained

from what Duke (1983) documented, that the gum causes partial destruction of many alkaloids including atropine, hyoscyamine, scopolamine, homatropine, morphine, apomorphine, cocaine, and physostigmine.

In some communities, the Taturu in particular, the gum had an additional medicinal use. The gum was dissolved in water and used for stopping hemorrhage and inducing depilation in new mothers.

In all of the applications above except the latter, the gum was administered by simply chewing the ball as food in any quantity. Elsewhere, Kloss and Moffet (1990) and Murphey (1993) noted that in India, gum arabic was usually dissolved in water to make a mucilage with a dose of from one to four teaspoons. For making syrups one part of the mucilage was mixed with three parts of a syrup and administered in from one to four teaspoon doses.

Several scientists have acknowledged the role of gum arabic in medicine. Wickens *et al.* (1995) for example, recognized the importance of gum in traditional medicine since Pharaonic times for diarrhoea, dysentery and hemorrhage. The British Pharmacopoeia (1993) cited in Wickens *et al.* (1995) reported that gum arabic was still officially recommended for use as a bulk-forming laxative and pharmaceutical aid.

Scientific observations made by Teichberg *et al.* (1999) indicated that addition of 2.5 or 5.0 gm litre⁻¹ gum arabic to oral re-hydration solution increased the absorption of sodium, potassium and water by two-fold in the model of chronic osmotic-secretory diarrhoea in rats.

Another significant observation by Leung (1980) on human dietary intake has indicated a reduction in blood cholesterol levels when above average amounts of gum arabic of 25 grams day⁻¹ are ingested in solution.

Gum from *Acacia nilotica* (gum babul) was also reported by Dwivedi (1993) to be used for medicinal purposes in which it is prescribed for diarrhoea, dysentery and diabetes.

Adhesive use

The gum was being used in place of office glue for sealing home-made envelopes. This occurs because most of the rural people do not like spending their meagre incomes on even an envelope.

4.4.1.2 Economy of the stake holders through collection and sale

The stakeholders here included the individual gum collectors, the gum middlemen, the final buyers and exporters and the local and central governments.

Gum collectors

Forest resources are a source of income for the people living around them. Research done in six communities in Tanzania, reported by CIFOR (1999), found that farmers living around forest areas were deriving up to 58 % of their cash income from the sale of honey, charcoal, fuel wood, wild fruits and vegetables.

Results in Chapter III indicated that the mean per capita production of gum arabic year⁻¹ was 0.1773 ± 0.0883 tonnes, determined from the sample of 630 collectors. Calculated at the mean price of TShs 304,050 tonne⁻¹, the average annual income accruing from gum activities by the collector was:

$$0.1773 \text{ tonnes year}^{-1} * \text{TShs } 304,050 \text{ tonne}^{-1} = \text{TShs } 53,908.07$$

The total amount earned by the collectors each year, was then estimated as TShs 1,225,321,500 (US\$ 1,289,812) (Also refer Table 5.3 in Chapter V).

The contribution of gum to the total income of the collector was, however, seldom 20 % (Refer Figure 4.1). But for 4 of the districts income from gum arabic, on average, was at least 15 % of total income. This is a clear indication that gum arabic collection is a secondary undertaking to supplement incomes. In a study conducted by Maliyamkono and Bagachwa (1990) on the informal economy of Tanzania, it was nevertheless revealed that the bulk of farmers' incomes came from their secondary non-farm activities. One old man recalled that collection of gum was once a good undertaking during the 1950's and 1960's, when he bought his first pair of shoes. During that time, the price ranged between TShs 0.10 and 0.15 kg⁻¹.

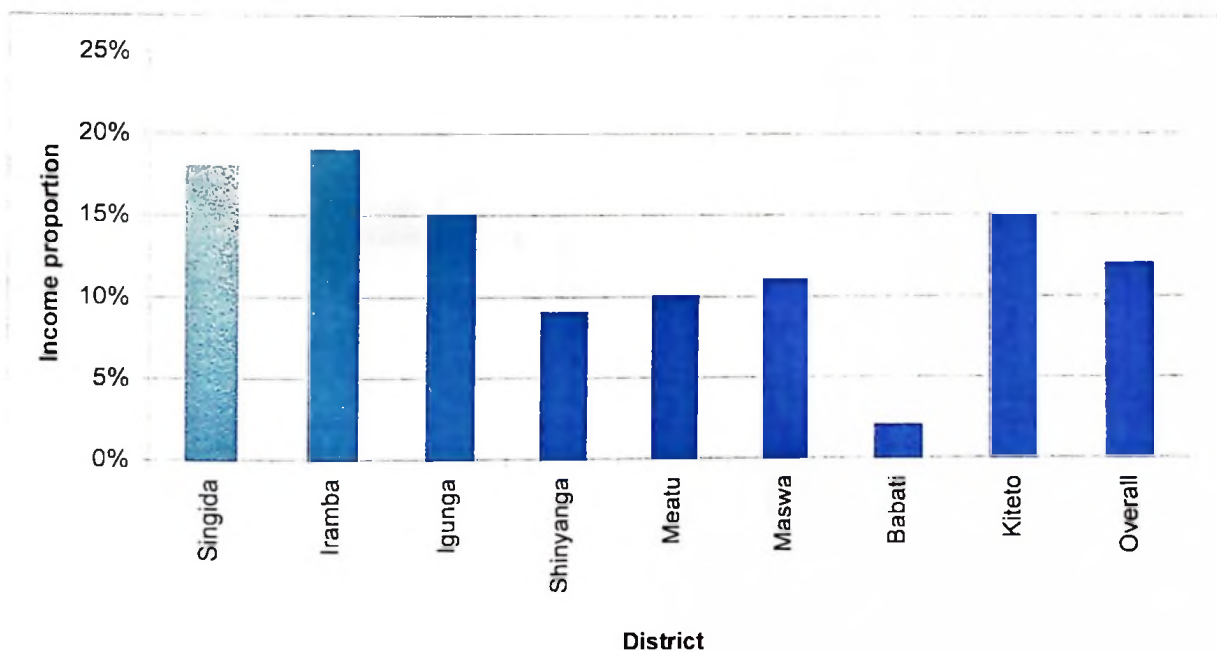


Figure 4.1 Contribution of gum arabic to the collectors' households mean annual incomes in Tanzania.

Figure 4.1 above indicates that collection of gum contributes more significantly to the incomes of collectors in Iramba, Singida, Kiteto and Igunga. In general, the contribution of gum is around 12 % and increases as other sources of income decrease.

Table 4.2 below presents results for gum collectors' and non-collectors' populations in terms of socio-economic aspects. The table suggests the following:



The contribution of gum to the total income of the collector was, however, seldom 20 % (Refer Figure 4.1). But for 4 of the districts income from gum arabic, on average, was at least 15 % of total income. This is a clear indication that gum arabic collection is a secondary undertaking to supplement incomes. In a study conducted by Maliyamkono and Bagachwa (1990) on the informal economy of Tanzania, it was nevertheless revealed that the bulk of farmers' incomes came from their secondary non-farm activities. One old man recalled that collection of gum was once a good undertaking during the 1950's and 1960's, when he bought his first pair of shoes. During that time, the price ranged between TShs 0.10 and 0.15 kg⁻¹.

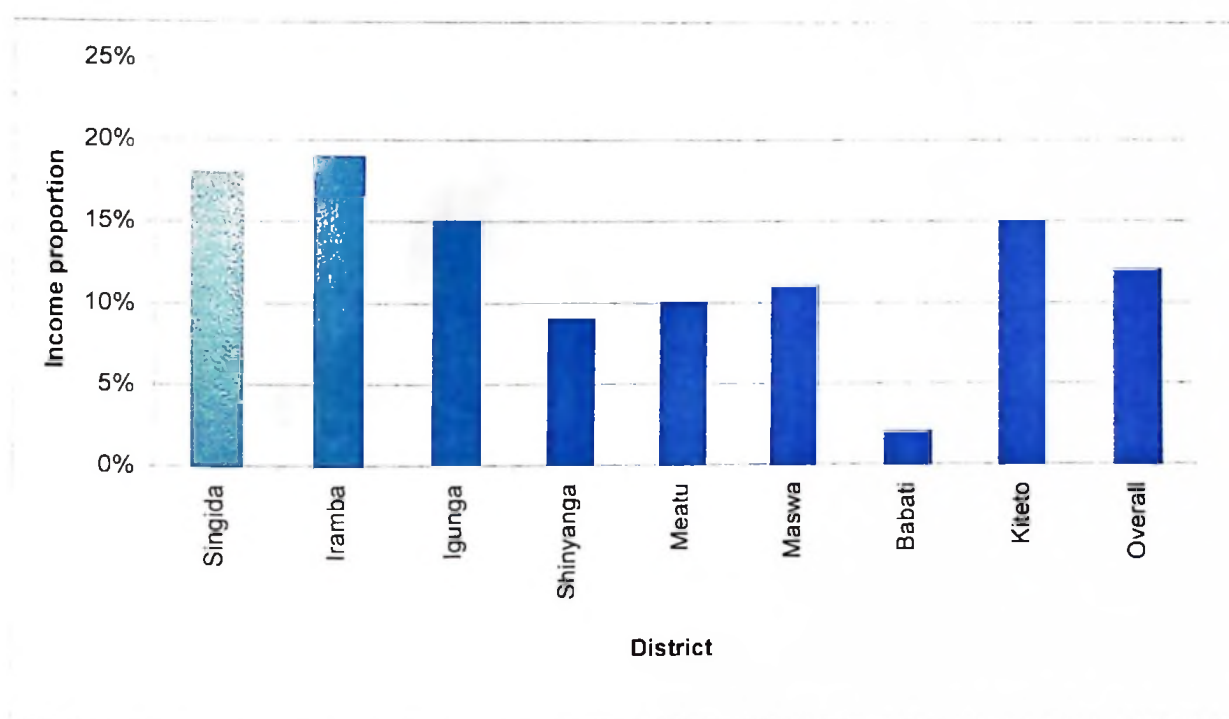


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Table 4.2 below presents results for gum collectors' and non-collectors' populations in terms of socio-economic aspects. The table suggests the following:



Table 4.2 Characteristics of gum and non-gum collectors' population in the gum arabic producing areas

District	Occupation (%)				Formal education level (%)				Type of house (%)				Household size		
	Farmers	Agro - pastoralists	Civil servants	Small business	None	Primary	Secondary	Tertiary	1	2	3	Max.	Min.	Mean	Std Dev.
Singida	62.0	38.0	0.0	0.0	38.0	62.0	0.0	0.0	0.0	1.0	99.0	14	6	9.5	1.8
	84.0	15.0	0.0	1.0	38.0	62.0	0.0	0.0	1.0	9.0	90.0	12	5	7.8	1.8
Iramba	64.0	36.0	0.0	0.0	37.0	63.0	0.0	0.0	0.0	1.0	99.0	14	5	8.7	1.9
	80.0	16.0	2.0	2.0	26.0	72.0	0.0	2.0	0.0	16.0	84.0	12	5	8.6	1.5
Igunga	68.0	35.0	0.0	0.0	36.0	61.0	0.0	0.0	0.0	8.0	92.0	14	5	8.6	1.8
	69.0	28.0	2.0	1.0	24.0	73.0	1.0	2.0	1.0	29.0	70.0	13	6	8.9	1.4
Shinyanga	39.0	61.0	0.0	0.0	25.0	75.0	0.0	0.0	0.0	6.0	94.0	16	8	10.8	1.7
	73.0	24.0	1.0	3.0	32.0	66.0	1.0	1.0	1.0	28.0	71.0	13	5	9.1	1.6
Meatu	44.0	56.0	0.0	0.0	48.0	52.0	0.0	0.0	0.0	0.0	100	16	8	11.5	1.5
	67.0	32.0	0.0	1.0	38.0	61.0	1.0	0.0	0.0	15.0	85.0	12	5	8.7	1.5
Maswa	50.0	50.0	0.0	0.0	36.0	64.0	0.0	0.0	0.0	1.0	99.0	16	8	11.0	1.6
	68.0	31.0	0.0	1.0	45.0	55.0	0.0	0.0	1.0	13.0	86.0	12	5	8.4	1.8
Babati	67.0	33.0	0.0	0.0	8.0	47.0	0.0	0.0	0.0	0.0	100	13	9	10.7	1.0
	47.0	53.0	0.0	0.0	40.0	60.0	0.0	0.0	0.0	13.0	87.0	11	7	8.3	1.2
Kiteto	33.0	67.0	0.0	0.0	9.0	40.0	0.0	0.0	0.0	0.0	100	15	7	10.4	1.8
	73.0	27.0	0.0	0.0	47.0	53.0	0.0	0.0	0.0	20.0	80.0	11	7	9.1	1.2
Overall	54.0	46.0	0.0	0.0	38.0	62.0	0.0	0.0	0.0	2.7	97.3	16	5	10.0	2.0
	73.0	25.0	1.0	1.0	34.0	64.0	0.0	1.0	0.6	18.3	81.0	13	5	8.6	1.6

Note: - The two rows, in plain and italics in each district represent data for gum-collectors and non-collectors, respectively

- House type 1 indicates block/brick with corrugated iron sheets, 2 indicates, mud/ pole with corrugated iron sheets and 3 indicates mud/pole, grass-thatched houses.

- There were proportionately nearly twice as many livestock keepers in the gum collectors' population than in the ordinary populations in the gum producing areas. This was particularly pronounced in Shinyanga Rural, Meatu and Kiteto districts.
- The gum collectors were marginally more disadvantaged in terms of formal education and more so in terms of housing. Most of them (97.3 %) had house type 3 compared to about 80 % of non-collectors (Refer Plate 4.1 below). Using χ^2 test, the observed differences in education levels attained between the two groups were significant ($p = 0.05$) and in house types, the differences were highly significant ($p < 0.01$). This could be explained by their semi-nomadic way of living coupled with a greater degree of poverty.
- The gum collectors' household size was higher than that of non-gum collectors ($p < 0.01$).

Holden *et al.* (1997) cited by Livestock in Development (1999) reviewed the relationship between livestock and the poor and concluded that livestock are important to the majority of the rural poor in developing countries, contributing in many and diverse ways to rural livelihoods as summarized below:

- Source of cash income from the sale or hire of animals or their products,
- Source of livelihood security as it is one of the few assets available to the poor and women,
- A central component of farming systems providing draught power and manure,
- Source of food, transport, fuel, access to social support networks, cultural well-being and a variety of other functions.

In Shinyanga Rural district, Kilahama (1994) observed that 40 to 72 % of households had livestock.



Plate 4.1 Typical rural houses in Tanzania: Left house type 2, Right house type 3

Further analysis using other indicators showed that the gum collectors were generally poorer in the community than the rest. These indicators were: household mean annual income, per capita income and farm land particulars.

Household mean annual income

Figure 4.2 below compares the household mean annual incomes between the gum collecting and non-collecting populations in the gum areas in Tanzania. Overall, the ordinary farmers (non-collectors) indicated a higher mean annual household income (US\$ 600) than gum collectors (US\$ 400) ($p < 0.01$). Igunga, Maswa and Shinyanga districts indicated higher incomes than the rest with US\$ 380, 420 and 620 and US\$ 750, 750 and 650 for the gum and non-collectors respectively. The poorest gum collectors were encountered in Singida, Iramba and Babati districts with incomes of less than US\$ 300.

Per capita income

The per capita incomes presented in Figure 4.3 below reveal a similar pattern to the household income between districts. There is, however, a wider disparity between the incomes of the two populations in question due to the larger household size of gum collectors than the non-collectors (Refer Table 4.2 above). The per capita income ranged from US\$ 30 in Singida to US\$ 60 in Shinyanga for gum collectors and US\$ 45 in Kiteto

to US\$ 90 in Maswa for ordinary farmers. The overall average per capita income in the areas was US\$ 40 for gum collectors and US\$ 70 for the non-collectors.

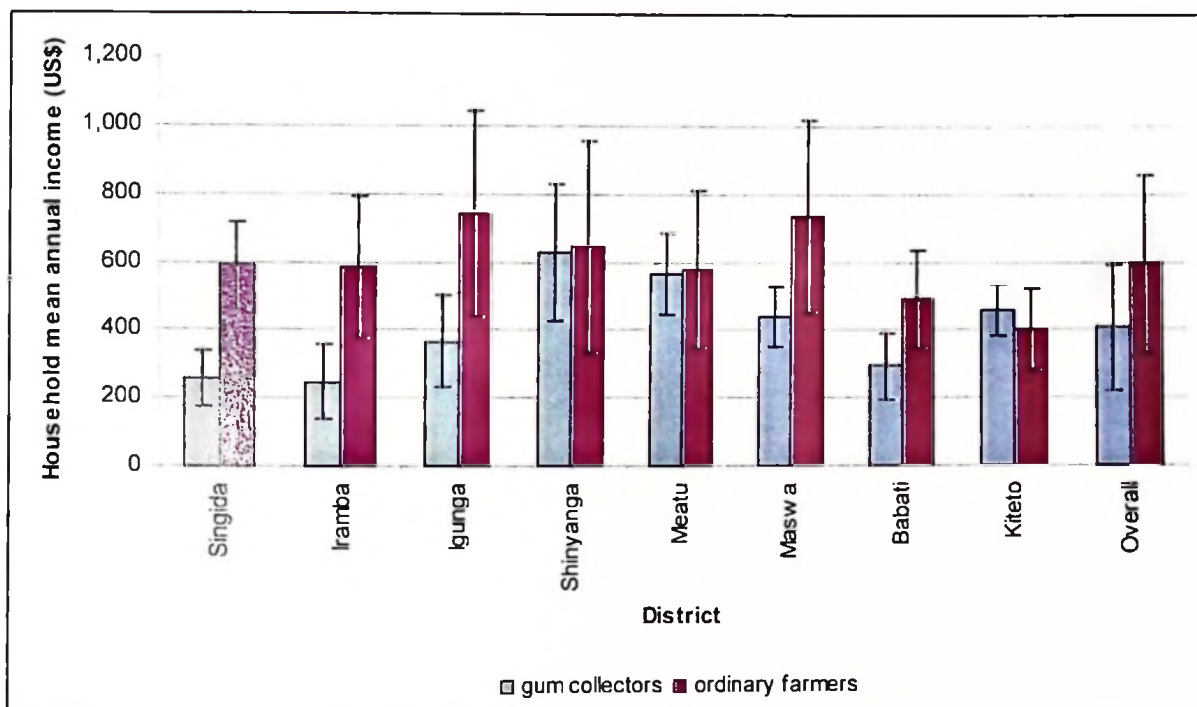


Figure 4.2 Comparison of mean annual household incomes between gum collectors and no-collectors in Tanzania. Note: lines indicate standard deviations.

The incomes altogether are far below the national figures for Tanzania of US\$ 251 year⁻¹ reported by World Bank (2000 and 2003). This is because the gum producing areas are too dry to support intensive agriculture which employs over 80 % of the Tanzania labour force. In these localities, the share of the population below the national poverty line was 91 % for Shinyanga, 62 % for Tabora (Igunga being one of its districts) and 57% for Singida (World Bank, 1996).

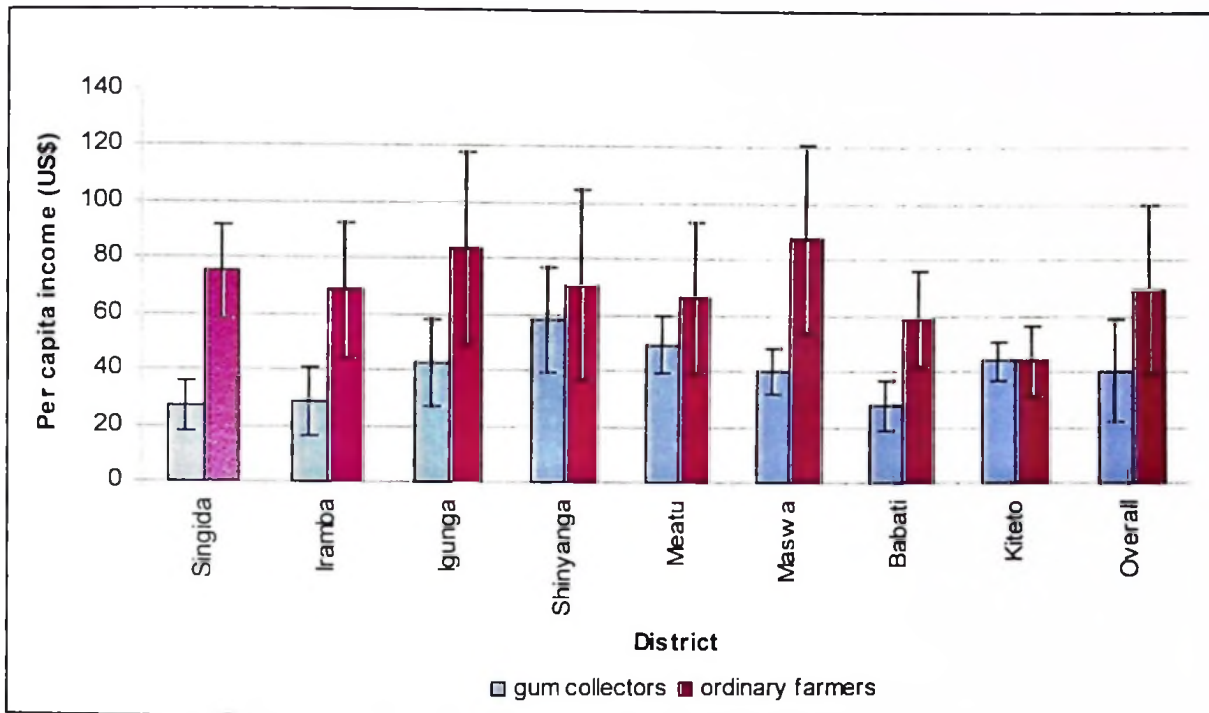


Figure 4.3 Comparison of mean annual per capita incomes between gum collectors and non-collectors in Tanzania

Farm land particulars

Table 4.3 below summarises information on mean farm land holding and how it was acquired, for both gum collectors and non-collectors in the gum producing areas. Analysis of the table indicates that the overall mean farm size for gum collectors is smaller (3.59 ha) than that of non-collectors in the same areas (4.03 ha) ($p < 0.01$) although in Igunga and Singida the reverse was the case.

In both populations, most of the households obtained their land through allocation by local governments (84 % and 63 %), followed by inheritance (15 % and 27 %) and the least by purchase (0 % and 9 %). Fewer gum collectors tend to inherit land than their counterparts and none of them obtain land by purchasing. This confirms earlier reports that most gum collectors lead a nomadic life (AGL, 1993; Barbier, 2000)). This prompted further analysis as presented in Figure 4.4 below.

Table 4.3 Farm land mean size distribution and acquisition process in the gum producing areas of Tanzania

District	Mean farm size (Ha)	Frequency of farm land acquisition process			
		Local government allocation	Inheritance	Purchase	Renting/Lending
Singida	3.57 (1.09)	80	19	0	1
	<i>3.69</i> <i>(0.99)</i>	<i>47</i>	<i>45</i>	<i>6</i>	<i>2</i>
Iramba	3.79 (1.13)	77	21	2	0
	<i>3.86</i> <i>(1.18)</i>	<i>65</i>	<i>28</i>	<i>6</i>	<i>1</i>
Igunga	4.40 (1.44)	81	19	0	0
	<i>4.37</i> <i>(1.76)</i>	<i>73</i>	<i>20</i>	<i>7</i>	<i>0</i>
Shinyanga Rural	4.26 (1.02)	92	8	0	0
	<i>4.10</i> <i>(1.24)</i>	<i>68</i>	<i>23</i>	<i>9</i>	<i>0</i>
Meatu	3.52 (0.63)	88	12	0	0
	<i>4.12</i> <i>(1.14)</i>	<i>70</i>	<i>17</i>	<i>13</i>	<i>0</i>
Maswa	3.35 (0.77)	86	14	0	0
	<i>4.04</i> <i>(1.22)</i>	<i>56</i>	<i>30</i>	<i>14</i>	<i>0</i>
Babati	3.13 (0.99)	14	1	0	0
	<i>4.27</i> <i>(1.44)</i>	<i>11</i>	<i>4</i>	<i>0</i>	<i>0</i>
Kiteto	3.33 (0.72)	12	3	0	0
	<i>4.00</i> <i>(1.20)</i>	<i>10</i>	<i>4</i>	<i>1</i>	<i>0</i>
Overall	3.59 (1.11)	530 (84%)	97 (15%)	2 (0%)	1 (0%)
	<i>4.03</i> <i>(1.29)</i>	<i>400</i> <i>(63%)</i>	<i>171</i> <i>(27%)</i>	<i>56</i> <i>(9%)</i>	<i>3</i> <i>(0%)</i>

Note: The two rows, in plain and italics in each district represent data for gum collectors and non-collectors respectively.

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Note: The two rows, in plain and italics in each district represent data for gum collectors and non-collectors respectively.

Figure 4.4 reveals clearly that the majority of the gum collectors (52 %) lived in one particular settlement for less than 10 years whereas 67 % of ordinary farmers lived in the same place for over 20 years. Only 20 % of the gum collectors had lived in one particular settlement for over 20 years whereas only 5 % of their counterparts had lived in the area for less than 10 years period. Using χ^2 test, the observed differences between the two groups were found to be statistically significant ($p = 0.05$).

The above results strongly confirm the reported high mobility of gum collectors (Sharawi, 1987; Booth and Wickens, 1988; AGL, 1993; Barbier, 2000).

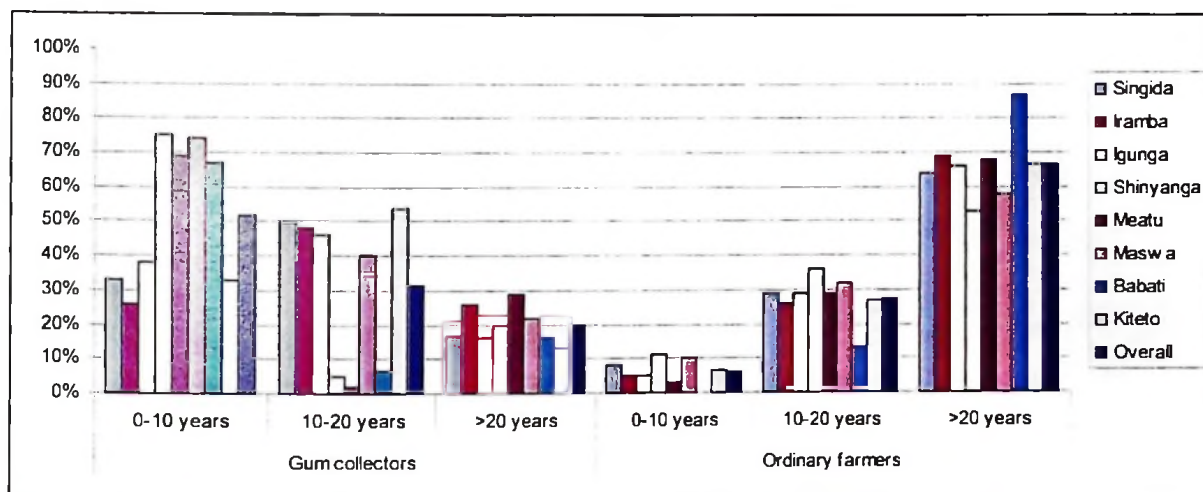


Figure 4.4 Comparison of permanence in the settlement between the gum and non-gum collecting populations.

As concluded by Arnold and Townson (1998), much of the involvement in labour intensive, low return activities by the rural poor is for income safety net motives but which decline once better alternatives become available.

Economic analysis carried out by Barbier (2000) in Sudan indicated that the relative profitability of gum compared to other crops was generally lower, suggesting that maintenance of the real producer price of gum by removing distortions in the market would be an economic incentive.

Gum middlemen

From the average price given to the middlemen by the final buyers and exporters of TSh 475,000 tonne⁻¹, the total annual income of all the gum middlemen could be computed as nearly TShs 2.0 billion:

$$4030 \text{ tonnes year}^{-1} * \text{TShs } 475,000 \text{ tonne}^{-1} = \text{TShs } 1,914,250,000 \text{ (US\$ } 2,015,000)$$

Final gum buyers and exporters

This is a group which seemed to benefit most from the gum activities. This is from the fact that none of them was ready to reveal the company's amounts traded and income flow. Using the world market price of TShs 807,500 (US\$ 850) tonne⁻¹ (FAO, 1995b), the total annual income earned by all the exporters could be calculated as:

$$4,030 \text{ tonnes year}^{-1} * \text{TShs } 807,500 \text{ tonne}^{-1} = \text{TShs } 3,254,225,000 \text{ (US\$ } 3,425,500)$$

The net incomes to these agents are shown in section 4.4.2.

Local and Central governments

The local and central governments earned some income through income taxation, issuing registration for forest products businesses and licenses. The registration fee for business in forest products during this study was TShs 30,000.00 per season (year), whereas licensees were to pay a revised fee of TShs 150.00 kg⁻¹ of gum traded (URT, 2001b). Between 1998 and 1999, the license fee was TShs 100.00 kg⁻¹.

The respective district councils were entitled to 10 % of the above collections with the balance taken by the central government. Tables 4.4, 4.5 and 4.6 below present annual revenues accrued from the gum activities. In Table 4.4 two sets of revenues are presented to compare the districts records with what was supposed to be collected, according to this

Table 4.4 Annual district actual and potential revenues from gum arabic activities in Tanzania

District	Annual gum arabic production (metric tons) and revenues (TShis)										Total
	Year	1994*	1995*	1996*	1997*	1998*	1999*	2000**	2001**	Tonnes	
Singida Rural	Recorded production	-	-	-	-	0.10	0.15	1.47	-	1.72	-
	Recorded revenue	-	-	-	-	10,000	15,000	220,710	-	-	279,293
Igunga	Actual production	-	-	-	-	789.97	709.20	592.97	520.08	2,612.22	-
	Corresponding revenue	-	-	-	-	78,997,000	70,920,000	59,297,000	78,012,000	326,393,159	-
Iramba	Recorded production	3.80	2.50	5.20	4.90	1.50	2.49	2.00	22.39	-	-
	Recorded revenue	380,000	250,000	520,000	490,000	150,000	249,000	300,000	4,248,253	-	-
Shinyanga Rural	Actual production	-	-	-	-	783.56	719.55	601.25	557.61	2,661.97	-
	Corresponding revenue	-	-	-	-	78,356,000	71,955,000	60,125,000	83,641,500	333,233,838	-
Meatu	Recorded production	-	-	-	-	-	-	-	-	-	-
	Recorded revenue	-	-	-	-	-	-	-	-	-	-
Maswa	Actual production	-	-	-	-	839.51	812.49	681.58	650.41	2,983.99	-
	Corresponding revenue	-	-	-	-	83,951,000	81,249,000	68,158,000	97,561,500	373,685,346	-
Babati	Recorded production	-	-	-	-	-	-	-	-	-	-
	Recorded revenue	-	-	-	-	-	-	-	-	-	-
Kiteto	Actual production	-	-	-	-	557.26	522.99	455.94	406.77	1,942.96	-
	Corresponding revenue	-	-	-	-	55,726,000	52,299,000	45,594,000	61,015,500	242,809,823	-
Maswa	Recorded production	-	-	-	-	-	-	-	-	-	-
	Recorded revenue	-	-	-	-	-	-	-	-	-	-
Babati	Actual production	-	-	-	-	1,110.53	1,027.61	917.06	866.81	3,922.01	-
	Corresponding revenue	-	-	-	-	111,053,000	102,761,000	91,706,000	130,021,500	491,531,585	-
Maswa	Recorded production	-	-	-	-	-	-	-	-	-	-
	Recorded revenue	-	-	-	-	-	-	-	-	-	-
Babati	Actual production	-	-	-	-	491.68	464.02	394.85	354.62	1,705.17	-
	Corresponding revenue	-	-	-	-	49,168,000	46,402,000	39,485,000	53,193,000	213,100,473	-
Kiteto	Recorded production	-	-	-	-	-	-	-	-	-	-
	Recorded revenue	-	-	-	-	-	-	-	-	-	-
Maswa	Actual production	-	-	-	-	29.25	30.55	24.70	24.05	108.55	-
	Corresponding revenue	-	-	-	-	2,925,000	3,055,000	2,470,000	3,607,500	13,585,134-	-
Kiteto	Recorded production	-	-	-	-	-	-	-	-	-	-
	Recorded revenue	-	-	-	-	-	-	-	-	-	-
Maswa	Actual production	-	-	-	-	36.60	35.40	31.20	31.20	134.40	-
	Corresponding revenue	-	-	-	-	3,660,000	3,540,000	3,120,000	4,680,000	16,872,906	-
Total	Recorded production	3.80	2.50	5.20	4.90	1.6	2.64	3.47	24.11	-	-
	Recorded revenue	380,000	250,000	520,000	490,000	150,000	264,000	520,500	4,512,137	-	-
Total	Actual production	-	-	-	-	4,577.63	4,278.14	3,655.57	3,364.25	15,875.59	-
	Corresponding revenue	-	-	-	-	457,763,000	427,814,000	365,557,000	336,425,000	1,818,220,005	-

*The license fee was TShs 100.00 kg⁻¹, ** the license fee was TShs 150.00 kg⁻¹. Source: Respective District Councils (2001)⁴ = Present Value adjusted of annual revenues at year 2001.

study. Table 4.5 gives the actual revenues recorded by the central government, whereas, Table 4.6 details data in Table 4.5 and gives further information on the potential of gum arabic to the economy in Tanzania. It is evident that the gum is underrated as a contributor to the local and national economy and therefore only a fraction of its production is included. It would therefore be undisputed to suggest that the bulk of the gum traded is unrecorded.

Table 4.5 Contribution of gum arabic to the National economy of Tanzania between January 1998 – May 2001

Year	Gum exports (Metric tonnes)	Total gum values		Average gum values tonne ⁻¹	
		US \$	TShs ^b	US \$	TShs ^b
1998	943.24	327,658	219,530,860	347.38	232,745
1999	869.96	481,725	349,251,350	553.73	401,454
2000	910.23	451,300	363,296,500	495.81	399,127
2001 ^a	246.75	101,814	96,723,300	412.62	391,989
Total	2,970.18	1,362,497	1,028,802,010	458.73	435,789

^a Data available for period January – May 2001 only. ^b Converted using an exchange rate of TShs 670, TShs 725, TShs 805 and TShs 950 US\$⁻¹ for 1998, 1999, 2000 and 2001 respectively (Fx Converter, 2003). Source: Adopted and modified from URT (2001a).

Table 4.6 Summary of actual and potential contribution of gum arabic to the economy of Tanzania

Main markets for Tanzania's gum arabic during 1998 - 2001				Annual marketed estimates							
Country	Consumption (%)	Price tonne ⁻¹ (US \$)	Current official pattern (a)			Actual existing pattern (b)		Potential pattern under grading (c)			
			Quantity (tonnes)	Revenue (US \$)	Quantity (tonnes)	Revenue (US \$)	Grade ^a	%	Quantity (tonnes)	Price tonne ⁻¹ (US \$) ^b	Revenue (US \$)
India	77.98	419.9	709.6	297,971.8	3,142.6	1,319,575.2	I	34	1,370.2	3,500	4,795,700
Pakistan	18.34	587.9	166.9	98,100.4	739.1	434,518.1	II	65	2,619.5	850	2,226,575
Oman	0.04	546.9	0.4	217.1	1.6	881.6	III	I	40.3	n.a	n.a
Yemen	0.67	210.3	6.1	1,283.9	27.0	5,678.3	IV	n.a	n.a	n.a	n.a
U. A. Emirates	0.60	374.6	5.5	2,058.6	24.2	9,057.8					
France	0.27	892.3	2.5	2,193.3	10.9	9,709.1					
United Kingdom	0.64	640.8	5.8	3,742.9	25.8	16,527.5					
United States	0.60	976.7	5.5	5,368.2	24.2	23,616.6					
Kenya	0.10	152.0	0.9	139.2	4.0	612.6					
Egypt	0.67	757.8	6.1	4,627.5	27.0	20,461.4					
D. Rep. Congo	0.08	459.9	0.7	325.8	3.2	1,482.7					
Subsistence use	-	-	23.0	0	0	0					
Total	100.0	X = 458.7^c	910.0	416,028.8	4,030	1,842,120.9		100	4,030	1,742	7,022,275
Unofficial (b - a)			3,180 tonnes US \$ 1,426,092.1								

^a only grades I and II are exported in the potential pattern under grading (c), ^b Source: FAO (1995b), ^c Weighted mean price calculated as a dividend of the total revenue and gum quantity in the current pattern (a).

Table 4.6 above, presents a summary of actual and potential contribution of gum arabic to the economy of Tanzania. The top left quadrant is a mean annual market for the gum for the export markets, calculated for a period between 1998 and 2001, whose information was extracted from Table 4.5 and Chapter V Section 5.4.1.5. The amount of gum used for subsistence has been estimated from the population of collectors (22,870), each consuming about 1 kg in a year. The middle left quadrant (a) presents the current official pattern of the Tanzania's gum markets, also extracted from Table 4.5 and Section 5.4.1.5 whereas, quadrant (b) presents the actual existing pattern obtained as products from the country's gum production survey presented in Chapter III, in Table 3.2 and the market consumption and prices in the top left quadrant for the respective country of destination.

The top right quadrant (c) presents potential pattern under grading, whose grade percentages were extracted from Chapter III in Figure 3.9 and quantities calculated from the percentages and the quantities in (b).

The table shows that the country's gum arabic industry had never been fully tapped, as only 22.6 % of the actual existing market potentials (b) calculated in Chapter III and presented in Table 3.2, was officially recognized under the current pattern (a). In the current pattern (a), the annual mean revenue was about US\$ 416,000 only instead of the actual existing potential revenue of about US\$ 1,842,100. The balance of the existing potentials, which is US\$ 1,426,092, was not registered, however, benefiting only the middlemen and the final buyers and exporters.

Further analysis of the table shows that the actual existing pattern (b) could be much more improved if the gum was processed and graded before being exported. This is shown in the pattern (c) that the revenues could be raised about 17 fold. By this token, the revenues in the current pattern (a) could also be improved 3.8 fold from about US\$ 416,000 to 1,585,675 if grading occurred. So basically, the gum is being sold as if it is all grade II or below. Even the higher payers, may be paying a low price since they have to sort themselves and do not know what proportion of good material they will get. However, the likelihood is, that the only importers likely to accept low quality unsorted material will be ethnic and non-food industrial users.

Nevertheless, to do grading would probably involve moving away from traditional trading patterns so that higher prices could be obtained in markets for more sophisticated uses of gum.

In 910 tonnes sold, there are about 300 tonnes of grade I gum, at US\$ 3,500 tonne⁻¹, the business could make the same revenue (US\$ 416,000) by selling about 120 tonnes. Thus collectors could collect 13 % of amount of total gum or 40 % of grade I gum and still get the same money.

The improvements to the revenues under (c) could generate at most 17.7 % of the revenues accrued in the gum arabic trade in Sudan.

The importance of gum arabic was grossly underrated in the country, as the bulk of the gum traded was not contributing to the country's official economic statistics, as depicted by Table 4.6. In Sudan, gum arabic is second ranked export commodity and hard currency earner reported by Nour (1999) to range from US\$ 36,783,204 to 78,791,426 year⁻¹ between 1979 and 1991. According to FAO (1983), Beshai (1984), Barbier (1990), Nour (1999) and Timberlake *et al.* (1999), these incomes contributed between 10 and 18 % of Sudan's foreign exchange earnings from total export proceeds.

4.4.1.3 Employment opportunities provided by the gum activities

The study in Chapter III estimated that there were 22,870 gum collectors in the country, comprising of 15,501 females and 7,369 males. From evidence in this Chapter, there appeared to be about 100 workers, mostly women, employed by the final buyers and exporters to do preliminary processing of gum in Dar Es Salaam. The employment was for three months a year during which they were paid the National minimum wage of TShs 43,000 month⁻¹. These, together with the middlemen and the exporters, made a population of around 23,000 in the whole chain of gum arabic production and trade.

The above results indicate that MLNRT (1989) under-estimated that 25,000 Tanzanians were engaged in activities in NWFPs, since gum is only a small element of such activities.

Further, the local use of the gum in Tanzania is at a household subsistence level; no factory in the country uses the Tanzanian gum. As Leung (1980) found, processed food makes use of gum arabic, so the food and beverage industry of Tanzania, for instance, could be employing the locally available raw materials.

Currently, Tanzania Breweries imports foam stabilizers from Japan under the trade name of Profoam, spending TShs 16,248 (US\$ 17.1) kg^{-1} . This product is scientifically known as Propane-1,2-diol alginate (Propylene glycol alginate) that fulfills the requirements of Kosher, FAO/WHO, FCC and EEC no. 78/663 food additives. Home produced gum arabic from the country could substitute for this import.

The consumption rate of the stabilizer is 4 gm Hlitre⁻¹ of beer produced, the company produces an average of 1.5 m Hlitre year⁻¹ and the amount of the beer foam stabilizer consumed annually by the TBL is therefore 6 tonnes which is valued at TShs 97,488,000 (US\$ 102,620).

The country's second beer producer is Kibo Breweries Limited (KBL) which produces an average beer volume of 0.5 m Hlitres year⁻¹. The company was importing its stabilizers from the Republic of Ireland. Using the above equations, the quantity and value of the import is 2 tonnes and TShs 32,496,000 (US\$ 34,206) respectively.

4.4.2 Economics of extractivism in gum arabic

4.4.2.1 Gum collectors

Costs, income generated and analysis of profitability

The costs, income generated and analysis of profitability for a gum collector are presented in Table 4.7 below. Only labour was considered for the costs involved by

the collectors of gum since there were no other requirements other than a freely obtained stick. The minimum wage for a Tanzanian worker during the study was TShs 43,000, but, since the collection of gum was not the main activity and was concentrated on only few hours of a day, the collector's labour was estimated at TShs 10,750 month⁻¹ head⁻¹, a quarter of this.

The labour cost head⁻¹ during the season (4 months) was henceforth estimated as:

$$\text{TShs } 43,000 \text{ month}^{-1} \text{ head}^{-1} \cdot 0.25 \text{ effective time} \cdot 4 \text{ months season}^{-1} = \text{TShs } 43,000 \text{ head}^{-1} \text{ season}^{-1}$$

The mean production of gum arabic head⁻¹ season⁻¹ in Tanzania was estimated in Chapter III as 177.3 ± 88.3 kg, the labour cost for gum collection kg⁻¹ could therefore be calculated as:

$$\text{TShs } 43,000 \text{ head}^{-1} \text{ season}^{-1} / 177.3 \text{ kg head}^{-1} \text{ season}^{-1} = \text{TShs } 242.53 \text{ kg}^{-1}$$

The revenue accrued by a gum collector season⁻¹ was calculated as a product of the gum price of TShs 304.05 kg⁻¹ and the gum collection of 177.3 kg season⁻¹, as TShs 53,908.07 ± 26,847.62.

If the labour cost element is considered, the profitability of gum collection becomes only TShs 10,908.07 person⁻¹ season⁻¹. Gum collection is a secondary occupation to all of the people engaged in the business which is undertaken to supplement incomes (Arnold and Townson, 1998). Therefore, its contribution to the livelihoods depends upon what the collectors' other activities are (see this on Section 4.4.1.2 above). However, it is likely to provide an important supplement to incomes (and possibly diet) during difficult times.

Table 4.7 Summary of costs, revenue and profitability involved in the trade of gum arabic by collectors in Tanzania

No.	Description	Amount (TShs)	
		kg ⁻¹	collector ⁻¹
1.	Labour cost for the time spent collecting gum	242.53	43,000.00
2.	Revenue, from sale of gum	304.05	53,908.07
3.	Total profit/gain	61.52	10,908.07

4.4.2.2 Gum middlemen

Costs, income generated and analysis of profitability

Table 4.8 and 4.9 below summarize the costs incurred by the middlemen and final buyers and exporters respectively, in Tanzania in the trade in gum arabic, as derived from this study.

The cost for the middleman's time was estimated as TShs 86,000 head⁻¹ month⁻¹, being higher than that of a collector as it involves a management type role, so a government official's rate has been considered for the middleman.

The labour cost head⁻¹ during the period could be estimated as

$$\text{TShs } 86,000 \text{ month}^{-1} * 4 \text{ months}^{-1} \text{ season}^{-1} = \text{TShs } 344,000.$$

The gum production per head during the season was estimated as:

$$4,030,000 \text{ kg season}^{-1} / 8 \text{ middlemen} = 503,750 \text{ kg}$$

The labour cost for aggregating gum kg⁻¹ could therefore be calculated as:

$$\text{TShs } 344,000 \text{ head}^{-1} \text{ season}^{-1} / 503,750 \text{ kg head}^{-1} \text{ season}^{-1} = \text{TShs } 0.68 \text{ kg}^{-1}$$

Table 4.8 Summary of costs, revenue and profitability involved in the trade of gum arabic by middlemen in Tanzania

No.	Cost item	Description	Amount (TShs kg ⁻¹)
1.	Registration fee	Annual fee of TShs 30,000 payable to the central government by a licensee in order to engage in any business in forest products. The mean gum production per middleman is 500,000 kg.	0.06
2.	License	Fee payable to the local government the amount which depends on the amount of gum collected.	150.00
3.	Gum purchase	Buying gum from individual gum collectors.	304.05
4.	Gum processing	Cleaning and grading	
		- Preliminary cleaning	2.00
		- Further sorting and grading*	4.00
5.	Packaging	Purchase of gunny bags each at TShs 400 and each has capacity of 100 kg.	4.00
6.	Labour	Cost for the time spent in the gum activities	0.68
7.	Transport	Costs involved in transport from when gathering the gum from the collectors to procurement by the exporters	
		- Gum gathering	2.85
		- Loading and unloading	1.00
		Total Costs	468.64
		Total Revenue	475.00
	Profit margin	With all the costs above	6.36
		With all costs except license	156.36
		Without grading	10.36
		Without grading and license	160.36

* Usually not done

Four cost options which would most likely to have been in use were employed to gauge the profitability of the business as described below:

Cost 1 All of the above cost items were involved, making the equation

$$C_1 = 30,000 + 468,580Q$$

Cost 2 All of the above cost items were involved except payment of taxes in form of license,

$$C_2 = 30,000 + 318,580Q$$

Cost 3 The gum is sold unprocessed on the middleman's site, only the preliminary cleaning (winnowing) is conducted therefore avoiding costs of further sorting and grading,

$$C_3 = 30,000 + 464,580Q$$

Cost 4 All of the cost items in C_3 were involved, except payment of taxes in form of license,

$$C_4 = 30,000 + 314,580Q$$

Where: C = Total costs involved, in TShs metric tonne⁻¹

Q = Amount of gum involved, in metric tonnes.

From the survey conducted with the gum arabic middlemen and final buyers and exporters, the mean gum price offered to the middlemen was calculated as TShs 475,000 metric tonne⁻¹. The income generated by the business was therefore,

$$I_1 = 475,000Q$$

Where: I_1 = Total income by the middlemen from sale of Q tonnes of gum, in TShs,

The profitability of the different cost options can be seen in Table 4.8. The analysis suggests that C_1 starts realizing a net profit when the sale is 4.7 tonnes. At this amount of gum sold, the profit obtained is TShs 174 tonne⁻¹. C_2 and C_4 start making net profits with sales of gum of 0.2 tonnes at which Tshs 1,284 and 2,084 is collected respectively. With C_3 , the middlemen realize a net profit of TShs 218 when the amount of gum traded is 2.9 tonnes.

The above results suggest that the gum middlemen are making profit from the business with any of the cost options used, but C_4 and C_2 being the most profitable and C_1 the least profitable option.

4.4.2.3 Gum final buyers and exporters

Costs, income generated and analysis of profitability

It is assumed that the final buyer and exporter of gum would incur all the expenses involved in gum procurement from the middleman to Dar Es Salaam and processing before exports are made as this is the actual state of affairs, shown in Table 4.9. The cost of TSh 87,210 (US\$ 91.75) tonne⁻¹ as a fee paid to the Customs Department for exports (URT, 2001a) has been calculated as 20 % of the average value of gum per tonne as depicted in Table 4.5 and 4.6 above, i.e.,

$$\text{TShs } 436,050 * 0.2 (\text{US\$ } 458.73 * 0.20) = \text{TShs } 87,210 (\text{US\$ } 91.75)$$

The labour cost incurred by the final buyers and exporters was estimated as TShs 1,000,000 head⁻¹ season⁻¹, calculated from the estimated wage of TShs 250,000 month⁻¹, being an official wage for a director's position. The labour cost head⁻¹ during the period could be estimated as:

$$\text{Tshs } 250,000 \text{ month}^{-1} * 4 \text{ months season}^{-1} = \text{TSh}1,000,000 \text{ head}^{-1}\text{season}^{-1}$$

The gum production per head during the season was estimated as:

$$4,030,000 \text{ kg season}^{-1} / 3 \text{ final buyers and exporters} = 1,343,333 \text{ kg}$$

The labour cost for the final buyer and exporter kg⁻¹ could therefore be calculated as:

$$\text{TShs } 1,000,000 \text{ head}^{-1} \text{ season}^{-1} / 1,343,333 \text{ kg head}^{-1} \text{ season}^{-1} = \text{TShs } 0.75 \text{ kg}^{-1}$$

The cost incurred by the final buyers and exporters of gum tonne⁻¹ therefore is C₅ which is,

$$C_5 = 30,000 + 589,060Q$$

Table 4.9 Summary of costs involved in the trade of gum arabic by final buyers and exporters in Tanzania

No.	Cost item	Description	Amount (TShs kg ⁻¹)
1.	Registration fee	Annual fee of TShs 30,000 payable to the central government by a licensee in order to engage in any business in forest products. The mean gum production per exporter is 1,343,000 kg.	0.02
2.	Gum purchase	Buying gum from middlemen.	475.00
3.	Gum processing	Cleaning and grading	
		- Preliminary cleaning	2.00
		- Further sorting and grading*	4.00
4.	Labour	Cost for the time spent in the gum activities	0.75
5.	Transport	Costs involved in transport from when procuring the gum from the middlemen to the port of export	
		- Gum hauling by truck to Dar Es Salaam	32.20
		- Gum hauling by train to Dar Es Salaam	20.00
		- Average hauling costs (truck and train)	26.10
		- Loading and unloading	2.00
		- Total costs (average hauling + load. and unloading)	28.10
8.	Exportation fee		87.21
		Total costs	593.08
	Total revenue	Under official pattern (URT, 2001a)	436.05
		As gum talha (FAO, 1995b)	807.50
		Under official pattern with all other costs	-157.03
	Profit margin	Under official pattern without export. fee	-69.82
		As gum talha with all other costs	214.42
		As gum talha without exportation fee	301.63

* Usually not done

Since the final buyers and exporters of gum in Tanzania declined to give information on the revenues accrued from the business, two price regimes were tested in this analysis: The weighted mean price of TShs 436,050 tonne⁻¹ during 1998 and 2001 indicated in the URT (2001a) statistics for Tanzania's gum arabic exports (see Table 4.5 and 4.6), and it was assumed that the world market price is TShs 807,500 (US\$ 850) tonne⁻¹ FOB Dar Es Salaam port. This has been adopted from FAO (1995b) for the price of Sudan's standard clean gum talha, the characteristic of the bulk of gum from Tanzania (Adamson and Bell, 1974; Robbins, 1987; Chikamai and Banks, 1993; Kilahama, 1994).

$$I_2 = \text{TShs } 436,050Q$$

$$I_3 = \text{TShs } 807,500Q$$

Where: I_2 and I_3 = Total income earned by the final buyers and exporters from sale of Q tonnes of gum, using TShs 436.05 and 807.50 kg^{-1} respectively, in TShs.

From the analysis of the above transactions shown in Table 4.9, it is evident that the official price leading to I_2 is associated with net losses to final buyers and exporters even if the taxes are evaded. However, when using the Sudan's gum talha price (I_3) the exporter starts making a net profit at above 0.1 tonnes, with TShs 13,688 tonne^{-1} at 0.2 tonnes. At this price, the profitability for exporters starts at above 0.1 tonnes even if the exportation fee is not evaded.

The above findings strongly conform to and confirm the following observations made in the country:

- The gum was being traded unprocessed and mostly bought at the middlemen's sites to maximize the margin for profit. Other processing costs (cleaning, sorting, etc.) therefore were borne by the final buyers and exporters and license fee evaded (Refer C_4 above) as local government records suggest little tax revenue (see Table 4.4). The final buyers and exporters, nevertheless, did not carry out any further processing apart from winnowing and limited sorting.
- The margins for profit, particularly for the collectors and middlemen (Table 4.7 and 4.8), were small. However, for the middlemen the margin improved as the amount of gum traded was increased. The profitability of the business to the middlemen would depend, therefore, upon the amount of gum traded.
- The preference for gum by the final buyers and exporters is that from around Shinyanga since transport costs were reduced through hauling by rail.
- The bulk of the gum was being traded unrecorded to avoid payment of the royalty to the local governments and also the exportation fee. This was being done by under-recording the amounts of gum in the transaction (Table 3.3 in Chapter III, Tables 4.4 and 4.6) or transporting the cargo in the name of other products (for example agricultural crops like maize and rice) which incurred little or no levy.

- The gum trading business was relatively financially capital intensive, therefore only a few individuals could profitably engage in that arena. It was observed that all the middlemen were running other businesses including retail shops, petrol stations and transport services and the exporters owned several enterprises including transnational companies.
- The difference between the reported and surveyed production figures for the country's gum arabic suggests a high likelihood that the bulk of the gum was being smuggled to neighbouring countries in which there were better prices, avoiding payment of export levies.
- The gum collector bears the burden of all economic shocks in the whole chain since it is unlikely for the exporter to be squeezed if export price is lower than expected.

4.4.3 Economic analysis of a gum arabic plantation

4.4.3.1 Introduction

As far as gum availability and its contribution to the economy of the stakeholders are concerned, the following problems are evident from the observations made in the previous and also in this chapter:

There is a high variability of gum production in the country because of among other reasons, variability in the gum sources and the operating conditions such as price, weather conditions and availability of gum trees as the country's gum resources are being depleted. Another major problem is the high production of poor quality gum arabic since collection is done haphazardly on a range of botanic sources. The collectors are therefore getting low returns from the gum activities which is a disincentive for further development of the gum industry in Tanzania. As a result, the product is not capturing the potential contribution to the economy.

Embarking on *Acacia senegal* plantations as source of gum arabic might provide solutions to the above listed problems, however, this is only possible if the farmers and the buyers are motivated to high quality gum production. In Sudan, for instance, Barbier (1992) noted that essential investments by farmers in cultivating gum would

depend on its real producer price being maintained and other incentives determining the relative profitability of gum.

The plantations are capable of giving more regular, stable and quality products because the gum will be collected from a single and homogeneous botanic origin, advocated by FAO (1990a, 1999). They are also potential for maintaining and even increasing reserves of gum arabic resources and allowing improvement of the stock.

Furthermore, the cultivated *A. senegal* have the potential of giving better returns to collectors if they were the cultivators because of the more regular, stable and higher quality gum. Also, gum collecting activities will be less difficult since the trees are confined so also less distance will be traveled to collect. Lastly, it is expected that the export price and export revenues will be raised as a consequences of the above improvement in the gum arabic production and trade.

4.4.3.2 The model

A model was constructed to assess the potential of plantations or on farm cultivation of *Acacia senegal* by individual farmers as a source of gum arabic. The figures used in the model were derived as follows:

The proposed plantations would be sited in villages on individual's farmlands for at least one crop rotation. From this study, it was noted that land could be rented with payment made in kind, the most common payment being two 100 kg bags of maize, millet or sorghum $\text{ha}^{-1} \text{ year}^{-1}$. Thus, the opportunity cost of the land occupied by the plantation was estimated as TShs 3,000, since the price of grain was approximately TShs 15 kg^{-1} .

The cost for raising *Acacia senegal* in the nursery was TShs 50 seedling⁻¹ (NTSP, 2001 personal communication), with a recommended stem density of 625 ha^{-1} (FAO, 1983), the total nursery cost would therefore be estimated as TShs 31,250 ha^{-1} . With that density, planting out would be on a spacing of 4 m x 4 m (Baumer, 1983), allowing for intercropping with millet, sorghum or maize in the first five years.

The land productivity for millet and sorghum was estimated by Kilahama (1994) to be seven bags ha^{-1} (700 kg) around Shinyanga. In the current study, it was assumed that this productivity would decline with time as the trees grow, due to competition for growth resources and shading effect. A shade factor of 0.03 for *Acacia senegal* was employed between years (Bright, 2003), making intercropping impossible beyond year 5 as depicted in Figure 4.5 below. The unshaded area ratio was calculated as:

$$[1 - (\text{crown area}/\text{spacing}) * \text{shade factor}].$$

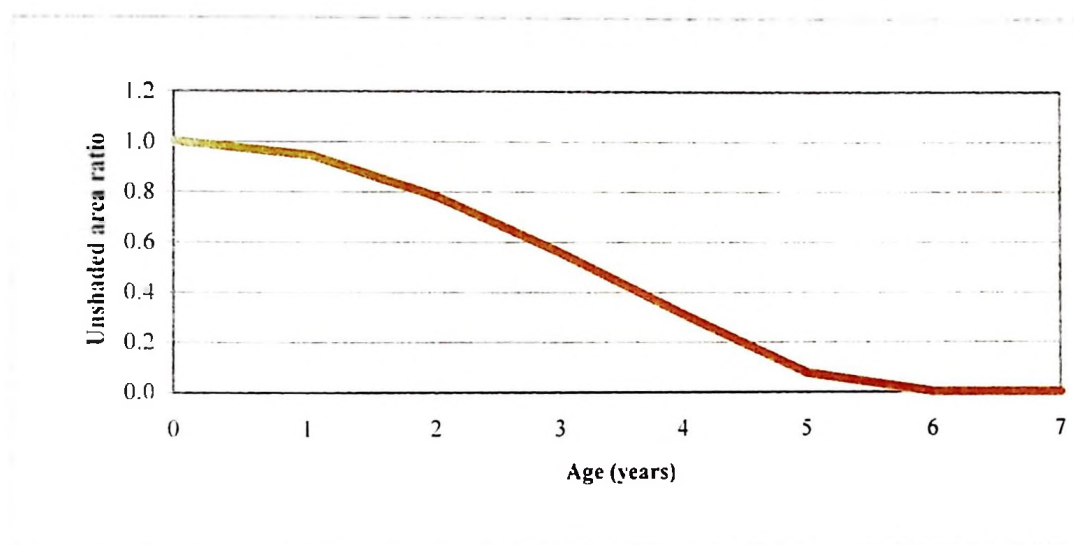


Figure 4.5 Estimating base crop unshaded area from *Acacia senegal* tree age

Since young *Acacia senegal* plants are susceptible to fire and animal damage (NAS, 1980; Doran *et al.*, 1983), it is important to protect the crop against these calamities. This can be done by weeding, fencing, making firebreaks and patrolling. Baumer (1983) however, pointed out that the plants could do well without weeding after two years. Weeding, therefore, has been considered only for the first two years. Weeding costs TShs 15,000 ha^{-1} , whereas the rest of the other forms of protection altogether cost TShs 5,000 ha^{-1} .

Gum tapping in planted *A. senegal* commences when the trees are five years old (Siddig, 1991) and the production is only sustainable to 15 – 18 years (Dale and Greenway, 1961; FAO, 1983; Weber and Stoney, 1986.). In the current study, the productivity of the plantation was assessed for a period of 50 years to be able to recommend an optimum rotation age.

After attaining an optimum age, the plantation is clear felled for wood and timber, whose annual production has been estimated by adopting and modifying Sheriff's (1998) volume equation for *Acacia mearnsii*, derived as follows:

$$\text{Diameter at age } x = [(\text{basal area/number of trees}) * (40,000/\pi)]^{0.5}$$

While,

$$\text{basal area} = b_1 \times (1 - e^{(b_2 \times \text{Age})})^{b_3}$$

Volume = basal area * height, where,

$$\text{height} = b_4 \times (1 - e^{(b_5 \times \text{Age})})^{b_6}$$

Where b_1, b_2, \dots, b_6 are constants.

These equations were adjusted to meet the current study's conditions by determining height as a function of diameter and relating the two to age. Regression analysis of tree diameter against height gave the following:

$$\text{Ht} = 1.539 + 0.235 \text{ Dbh} + 0.00454 \text{ Dbh}^2$$

$$\text{s.e. } (0.081)^* \quad (0.019)^{**} \quad (0.001)^{**}$$

Where: Ht = Estimated height of *Acacia senegal* tree,

Dbh = Diameter of *A. senegal*.

The above equation was statistically highly significant at the 1 % level with $F = 698.13$ and an R^2 of 0.56. Applying this equation, a plot of height against age could be developed, as shown in Figure 4.6 below.

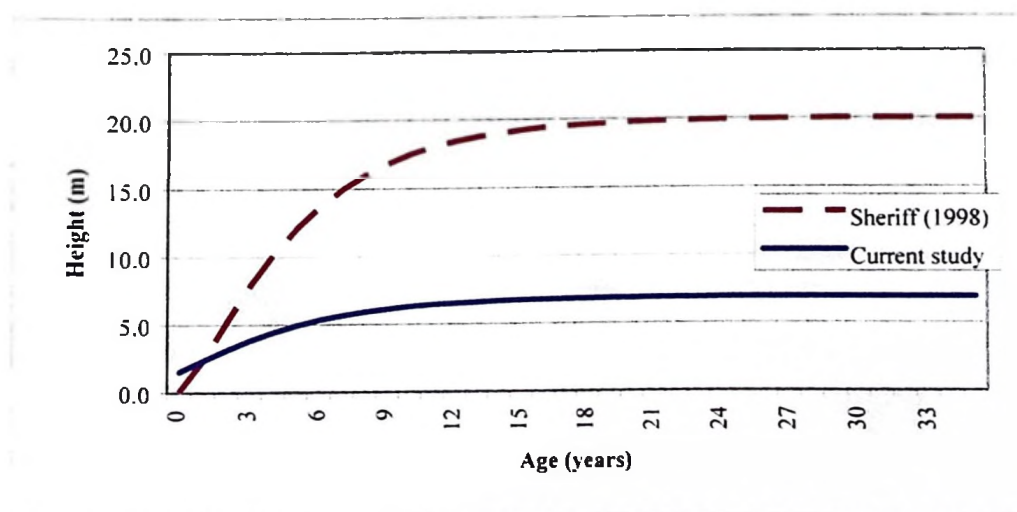


Figure 4.6 Estimation of *Acacia senegal* tree height from age

In the model developed by Sheriff (1998), the *A. mearnsii* trees had diameters ranging from 3.3 cm for age 1 to 17.1 cm for trees aged 22 onwards. In the current study, Sheriff's diameter-age equation was adjusted to more closely reflect the values obtained for *A. senegal* trees in this study, using the equation below:

$$Dbh = j * [b_1 * (1 - e^{(b_2 * Age^x)})^{b_3} * spacing^2 * 4/\pi]^{0.5}$$

Where: Dbh = Estimated diameter for *Acacia senegal* trees at age x ,
 j = A factor of 0.7 for diameter adjustment,
 b_1, b_2, b_3 = Constants.

Figure 4.7 below shows diameter prediction from age.

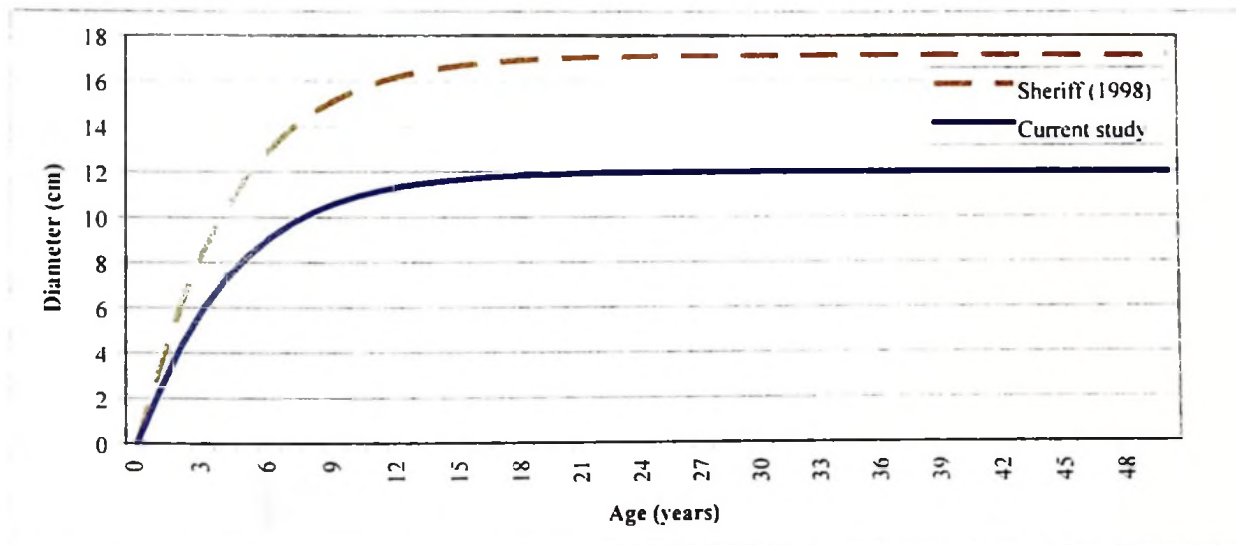


Figure 4.7 Estimation of *Acacia senegal* tree diameter from age

The tree volume is calculated using the equation:

$$V = 0.785 * Dbh^2 * Ht$$

Where: V = Volume of wood, in $m^3 \text{ tree}^{-1}$,
 Dbh = Diameter of tree at breast height (1.3 m),
 Ht = Height of tree, in m.

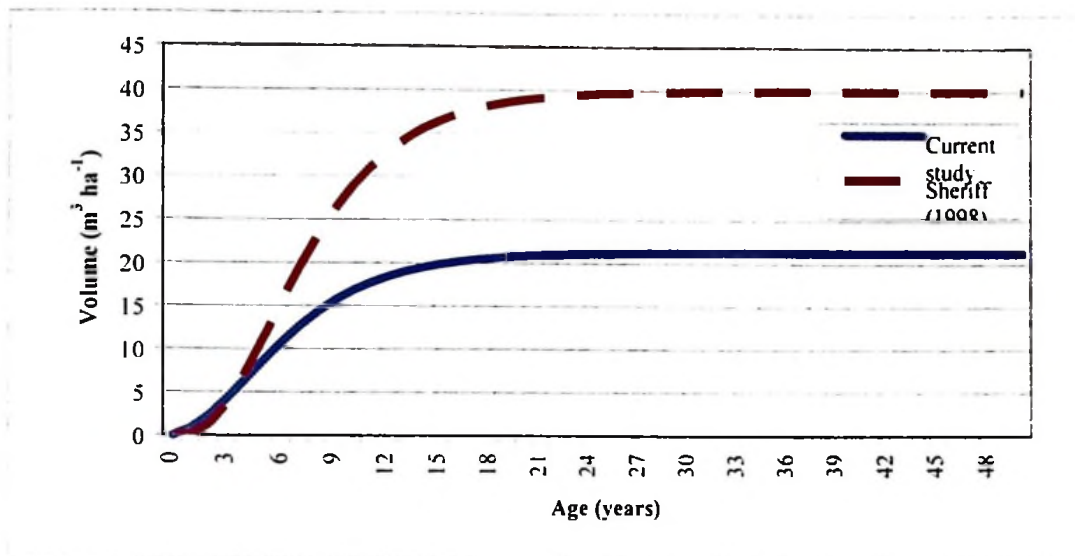


Figure 4.8 Estimating *Acacia senegal* wood volume from tree age

The tree stem taper was not considered in the volume calculation since the whole tree, branches and twigs inclusive, would be used for wood therefore compensating for what would have been lost when only using the main stem. Although effectively using a form factor of 1.0 here to compensate for twig and branch volume seems reasonable, no reference to work on whole tree volume could be found elsewhere.

Results indicate that the wood volume of *A. senegal* effectively plateaus at $22 \text{ m}^3 \text{ ha}^{-1}$ when the trees are about 20 years old (Figure 4.8). These results agree with observations made by Siddig (1991) for 18 year old *A. senegal* trees in Sudan.

Hunting Technical Services (1964) estimated that one person could tap up to 100 trees day^{-1} , as the following relationship was used to determine the number of days required in the tapping operations:

$$625 \text{ trees ha}^{-1} \cdot 100 \text{ trees day}^{-1} = 6.25 \text{ days ha}^{-1}$$

Since tapping would be done in four cycles per year (season), the total number of days required becomes 25 i.e one month, hence the opportunity cost of labour-time spent in tapping is TShs 43,000 for trees reaching maximum gum yield i.e age 12 (Figure 4.9). Below this age, the costs were estimated to decline by 20 % with a decline in age by a year, as gum production would also be declining by 20 % (also see Table 4.11).

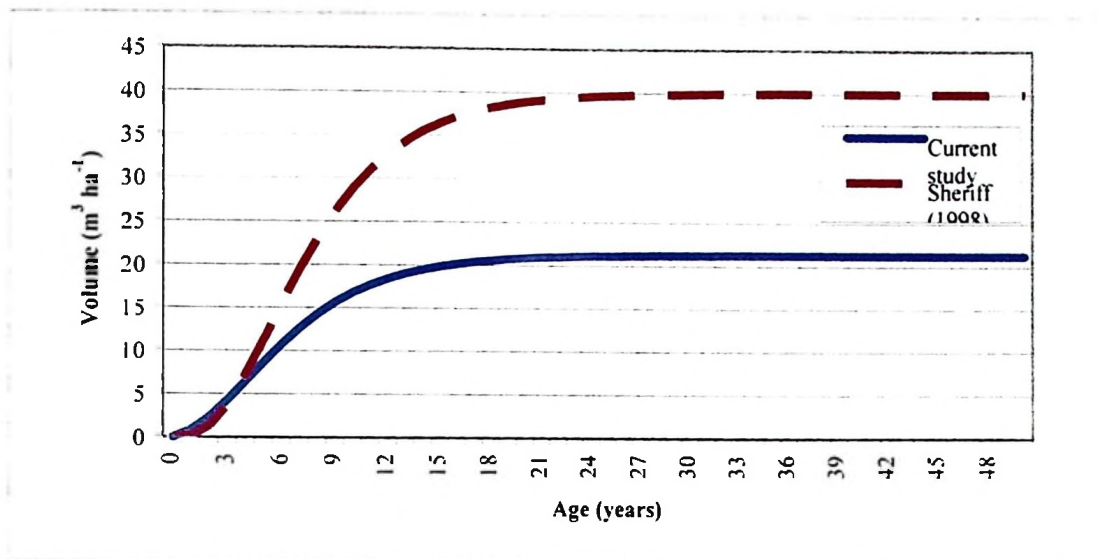


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The tree stem taper was not considered in the volume calculation since the whole tree, branches and twigs inclusive, would be used for wood therefore compensating for what would have been lost when only using the main stem. Although effectively using a form factor of 1.0 here to compensate for twig and branch volume seems reasonable, no reference to work on whole tree volume could be found elsewhere.

Results indicate that the wood volume of *A. senegal* effectively plateaus at 22 m⁻³ ha⁻¹ when the trees are about 20 years old (Figure 4.8). These results agree with observations made by Siddig (1991) for 18 year old *A. senegal* trees in Sudan.

Hunting Technical Services (1964) estimated that one person could tap up to 100 trees day⁻¹, as the following relationship was used to determine the number of days required in the tapping operations:

$$625 \text{ trees ha}^{-1} * 100 \text{ trees day}^{-1} = 6.25 \text{ days ha}^{-1}$$

Since tapping would be done in four cycles per year (season), the total number of days required becomes 25 i.e one month, hence the opportunity cost of labour-time spent in tapping is TShs 43,000 for trees reaching maximum gum yield i.e age 12 (Figure 4.9). Below this age, the costs were estimated to decline by 20 % with a decline in age by a year, as gum production would also be declining by 20 % (also see Table 4.11).

It was estimated that clear felling fully grown trees would require 15 person-days ha⁻¹, i.e Tshs 21,500. From Figure 4.9 and Table 4.11, it is evident that trees would reach a gum yield plateau at age 12 years, below this age, the gum tapping costs were estimated to decline by 20 % with a decline in age by a year.

From this study, the mean yield of gum was estimated from the tree diameter using the following equation derived in Chapter II.

$$Y = 0.000032 \cdot \exp^{-0.94Dbh} \cdot Dbh^{11.17}$$

Where: Y = Gum yield tree⁻¹,
 Dbh = Diameter of tree at breast height (1.3 m),

Combining this data with the diameter-age equation on page 195, Figure 4.9 below presents gum yield ha⁻¹ trends with age. The yield plateaus shortly after 10 years due to the slow growth in dbh beyond that point, and the consequent low degree of movement on the dbh : yield curve.

It was observed that pure gum from *A. senegal* would fetch a price of TShs 500 kg⁻¹ for the collector (occasional orders for the Asian community use), and in an annual report prepared by the Igunga District Council (2001) it was documented that the price for fuelwood was TShs 4,500 m⁻³.

All costs and revenues were adjusted to year 2001 values using inflation rates shown in Chapter III. A discount rate of 10 %, was used the rate that is advocated by most of the international financial institutions for the developing countries (Yost and Carreiro, 1999). The World Bank for instance, does not generally accept projects for financing with IRR less than 10 % (Adler, 1987) presumably an estimate of the rates of return generally available (Price, 1993).

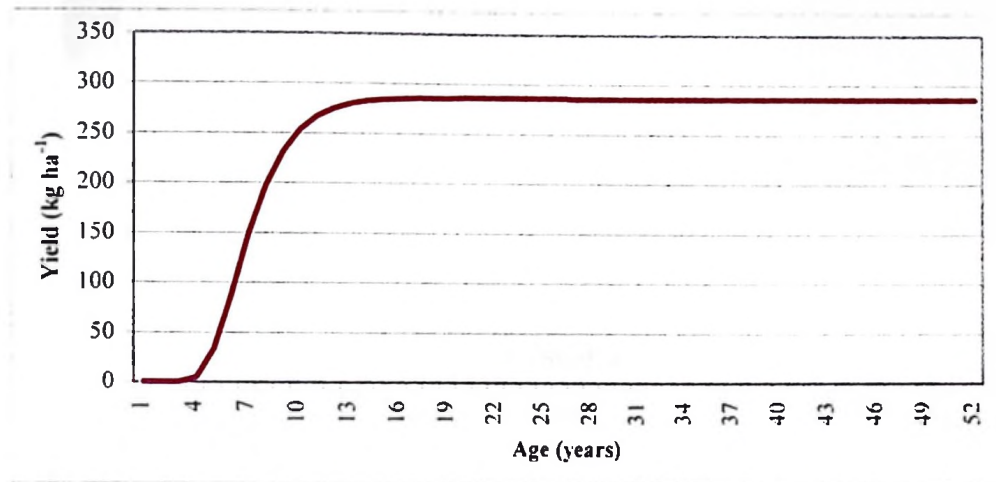


Figure 4.9 Estimation of gum arabic yield from tree age

Table 4.11 (also see Appendix VIII, Table 1) shows the cash flows for both crops and trees (gum and wood) for each year of the lifetime of the proposed plantation as well as the discounted measures of project worth, namely Net Present Value (NPV) and Land Expectation Value (LEV).

$$NPV = \sum_{t=0}^n \frac{B_t - C_t}{(1+r)^t}$$

Where:

- B = benefit in a particular year,
- C = cost in a particular year,
- t = time in years,
- r = discount rate, and
- n = rotation length in years.

In order to be able to compare rotations of different lengths, LEV should be used (Price, 1989).

$$LEV = NPV \cdot \frac{(1+r)^n}{(1+r)^n - 1}$$

The model indicates that the project is profitable with a maximum Net Present Value (NPV) of TShs 570,209 in year 26, a maximum Land Expectation Value of TShs 814,529 in year 9 and a high Internal Rate of Return (IRR) of 63 % at this age.

Given the assumptions and at this discount rate therefore, the optimum rotation age of *Acacia senegal* gum plantation is 9 years. Further analysis indicated that changing the discount rate does not affect the rotation age much. Between 15 to 20 % for instance, the rotation age is lowered by one year only to become 8 years and at 25 %, the rotation age is 7 years. The model nevertheless, is more sensitive to gum prices, lowering the price to TShs 200 kg⁻¹ for instance, the rotation age is reduced by two years with an IRR of 54 %. At TShs 600, TShs 700 and TShs 800 kg⁻¹, the age is 10, 11 and 13 years with IRR of 66 %, 68 % and 70 % respectively.

The effect of price of wood on the rotation age showed a reverse of the behaviour portrayed by the effect of the gum prices. Reducing the price to TShs 2,000 m⁻³, results in elongating the age to 18 years with IRR of 39 % whereas improving the price to TShs 6,000 and TShs 8,000 m⁻³ would shorten the age to 8 and 7 years with IRR of 79 % and 99 % respectively.

The average production of gum ha⁻¹ year⁻¹ for the period of 9 years can be estimated as 0.1362 tonnes. In order to match the current pure gum arabic production of 4,030 tonnes year⁻¹ (Table 3.2, 4.6), 29,600 ha of *A. senegal* plantations are required and if this is thought in terms of the current general gum production, 10,064 ha (34 % of the composition, see Figure 3.12) of the plantations would be required.

Apart from the above tangible benefits, the plantation would also serve other purposes. We have already seen that the tree is used for fuelwood and livestock fencing. Furthermore, *A. senegal* is planted for ornament in Virgin Islands and Puerto Rico (NAS, 1979), for desertification control, sand dune fixation and windbreaks (NAS, 1980) and also incorporated in agroforestry systems for soil fertility improvement in the Sahel region of Africa (NAS, 1979; 1980; Anderson, 1984).

Table 4.10 Economic analysis of managing a gum arabic plantation

Year	Costs (TShs ha ⁻¹)										Revenue (TShs ha ⁻¹)										
	Notional land rent	Nursery	Land prepn	Planting	Weeding	Protection	Inter cropping	Gum tapping	Clear felling	Total	Base crops	Gum	Net (except wood)	NPV (expt wood)	Wood	Net (wood)	NPV (wood)	NPVtot	LEV	Max LEV	Max NPV
0	3,000	31,250								34,250	0	0	-34,250	-94,367	0	0	0	-94,367			
1	3,000	0	15,000	5,000	15,000	5,000	2,000	0	1,847	45,000	9,922	12	-35,066	-66,128	38,881	37,035	33,668	-32,460	-357,065		
2	3,000	0	0	0	15,000	5,000	2,000	0	2,309	25,000	8,192	2,082	-14,726	-78,298	107,251	104,942	86,729	8,431	48,580		
3	3,000	0	0	0	0	5,000	3,000	0	2,886	11,000	5,819	16,439	11,259	-69,839	196,599	193,713	145,540	75,700	304,402		
4	3,000	0	0	0	0	5,000	3,000	0	3,607	11,000	3,257	44,398	36,655	-44,803	296,117	292,510	199,788	154,985	488,932		
5	3,000	0	0	0	0	5,000	3,000	0	4,509	20,018	788	74,556	55,326	-10,450	396,127	391,618	243,164	232,714	613,894		
6	3,000	0	0	0	0	5,000	0	0	5,636	19,272	0	98,917	79,645	34,507	489,940	484,304	273,377	307,885	706,926		
7	3,000	0	0	0	0	5,000	0	0	7,045	22,090	0	115,889	93,799	82,641	573,823	566,778	290,847	373,488	767,164		
8	3,000	0	0	0	0	5,000	0	0	8,806	25,613	0	126,821	101,208	129,856	646,294	637,488	297,393	427,248	800,851		
9	3,000	0	0	0	0	5,000	0	0	11,008	30,016	0	133,565	103,549	173,771	707,354	696,346	295,319	469,089	814,529	***	
10	3,000	0	0	0	0	5,000	0	0	13,760	35,520	0	137,622	102,102	213,135	757,848	744,088	286,878	500,013	813,749		
11	3,000	0	0	0	0	5,000	0	0	17,200	42,400	0	140,021	97,621	247,351	799,025	781,825	274,025	521,375	802,726		
12	3,000	0	0	0	0	5,000	0	0	21,500	51,000	0	141,420	90,420	276,161	832,249	810,749	258,330	534,491	784,436		
13	3,000	0	0	0	0	5,000	0	0	21,500	51,000	0	142,225	91,225	302,586	858,840	837,340	242,548	545,134	767,431		
14	3,000	0	0	0	0	5,000	0	0	21,500	51,000	0	142,680	91,680	326,728	879,992	858,492	226,068	552,796	750,400		
15	3,000	0	0	0	0	5,000	0	0	21,500	51,000	0	142,931	91,931	348,736	896,736	875,236	209,525	558,261	733,966		
16	3,000	0	0	0	0	5,000	0	0	21,500	51,000	0	143,064	92,064	368,772	909,943	888,443	193,351	562,123	718,487		
17	3,000	0	0	0	0	5,000	0	0	21,500	51,000	0	143,130	92,130	386,999	920,331	898,831	177,829	564,828	704,138		
18	3,000	0	0	0	0	5,000	0	0	21,500	51,000	0	143,159	92,159	403,575	928,483	906,983	163,129	566,704	690,983		
19	3,000	0	0	0	0	5,000	0	0	21,500	51,000	0	143,168	92,168	418,645	934,869	913,369	149,343	567,988	679,012		
20	3,000	0	0	0	0	5,000	0	0	21,500	51,000	0	143,166	92,166	432,345	939,866	918,366	136,509	568,854	668,174		
21	3,000	0	0	0	0	5,000	0	0	21,500	51,000	0	143,160	92,160	444,799	943,772	922,272	124,627	569,426	658,395		
22	3,000	0	0	0	0	5,000	0	0	21,500	51,000	0	143,153	92,153	456,119	946,822	925,322	113,672	569,791	649,591		
23	3,000	0	0	0	0	5,000	0	0	21,500	51,000	0	143,145	92,145	466,410	949,203	927,703	103,604	570,014	641,675		
24	3,000	0	0	0	0	5,000	0	0	21,500	51,000	0	143,138	92,138	475,764	951,060	929,560	94,374	570,138	634,563		

4.5 Conclusion and recommendations

4.5.1 Conclusion

The results from this study indicate that gum arabic is important to the subsistence economy of many rural inhabitants of the gum producing areas. The gum is used for food, medicine and glue.

The gum is also economically important to the collectors, the middlemen and the final buyers and exporters, as well as in its potential contribution to the local and central government revenues.

The economically disadvantaged population, the majority of whom own livestock and lead a semi-nomadic life and carry out collection as a secondary occupation to supplement their incomes, mostly does collection of gum.

There is not much attention by both local and central governments paid to tapping the potential of this resource as very little is collected as revenue. No use is made of the gum by the country's industries as all requirements are met by imports.

The current market and pricing structure does not seem conducive to the optimum production of high quality gum. Steps could be taken by all stakeholders to improve this situation.

The establishment of *Acacia senegal* plantations for gum arabic production is economically viable with an optimum rotation age of 9 years, the age increasing with increased gum price.

4.5.2 Recommendations

The following recommendations could be made arising from this study:

- Government interventions are of crucial importance in order to realize more revenue from this field, therefore improving the government income and the contribution of forestry to the recorded revenues, although the disincentive effect of different levels of tax should be borne in mind.
- The government should also create conducive environments for utilization of the gum by the local industries.
- Further work into the feasibility of *Acacia senegal* plantations needs to be carried out. At this stage, the establishment of the plantations as sources of gum arabic and other products and services would appear to be viable.

CHAPTER V

MARKETING OF GUM ARABIC FROM TANZANIA

5.1. Introduction

5.1.1 General

The rate of population growth for Africa is around 3 % for cities and about 4 % for towns (FAO, 1997b), in Tanzania, the overall average was 2.8 % over the period 1978 – 1988 (MFEAP, 1988). In order to reduce poverty, economies must grow substantially faster than population or change the distribution of income.

In a study commissioned by DFID on growth in sub-Saharan Africa, reported by Fafchamps *et al.* (2001), it was suggested that for many African countries agriculture, tourism and mining offered the best prospects for exports and growth. It was for instance, reported by the World Bank (2000) that in Sub-Saharan Africa, agriculture employed about 66 % of the labour force, contributing 37 % of Gross National Product (GNP) and 50 % of exports. Coulter *et al.* (1999) however, identified marketing as one of the main development challenges in Africa. As FAO (1997b) concluded, the development of agriculture and the marketing systems are therefore the heart of the economic growth process.

FAO (1997b) described the recent market liberalization that was taking place in many countries as part of economic structural adjustment programmes. In Tanzania, the economic reform programmes that commenced in 1986 have converted the command-based economy into a market one; trade, exchange rates and interest rates are now claimed to be fully liberalised (URT, 2002). FAO (1997b) noted that individual commodity exporters could now retain 35 % of export earnings in Tanzania as foreign exchange, to purchase production inputs and reduce the incentive for smuggling.

In order to maintain high rates of agricultural output growth, the World Bank (1994) recommended that Tanzania should focus in the short run on export products, where world markets could absorb the increased production without affecting prices. Among these agricultural export products is gum arabic.

Earlier on, in 1975 the Lomé Convention was introduced with a mechanism for guaranteeing a minimum level of earnings from specified exports from the developing countries, Tanzania included, to the European Economic Community (URT, 1977). The convention was amended in 1977 to include gum arabic. Thus, gum arabic appears to have great potential for improving exports and contributing to economic growth in Tanzania.

5.1.2 Problem statement and justification for this study

Becker and Engel (2000) advocated expanded and improved commercialisation of NWFPs to increase cash incomes of rural households in tropical countries, thereby motivating sustainable management by local actors.

In a regional and national overview of NWFPs in Africa, conducted by FAO (2001b), however, it was claimed that there were inadequate research, incomplete and poor quality data concerning these resources. Stiles (1988) proposed a detailed study of potential markets for NWFPs from arid and semi-arid regions including gum arabic. In Tanzania, the absence of literature on rural marketing has been described by Amani and Kapunda (1990), Limbu (1993) and Shechambo (1993) as conspicuous. The need was also underscored by Abbott (1993) who pinpointed that despite marketing being an essential component of successful agriculture, its importance is often underestimated, especially in developing countries.

It is against this background that one element of this study involved an analysis of the marketing of Tanzania's gum arabic.

5.1.3 Objectives

5.1.3.1 Overall objectives

The overall objective of this study was to analyse marketing of gum arabic from Tanzania.

5.1.3.2 Specific objectives

The specific objectives were:

- To identify and examine the trade chains of Tanzania's gum arabic
- To examine market functions executed by the stakeholders at the different gum flow levels in the trade chains
- To analyse prices of gum arabic offered at the different levels in the trade chain.
- To examine the costs involved in the marketing of gum arabic in Tanzania.
- To develop a hypothetical gum arabic supply model under different prices.

5.2 Literature review

5.2.1 Marketing – African context

5.2.1.1 General

Several scholars have attempted defining marketing, but the general consensus is “the business activities associated with the flow of goods and services from production to consumption” (Whetham, 1972; Harrison *et al.*, 1974; Abbott, 1986; 87; 93).

Marketing has been described by Coulter *et al.* (1999) as the main challenge for development in Africa. In a monopolized system for instance, Harris (1979) lamented that markets, if misused, can be powerful agents of underdevelopment through exploitation of producers and consumers. Barbier (2000) gave reasons for the Sudan’s recent increase in gum smuggling to neighbouring countries as a distortionary government exchange rate and export and pricing policies, giving the farmers a low share of the export value.

Abbott (1987) concluded that a far-sighted government would therefore orient its overall policy framework towards growth of those enterprises that are able to take on the necessary marketing responsibilities and would establish and maintain a favourable climate for this to happen.

In the market, there are basically three functions that are performed, namely exchange, physical and facilitating (Kohls and Uhl, 1990). Within each function, a set of activities (Kohls and Uhl, 1990) or marketing services (Gittinger, 1982) exists, as presented in the matrix below.

	Function		Activities/services
A.	Exchange	1.	Buying
		2.	Selling
B.	Physical	3.	Storage
		4.	Transportation
		5.	Processing
C.	Facilitating	6.	Standardisation
		7.	Financing
		8.	Risk bearing
		9.	Market intelligence

Value added products normally carry a higher margin than raw commodities. Each of the above functions and activities therefore, adds value to the product and requires inputs, and hence costs.

5.2.1.2 Problems

Marketing systems for agricultural produce in developing countries have mostly been inefficient due to a number of reasons. An efficient agricultural market should meet the following criteria (Breimyer, 1976):

- encouraging increased supply to the market of a product in its different forms,
- stimulating an increased demand of a marketed output,
- operating with as minimum costs and margins as socially allowable,
- delivering the right quantity, quality and form of a product to the right consumers, at the right places and at the right time.

Several authors have branded transport as the most binding problem in marketing produce from developing countries (Scarborough and Kydd, 1979; FAO, 1997b; Coulter *et al.*, 1999; Becker and Engel, 2000; von Braun *et al.*, 2002). This has been due to the nature of the countries' transport networking in terms of types, spatial coverage, quality and passibility, all of which often happen to be unfavourable. In Tanzania for example, of the 33,722 km of road, only 2,625 km (8 %) are hard surfaced, 14.5 % are gravel roads while the rest are dirt roads, sometimes accessible during the dry season only (Maliyamkono and Bagachwa, 1990). As a result, transport costs, which add to the commodity the utility of place (Whetham, 1972) account for over 25 % of the total value of developing countries' exports.

Another major hindrance noted by FAO (1997b) was poor and inadequate storage and handling facilities for the agricultural products, resulting in the increase in the risk of physical deterioration or losses from rain, pests and theft. This is largely due to inadequate capital markets resulting in insufficient liquidity in the marketing system to match supply and demand over time and space (Scarborough and Kydd, 1992; FAO, 1997b).

In many countries, marketing boards are normally given authority for controlled crops only, which in any one country are fewer than five (FAO, 1997b). The absence of control in the other crops results in reduction in the effectiveness of their marketing, observed by Harrison *et al.* (1974), Scarborough and Kydd (1992) and FAO (1997b) as:

- Relatively high cost of the buyers contracting with a large number of scattered smallholders located in remote areas
- Absence of standardised grades, varieties and qualities of those crops whose marketing is uncontrolled
- Poor market information: Because of this, there is uncertainty in the stability of the crops' prices in the open world markets. In order to hedge against price variability, traders keep high profit margins of between 20 and 25 %.
- Weak legal means of enforcing marketing contracts.

One of the suggestions for overcoming these weaknesses given by FAO (1997b) and Becker and Engel (2000) was formation of farmers' organisations or co-operatives with the following main objectives:

- To protect against exploitation of individuals by powerful buyers.
- To secure the best possible returns.

A good example of a marketing organ is the Sudan's Gum Arabic Company whose roles as documented by Omer and Wasila (1993) included the following:

- Farmers' participation in policies concerning production, marketing and the future of gum arabic.
- Purchasing all the gum produced in the year.
- Execution of the minimum price policy announced by the government.
- Providing non exploitative insurance to the farmers and middlemen.
- Execution of emergency programmes to combat pests, diseases, drought, and execution of development programmes for production, protection and promotion of other gums.
- Promoting availability of inputs and requirements, solving transport problems and combating smuggling.
- Organizing internal markets and opening new ones and organizing cleaning operations in addition to selection and quality.

5.2.2 Marketing – Tanzanian context

5.2.2.1 General

Being one of the poorest countries in the world (Booth *et al.*, 1998; World Bank, 2001), Tanzania is not immune from marketing problems mentioned above. Until 1986, the country had government established marketing boards (Lundahl and Ndulu, 1987; Eriksson, 1993), which controlled trade of some agricultural crops namely, cotton,

tobacco, coffee, tea, cashew nut, pyrethrum and sisal (Ellis, 1982; Odegaard, 1985; Eriksson, 1993). After trade liberalization, these organs were transformed into crop boards, are now only overseers of the respective crop regulations at the national level.

Under the country's Economic Recovery Programme of 1986 supported by the International Monetary Fund and the World Bank, and the Economic and Social Action Programme of 1989, there has been promotion of private sector expansion. This includes liberalization of the trade and exchange system, eliminating price controls and most state monopolies/monopsonies and opening the financial sector to private sector participation (van Cranenburgh, 1990; Eriksson, 1993; FAO, 1997b; URT, 2002). Additionally, private middlemen who were in the past considered as the sources of exploitation of the peasants were reinstated (Hedlund and Lundahl, 1987)

Other crops are totally under private enterprises controlled through licences. FAO (1997b) suggest that licences can be important since they allow some residual control over the private sector. According to COMESA (1994), the Business Licensing Act of 1973 prohibits the carrying out of any business in the country without a valid business licence.

Apart from licences, the government collects revenue in the form of taxes. The export tax is payable in respect of commodities, whose rate is specified in the Export Tax Act of 1974, and is due and payable prior to the removal of the commodity from the country (COMESA, 1994).

Only a few products for export are subject to quality qualification. The Tanzania Bureau of Standards was established by the Standard Act of 1975 to control specifications of production and marketing processes, and of materials and equipment to be used in the production and marketing of commodities (COMESA, 1994).

5.2.3 World marketing of gum arabic

5.2.3.1 History

Obeid and Seif el Din (1970) and Seif el Din and Zarroug (1998) attempted to trace the commercial use of gum arabic back to around the year 4000 B.C, when the Egyptians used it in foods, adhesives, colours and paint industries. By 1820, a well-organised trade was established and according to these authors, most gum traders during that time came from Arab countries and the European traders who imported the products from the Arabian ports of Jeddah and Alexandria gave the name “gum arabic” to the product. The gum was channelled to Europe through Trieste and Marseilles in Italy and France respectively. During the 1960’s and 1970’s, Bordeaux (France) was the main trading centre of gum arabic from the West African countries (ITC, 1972; Adamson and Bell, 1974).

Philip (1975), Muthana (1988), FAO (1991) and Hanson *et al.* (1992) documented that gum arabic was among the NWFPs that excelled in the trade inside and outside Africa after slave trade abolition. In the 19th century, intensive harvesting occurred for the world market, which increased environmental degradation in the gum producing areas of West Africa (Hanson, 1992).

5.2.3.2 Trade and trend

Demand and supply

Figure 5.1 presents a summarised history of gum arabic world trade between 1825 and 1995. The establishment of the first gum trade firm “Trieste and Marseilles” in 1827 saw a tremendous rise in the quantities traded from 126 tonnes in 1825 to 1270 tonnes in 1827 and the figure had gone up to tens of thousand tonnes by 1901.

Adamson and Bell (1974), Philip (1975), FAO (1995b) and Timberlake *et al.* (1999) have reported the world production of gum arabic as fluctuating with a peak of about 70,000 tonnes in 1965 and only about 30,000 tonnes to-date. This has been explained as a result of irregularity in supply and fluctuating prices causing gum arabic to lose out to synthetic substitutes on the world market. Gum shortages, which occurred between 1973 and 1975 and again between 1983 and 1985 following severe droughts in Sudan, for instance, increased prices (see Figure 5.1) and led to the development of more cost effective modified products that could replace or reduce gum arabic requirements. From the figure, it can be seen at a glance that there is a direct negative influence of the world gum arabic production on its market value.

Formerly, the international market largely absorbed all gum available, though recently international demand has declined together with gum prices (Roshetko, 2001). The export price of Sudan's gum arabic in the mid 1980's was reported by Roshetko (2001) to be US\$ 3,450 tonne⁻¹ but the prevailing trend was towards a lower price until 1990. However, Becker and Engel (2000) argued that declining demand for certain products on international markets must not be regarded as conclusive as consumer preferences may shift back to products that had lost significant market shares in the past. Based on the research data presented by Payne (2001) however, the demand and price for gum arabic at this moment appears flat or only slightly increasing.

In the case of Tanzania, quantities of up to 2,000 tonnes were exported annually, during the 1950s, but came down to 1,000 tonnes in the 1960s and 500 in the 1970s (Adamson and Bell 1974; Chihongo 1992). Recent figures on production and sale of gum arabic documented by Chihongo (1992,1995; 2000) and Ishengoma (1995) indicated an annual production of 1,000 tonnes out of which 50 % were exported.

In a report by Muller (1995), it was noted that the world gum industry was facing an uncertain future unless production and marketing were geared to overcome climatic and other external influences. The marketing of gum arabic in Sudan has been conducted under well-regulated government supervision for many years (Adamson and Bell 1974;

Chikamai *et al.*, 2000). In other countries, the marketing structure for gum varies from a degree of government control to a situation of total private enterprise, leading to great variation in amounts and quality available for export.

Fortunately, Awouda (1976), Stiles (1988), Anderson and Wang (1991a; 91b; 92a), Anderson (1993) and Roshetko (2001) observed that there was still commercial demand for gum meeting international specifications if steady supplies were available from year to year at competitive prices. Furthermore, for some applications, the introduced substitutes are not as satisfactory as gum arabic (Anderson, 1987; Mothé and Rao, 1999).

Superficial analysis conducted by Anderson and Wang (1992b) for example, suggested that *Leucaena* gums from some taxa could have potential industrial use as substitutes for gum arabic. Nuclear magnetic resonance spectroscopy, however, showed that *Leucaena* gums differ structurally from gum arabic and thus cannot be considered for foodstuffs. Mothé and Rao (1999) found that gum arabic was a much better thickener than cashew-tree gum. Gabb (1997) concluded that there were no artificial substitutes that matched gum arabic for quality or cost of production.

In nominal terms, the international market price for gum rose considerably, more than doubled that of 1965, reaching £700 per ton in 1973 due to prolonged drought in some producing areas and a crop shortage in the Sudan (Adam and Bell 1974; Anderson 1987; Jamal and Huntisinger 1993). In 1995, the prices had gone up to £3,500 per ton but have again fallen steeply over the past four years reaching £1,350 per tonne (Timberlake *et al.* 1999).

The price-controlling factor is therefore supply since demand seems to be constant. With increasing incomes on a global scale one would expect demand to show a rising trend, although this might be offset, to some degree, by substitution as synthetic alternatives are developed. However, one would not expect demand to show erratic shifts. Supply, on the other hand would be expected to shift up and down with changing weather, economic and political conditions, particularly in Sudan, the main supplier.

Anderson (1993) recommended spreading of sources of supply to give the Sudan control of only 50 % of the market to lessen the risk of a major crop failure and improve confidence. Awouda (1990) documented that Nigeria and Senegal had improved their market share through improved methods of field production as well as incorporating practices in domestication and dry land agroforestry. It has also been noted by FAO (1995b) that Kenya has emerged as a new supplier of gum arabic to the world market in recent years, accounting for almost 1 % of the total production.

Gum arabic export markets

The major markets for gum arabic reported by Adamson and Bell (1974), Nour (1999) and Payne (2001) were the United States of America, the United Kingdom and France. Others are Italy, the Netherlands, Germany, India, Japan, Belgium, Luxembourg, Australia, South Africa, Denmark, Sweden and Finland. The other European countries are Denmark, Belgium, Luxemburg, Spain, Greece, the Netherlands, Portugal and Ireland (Nour, 1999). Table 5.1 presents the world major gum arabic market and some selected producer countries and their respective annual average gum quantities involved, between 1988 and 1994. This table suggests that France consumed almost one third of the total production. The other major consuming countries in order, were UK, USA, Germany and Italy. The major producing countries were Sudan, Nigeria and Chad.

In 1993, Payne (2001) noted that the European Union countries imported 23,200 tonnes of gum whereas the United States imported 5,500 tonnes for the same period. These data strongly concur with the reported statistics in Table 5.1 in which USA had been importing an annual average of 4,130 tonnes whereas the European Union countries had been taking about 22,000 tonnes annually.

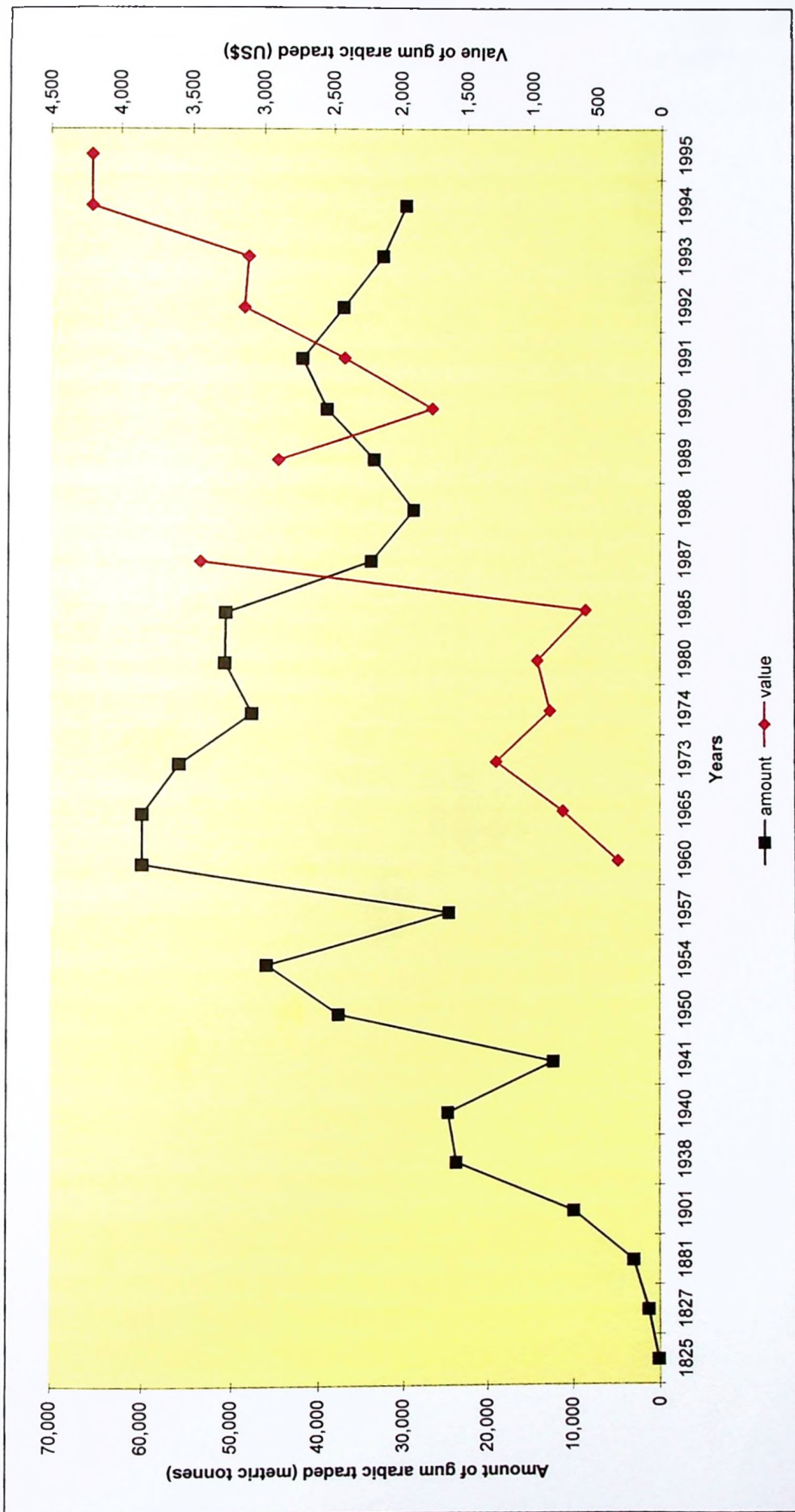


Figure 5.1 Gum arabic world trade history between 1825 and 1995.

Source: ITC (1972), Adamson and Bell (1974), Awouda (1974), Philip (1975), FAO (1995b), Timberlake *et al.* (1999), Anderson (1987), Seif el Din and Zarroug (1998), Rotsheko (2001), Chikamai *et al.* (1997) and Payne (2001).

Table 5.1 Gum arabic exports from some selected countries into the main European markets, United States of America and Japan between 1988 - 1994

Exporting country	Annual exports to the country of destination (metric tonnes)							Total
	France	UK	Italy	Germany	Other EC	USA	Japan	
Sudan	4,900	2,400	2,300	1,300	1,300	3,800	1,750	17,750
Nigeria	650	2,500	-	1,300	50	300	3	4,803
Ethiopia	-	-	-	80	-	-	-	80
Kenya	-	10	25	-	5	30	2	72
Ghana	-	50	-	-	-	-	-	50
Chad	2,800	600	-	-	100	-	-	3,500
Mali	45	-	-	-	95	-	-	140
Mauritania	-	-	-	-	180	-	-	180
Niger	115	-	-	-	35	-	-	150
Senegal	300	130	-	-	20	-	-	450
Total	8,810	5,690	2,325	2,680	1,785	4,130	1,755	27,175

Source: Chikamai *et al.* (1997).

Processing, packaging and shipment

Processing and grading are known to add or change utilities of form (Wetham, 1972). Processing of gum arabic essentially involves grading, further drying, cleaning, blending if necessary, and grinding. Gum grading in the producing countries is entirely by hand based on the colour and size of the balls (NAS, 1979). Generally, the trade structure in the major export markets is for a merchant to buy the supplies of gum and either resell them in the same form or process them before resale to the ultimate users (Adamson and Bell, 1974).

Historically, gum arabic was simply sold in its natural state with little or no processing, and even now, much of the product is merely pre-cleaned to remove bark, sand and impurities. After cleaning, the bark and foreign matter is below 0.5 % in food grade powdered gum (Payne, 2001).

Sudan exports only semi-processed or processed, kibbled gum arabic instead of crude gum lumps. Elsewhere, the crude gum arabic is exported either in burlap, kenaf or jute sacks. According to Payne (2001), the United States regulations require that only new, unused jute sacks be used. Semi-processed kibbled gum, granules and powdered gum arabic are exported in drums, polyethylene-lined, multi-wall paper bags or polyethylene-lined cardboard boxes. It was noted by Payne (2001) that about 40 % of the United States imports were processed gum arabic and the European imports consisted mostly of crude gum. The author concluded that the European countries, France in particular, re-exports processed gum arabic to the United States.

FAO (1995b) attempted to describe how gum arabic processing is carried out. Imported gum is purified by removal of pieces of bark by air floatation methods. Other mechanical methods are used to remove sand, dirt and other types of foreign matter. Further processing is by kibbling which entails passing whole or large lumps of gum through a hammer mill then screening it to produce smaller granules of more uniform size.

Alternatively, the gum can be ground into powdered forms. The two forms of gum are more easily dissolved in water than the raw gum and so are preferred by the end users.

The powdered gum may be produced from kibbled gum, but it may also be produced by a process known as spray drying which gives a high quality, free-flowing powder with even better solubility characteristics than kibbled gum. The gum is dissolved in water, filtered and/or centrifuged to remove impurities and the solution, after pasteurization is sprayed into a stream of hot air to promote evaporation of the water. By altering atomizing conditions, powder can be produced with varying particle sizes and bulk densities, according to the end user's requirements.

Exported gum arabic is mostly transported by vessel which is much cheaper than transport by air. In 1993 for instance, Payne (2001) noted that 70 % of the United States imports of gum arabic was transported by sea.

Degradative and analytical studies on plant gum exudates conducted by Morrison (1994) indicated convincing results that gum arabic had remained remarkably constant in chemical nature over the past 40 years. Since the shelf life of gum arabic is virtually unlimited, the slower transportation by vessel compared to transportation by air is not a limiting factor.

5.3 Materials and methods

5.3.1 Study sites

This study was conducted in eight districts in which gum arabic collection and trade were being carried out. These are Singida Rural, Iramba, Igunga, Shinyanga Rural, Meatu, Maswa, Babati and Kiteto, located in arid and semi-arid agro-ecological zones of Tanzania (Table 1.1).

5.3.2 Sampling and data collection

5.3.2.1 Sampling

The sources of data concerning gum trade chains, market functions, prices and costs involved were arrived at, from information that was gathered in a preliminary survey with considerable assistance from the Forest and Bee-keeping Division Headquarters and forest officers in their respective areas.

These data were collected from 630 gum collectors in 64 villages, eight gum middlemen in the areas and three final buyers and exporters of gum, all of whom together, formed the gum trade chains. Also, the following government offices were consulted for secondary data: District and regional forest and natural resources offices in areas from which gum arabic is collected, Tanzania Forest and Bee-keeping Division Headquarters and the Tanzania Revenue Authority – Customs Statistics Section, both in Dar Es Salaam.

The collection of data from the gum collectors was carried out at the gum trading centres. A total of 630 gum collectors was sampled in the study, 15 people each from Babati and Kiteto and 100 people in each of the rest of the districts. These people were sampled and interviewed upon their arrival to the gum middlemen in the respective areas, with lots of gum for sale. Since the gum middlemen knew the identity of the informants, there was no problem of repetition of the interviewing process with the same persons.

Gum middlemen

There were eight gum arabic middlemen identified in Tanzania, being recognised by the gum final buyers and exporters and gum collectors, and licensed by the relevant district council's forest offices. These were situated in the main gum trading centres with various branches in the gum producing areas, and were all sampled in this study.

Final buyers and exporters of gum

There were three companies in the country buying and exporting gum arabic, namely Mohamed Enterprises Company Limited, Fida Hussein Company Limited and Export Trading Company Limited, all based in Dar Es Salaam, but with branches upcountry. These were all sampled for this study.

5.3.2.2 Data collection

Data collection based on social survey methods was conducted using the tools of Participatory Rural Appraisal (PRA) that are well documented by Chambers (1992). The methods have been successfully applied by several researchers in various localities, such as Brokensha and Riley (1980) in Kenya, Kajembe (1994), Kilahama (1994) and Kikula (1996) in Tanzania, Bishop and Scoones (1994) in Botswana, Fujisaka *et al.* (1994) in Thailand and Campbell *et al.* (1995) in Zimbabwe.

The method relied upon interviews with individuals, i.e gum collectors, gum middlemen, buyers and exporters of gum and government officials.

Questionnaires of two kinds were used for gum arabic key informants (gum collectors and middlemen, local leaders and foresters) and gum final buyers and exporters (Appendices IV and V respectively). Government and public offices, including the Forestry and Beekeeping Division Headquarters, Tanzania Revenue Authority, Regional and District Forest Offices provided useful secondary data.

Gum arabic trade chains

Data from the gum trade chains were collected with the help of Appendix IV (Section B 1, 2, 5, 10 and 15) for the collectors and the middlemen and Appendix V (Section B 1, 2, 4, 8, 11 and 13) for the final buyers and exporters. Secondary data were collected from government offices.

Gum arabic marketing functions

Information on marketing functions performed at the different flow levels, in the chain were made available through Appendix IV (Section B 2, 14 and 15) for the collectors and the middlemen and Appendix V (Section B 10, 12 and 13) for the final buyers and exporters.

Gum arabic prices

The prices offered at the different gum flow levels in the country were made available and recorded in Appendix IV (Section B 7, 8 and 20) and Appendix V (Section B 5 and 16) for the collectors and middlemen and the final buyers and exporters respectively.

Costs in the marketing process

Appendix IV (Section B 11 and 16) and Appendix V (Section B 14 and 16) facilitated collection of data concerning the costs involved in the marketing process for gum arabic in Tanzania, for the collectors and middlemen and the final buyers and exporters respectively. Secondary data were collected from government offices.

Hypothetical supply model for gum arabic

All the data collected from the methods shown above, were used to develop the model.

5.3.3 Data analysis

Data analysis was carried out using the Microsoft Excel package of Microsoft Office 98 and 2000. Descriptive statistics facilitated determination of such important information as means, minimum and maximum values.

The variation in prices between districts and years was analysed in a plot. Analysis of the marketing costs was done and presented using a pie chart. The marketing margin for the added values was calculated using the associated costs and incomes. The exchange rates, the inflation indices and the equation used for adjustment of monetary values to 2001 constant values were as those shown in Chapter IV.

5.4 Results and discussion

5.4.1 Trade chains and market functions for gum arabic in Tanzania

Figures 5.2 and 5.3 below depict the production and trade regime for gum arabic in Tanzania. The production and trade flow (Figure 5.2) recognised five main levels, namely: the gum collectors, middlemen, final buyers and exporters, re-exporters and the final importing countries. A similar gum trend was reported for Kenya by AGL (1993) in which the re-exporters were sited in the Middle East.

Both have to apply and pay for registration in the trade in forest products (URT, 2001b).

5.4.1.1 Gum collectors

There are two groups of collectors whom shall be termed independent free-lance collectors and opportunistic collectors.

Independent free-lance collectors

Independent free-lance collectors were women and children whose involvement in gum collection was of secondary interest, the main interest in the forest products being fuelwood. This group was estimated to have a population of 17,038, which is about 75 % of the population of all the collectors. These collectors gather about 230 kg each and together, supply an annual average of 3,926 tonnes, which is almost 97 % of the total supply from the country.

Opportunistic collectors

These were normally pastoral nomads, who combine livestock herding activities with occasional gum collection. The amateur collectors were estimated to be 5,832 throughout the country, individually gathering an average of about 18 kg each and supplying about

104 tonnes a year (Figure 5.2). Thus, in terms of production, independent collectors are much more important than the second group, whose supply totals only 3 % of the total.

The gum collectors performed only a few market functions, namely, physical and exchange functions.

Physical function

The activities in this function included gum picking in the field, storage at homes and short distance transportation, from the field to homes and from homes to the middlemen. The gum was picked, collected, stored and traded in various forms of containers including cloth wrappings, tins, aluminium cooking pots and gunny bags. Storage and transportation was by simple and cheap means. Transport to the middlemen was mainly done on foot and other means included bicycles and ox and donkey carts.

Exchange function

The only activity performed by the gum collectors with regard to the exchange function was selling of the gum to the middlemen. Weighing of the gum was done by the middlemen using the bean balance weighing scale and the value computed exclusively by the middlemen as most of the collectors had no knowledge of how to go about it.

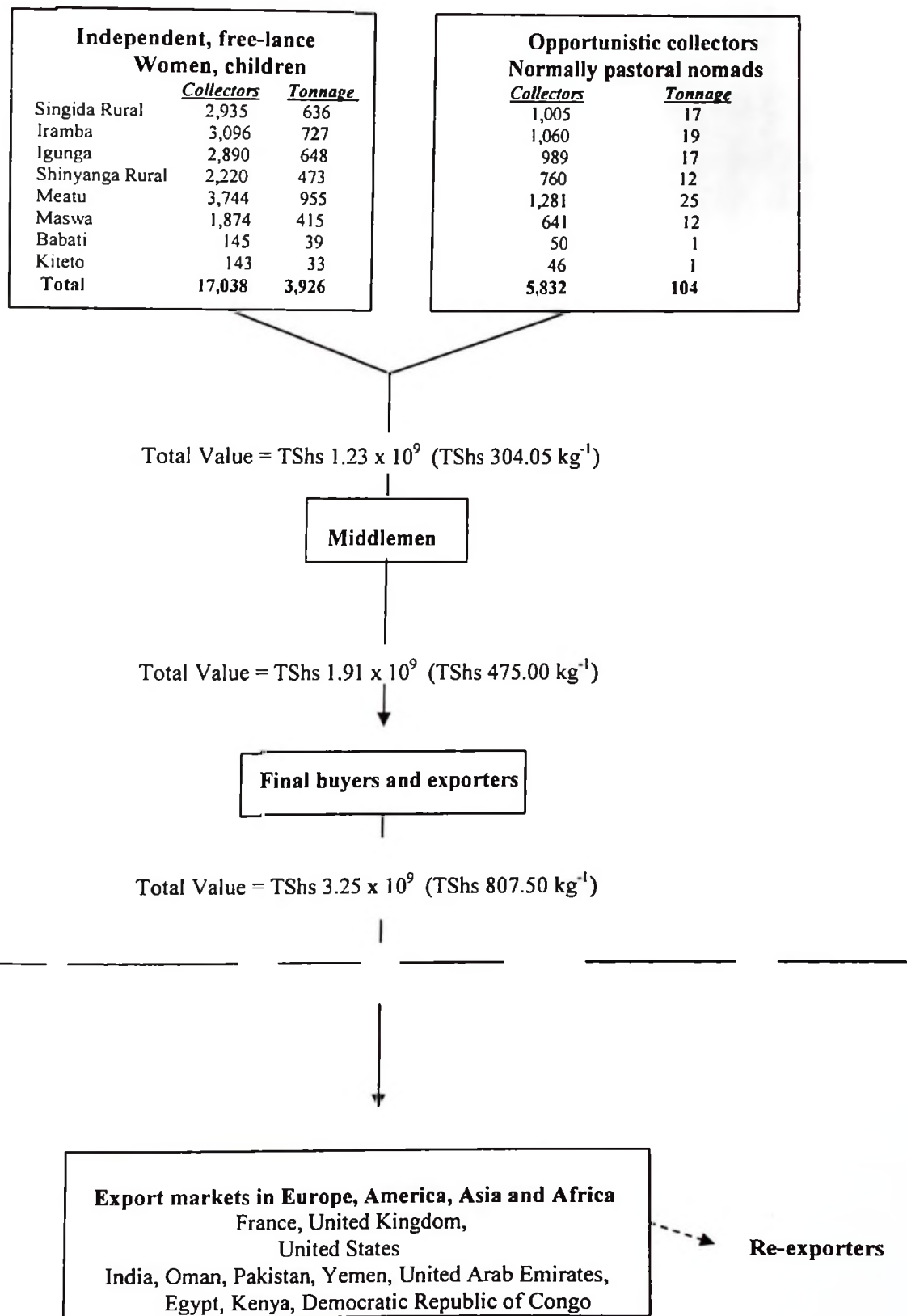


Figure 5.2 Production and Marketing Chain for gum arabic in Tanzania.
 Figures in parentheses indicate gum arabic prices at the different levels of the chain.

5.4.1.2 Middlemen

The middlemen in Tanzania were the foci through which the gum trade thrived. They had to be available at appropriate understood times and in appropriate places and trusted by the collectors and the final buyers and exporters. The middlemen performed the market exchange function by buying the gum from collectors and selling to the final buyers and exporters and the physical function of providing storage (gum kept in middlemen's warehouses), simple processing (hand picking of clear impurities and bagging) and transportation to the buyers and exporters. The gum was at this stage put in gunny bags each weighing 100 kg ready for collection by the final buyers or transportation, using trucks to the final buyers and exporters' centres. The former was the most common option used.

The value of the middlemen, according to McVey (1960), is as intermediaries between a number of producers and consumers thereby reducing costs and time in procurement and selling. McVey (1960) stated that "*You can do away with the middleman but you cannot do away with his functions*". Gaedeke and Tootelian (1983) gave two more roles of middlemen: firstly, they provide wider market exposure and secondly, normally producers have insufficient capital and quantities to market the products directly; the middlemen, therefore, provide this important service.

5.4.1.3 Final buyers and exporters

The final buyers and exporters of gum in Tanzania who were a few private individuals and their companies, performed a number of the market functions including facilitation, risk bearing and conducting market intelligence to obtain information on gum customers and price.

No quality checks or grading, apart from checking the contents of the bags, was being conducted and very little was being spent on gum processing as the gum was only

winnowed, re-bagged and exported in its mixed forms making the quality of the product essentially poor as the bulk of it was derived from *A. drepanolobium*.

Observations around Africa, made by Timberlake *et al.* (1999) indicated that gums from at least 10 species of African acacias had been sources of what was marketed as gum arabic giving rise to considerable controversy in the trade.

This study noted a serious lack of a clear definition of gum arabic in Tanzania, as no emphasis was being put on collection of pure grades from *Acacia senegal*. This was the major reason for the mixed gum cargo from Tanzania, suggesting the small volume of the trade with the major world's gum markets. Adamson and Bell (1974) suggested that it was important for gum collectors to be able to distinguish between *A. senegal* and those acacias which provide inferior gum. Sharawi (1987) attempted to explain these problems as being related to lack of incentives to farmers and poor organization of the internal market in the country. According to Whetham (1972), the grading of any agricultural commodity offered for sale assumes that buyers recognise differences in quality, and that some buyers are willing to buy more, or to pay higher prices than the average when they obtain the quality they prefer.

In Sudan, Omer and Wasila (1993) and Seif el Din and Zarroug (1998) noted that the Gum Arabic Company established in 1967/68 was the sole purchaser of all quantities of gums in the country. The authors pointed out that the gum collector performed little cleaning and the middleman undertook only some degree of cleaning. Final cleaning, sorting and grading were done prior to export by the Gum Arabic Company.

Further reports on exports of gum in Sudan were given by Gabb, (1997) who outlined that the product is subject to quality checks and grading by the Sudanese Standards and Metrology Organisation.

5.4.1.4 Re-exporters

The most important market function activities performed by the re-exporters would be processing (hand picking, cleaning, blending and grinding) and standardization to add value to the product prior to re-exporting to the countries of final destination. There are suggestions that the re-export is for low value usage sector, perhaps all ethnic markets, whereas if one was re-exporting large amounts to high value usage markets, there would probably have to be significant amounts of grading.

5.4.1.5 Export markets

Most of the countries of final destination of the gum arabic from Tanzania were located in Asia (India, Pakistan, United Arab Emirates, Oman and Yemen) followed by Europe (France and United Kingdom), Africa (Kenya and Congo) and lastly America (United States of America). Results presented in Table 5.2 below indicate that during the period January 1998 to May 2001, a total of 2,970 metric tonnes of gum was exported to 11 countries, which is an average of 869 tonnes year⁻¹.

The export was highest in 1998 (943.24 tonnes) but experiencing the lowest prices in the period (US\$ 347.4 tonne⁻¹). In 1999, the export declined to 869.96 tonnes, however, enjoying the highest prices of US\$ 553.7 tonne⁻¹ triggered the export to increase in 2000 to reach 910.23 tonnes. The prices for 2001 had gone down again to US\$ 869.32 tonne⁻¹. In general, the revenues were highest in 1999 followed by 2000 and 1998. The prices for gum varied between years, apparently affecting the supply in the following year. Gum supply is expected to be influenced by price but particularly the price paid to the collectors. However, the weather conditions (via better/worse gum production and opportunity cost of collectors' time) can be expected also to have a major influence.

The major importers of Tanzania's gum were India, consuming 78 % of all exports and Pakistan with 18 %. The balance of the Tanzania's gum export (4 %) for the period of 3 years was shared in the following descending order: the United Kingdom, Egypt and

Table 5.2 Gum arabic exports from Tanzania between January 1998 – May 2001

Year	Country of destination	Amount (tonnes)	Value		Total annual metric tonnage	Total FOB gum values	
			US \$	TShs		US \$	TShs
1998	France	8.05	7,183	4,812,610	943.24	219,530,860	282,958,069
	India	799.25	222,757	149,247,190			
	Kenya	3.00	456	305,520			
	Pakistan	130.62	96,196	64,451,320			
	Dem. Rep Congo	2.32	1,067	714,890			
	Un. Ar. Emirates	18.00	6,742	4,887,950			
1999	Egypt	20.00	15,155	10,987,375	869.96	349,251,350	399,075,897
	United Kingdom	19.00	11,467	8,313,575			
	India	654.26	345,870	250,755,750			
	Pakistan	140.70	84,911	61,560,475			
	United States	18.00	17,581	12,746,225			
	United Kingdom	0.13	791	636,755			
2000	India	720.50	346,325	278,791,625	910.23	363,296,500	384,730,994
	Pakistan	189.60	104,183	83,867,315			
	India	149.95	60,909	57,863,271			
2001 ^c	Oman	1.30	711	675,000	246.75	96,723,300	92,117,429
	Pakistan	75.50	35,990	34,190,270			
	Yemen	20.00	4,205	3,994,650			
	Total						

^a Converted using an exchange rate of TShs 670, TShs 725, TShs 805 and TShs 950 US\$⁻¹ for 1998, 1999, 2000 and 2001 respectively (Fx converter, 2003).

^b Constant (2001) values, ^c Data available for period January – May 2001 only.

Source: Adopted and modified from URT (2001a).

Yemen (each consumed 0.67 %), United States and United Arab Emirates (each consumed 0.61 %), France (0.27 %), Kenya (0.10 %), the Democratic Republic of Congo (0.08 %) and Oman (0.04 %). During this period, there were continuous gum trade links with India and Pakistan, and more regular with United Kingdom, but all of the other countries only occurred once. This suggests that the exporters get a contract every so often and these importers are buying from a number of suppliers.

The results are, however, of debateable accuracy since observations made by Autoon (personal communication, 2000) noted that India and Germany were the major markets for gum from Tanzania. This could be explained by the fact that the Tanzania Revenue Authority records were available only for the last 3½ years and that it appears that official records only account for 25 % of production (see Chapter III and IV).

Reports by FAO (1995b) indicated that Tanzania exported 88 tonnes of gum into the European Community in 1988 and the figure had reached 176 tonnes in 1993. During this period, no exports were apparently made into the United States and Japan markets.

Comparing these results with the gum export information presented in Table 5.1, it can be concluded that Tanzania has the potential of being among the five major gum suppliers to the world market. However, the European and American markets have not been fully utilized and the Japanese market remains totally unserved hitherto. Tanzania supplies negligible quantities of gum to the major world gum arabic markets, according to the country market list given by Adamson and Bell (1974), FAO (1995b), Chikamai *et al.* (1997), Nour (1999) and Payne (2001). As Chihongo (2000) noted, Tanzania has one of the largest export potentials for gum arabic among the East African countries, though the industry is yet to be developed.

Although India dominated the market for Tanzania's gum, taking 78 % during the period studied, the analysis in Table 4.6 on price tonne⁻¹ and 5.2 shows that it was among the countries which paid the lowest prices (US\$ 420) with Pakistan importers paying slightly more. The other countries in the group in descending order were the United Arab

Emirates (US\$ 375), Yemen (US\$ 210) and Kenya (US\$ 152). In the other hand, the United States of America, France, Egypt and the United Kingdom offered the highest prices of US\$ 977, 892, 758 and 641 respectively.

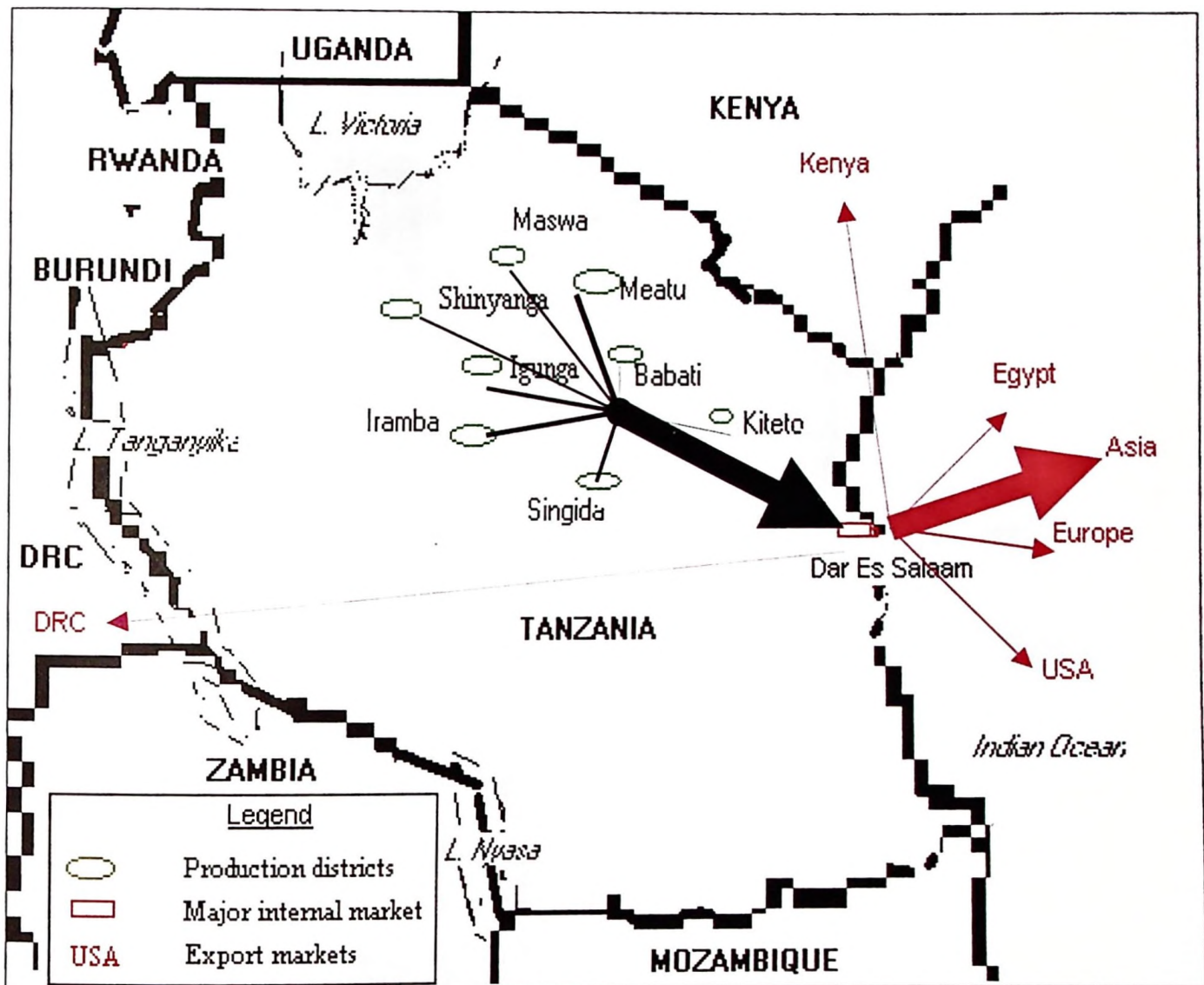


Figure 5.3 Gum arabic marketing flow chart in Tanzania

Note: The size of the ellipses and the thickness of the gum flow lines are indicative of the magnitude of the business in the respective areas.

The countries using advanced technologies, also require high technology gum i.e highly processed and graded gum. There is therefore, potential for Tanzania to do more of its own processing. However, the current main markets (India and Pakistan) seem not to require much processing. In order, therefore for the other markets to be developed, Tanzania needs to offer a high and constant quality gum product with stable supply. This

could be achieved through taking out the *Acacia senegal* gum and selling it elsewhere, since India and Pakistan take mostly gum from *Acacia drepanolobium* and do not, presumably, differentiate between them.

From this analysis the following insinuations could be arrived at:

- The United States of America, European and Egyptian requirements seem to have been for higher quality uses, whereas, India and Pakistan who purchased 96 % of the Tanzania's official gum exports required less sorting, thus implying lower quality gum uses. It might, however, have been a case, not so much of differing quality produce, but of charging what the market would bear.
- It is likely that there were strong links between the gum exporters in Tanzania and the importers in India and Pakistan suggesting existence of a close relationship between exporters and importers, either through one or more multinational companies or close family and cultural ties.

Multinational companies practice transfer pricing (Neighbour, 2002), which was defined by Hussey (1995) as "the price at which goods and services are bought and sold between divisions or subsidiaries within a group of companies". The importance of transfer pricing becomes clear in the light of the fact that over 60 % of World trade takes place within multinational enterprises (Neighbour, 2002).

Neighbour (2002) and Meier (1995) noted that abuse of transfer pricing is a particular problem for developing countries in which companies take advantage of it to avoid exchange controls and to repatriate profits in a tax free form. The practice allows the multinational enterprises to minimize taxes, escape from tariff charges, or be the means of remitting profits from a subsidiary to the parent company that would otherwise not be allowed by exchange restrictions (Meier, 1995).

Nevertheless, since the transfer price is arbitrary, it can be used by the company to minimise its liability for corporation tax, which is legal until governments legislate to prevent the practice (Davidmann, 1996). Transfer pricing can therefore, deprive governments of their share of taxes from global corporations (Neighbour, 2002).

It might, therefore, be that Tanzania's gum exporters and, as far as they are part of multinational businesses, engaging in transfer pricing, with the apparent export price being lower than the true market value. Nevertheless, given that the quality of the gum exports are low because of the relatively high *Acacia drepanolobium* gum content, this would appear to be the major factor giving rise to the relatively low price achieved.

5.4.2 Gum prices

5.4.2.1 Pricing

The final buyers and exporters of gum tended to determine the prices at all levels. This started by fixing prices to be offered to the middlemen who in turn fixed prices to be offered to the collectors after deducting costs and setting profits.

Figure 5.2 above and Table 5.3 below show that the collectors earned an average of TShs 304.05 kg⁻¹ during 1998 – 2001 period, whereas the middlemen earned TShs 475.00 kg⁻¹ and the final buyers and exporters received TShs 807.50 kg⁻¹. The figures indicate that there was a percentage mark-up of 56.2 and 70.0 in the prices earned by the middlemen and final buyers and exporters respectively and the collectors' share was 38 % of the final price.

FAO (1997b) pointed out that for profitability objectives, the returns on investment is about 20 – 25 % and that on sales is between 5 – 8 %. It has been suggested by FAO (1997b), Farris (1997) and Padberg (1997) that the producer price offered by parastatal marketing boards is often calculated as a residual of the export price minus marketing costs and profit margin. There is no particular motivation to minimise those marketing

costs, due to the lack of a mechanism and incentive for them to become efficient, being a public body and staff do not see any gain to themselves from the increased efficiency. As export-marketing boards cannot influence these prices, they tend to set low producer prices to avoid a trading deficit when world prices fall.

Harris (1981) described private traders as more efficient at bringing about rural development than parastatals; they perform activities which release government funds and personnel to be used for other purposes, they are able to mobilise scarce resources, they are innovative and they can create employment. This author however, also portrayed private traders as agents of stagnation as possibilities are high that they are oriented towards short-term easy profits. Nevertheless, like parastatals, private traders may also occupy a monopsonistic or oligopsonistic position in the country and in particular areas. Therefore, they are likely to offer lower prices to suppliers than if they were in a more competitive situation.

In Tanzania, the gum arabic export trade is not controlled by any board; it is the final buyers and exporters who assume the roles of export-marketing boards. In such a state of affairs, it is inevitable to suspect tax evasion and underpayment to the middlemen and gum collectors by the final buyers and exporters. Comparing the gum arabic prices for the four major world producing countries, Sudan, Senegal, Nigeria and Tanzania, Adamson and Bell (1974) concluded that the prices in Tanzania were considerably lower than in the other countries.

For other crops in Tanzania, it was reported (URT, 1992) that government prices were generally much lower than those in the open market. Amani and Kapunda (1990) attempted to quantify the official and parallel marketing margins for maize and rice in the country in 1984/85 and 1986/87 for which they uncovered a range running between 40 % and 72 %.

In order to help the farmers, Abbott (1987) proposed direct government intervention including announcing official prices with penalties for non-observance. Such policies

nevertheless, may have the desired effect in the short term only, the next step therefore, might be to establish an official supply-and-price stabilizing agency. Government intervention may have negative effects on the market since it puts a rigid structure on the marketing, thus limiting flexibility and adds a layer of costs and inefficiency potential. Nowadays, the thinking in development circles would probably be against such involvement.

Another proposal by Abbott (1993) was formation of farmers' associations or co-operatives that could enable small farmers to economise on some activities, undertake initial processing themselves and increase their bargaining power.

However, Whetham (1972) observed that co-operative societies tend to be best developed in areas where the farmers are already commercial producers and accustomed to thinking in terms of costs, risks and returns on capital invested. Abbott (1993) concurred with the observations and added another condition of dependency on one or a few crops for total income. In addition, cooperatives would be unlikely to work in a situation in which the final buyers are not willing to pay for processed commodities.

The current environments of Tanzania are therefore not conducive for the formation of co-operatives for gum arabic marketing. In Chapter III, for example, it has been observed that the gum collectors have the least formal education, and are highly mobile and in both Chapter III and IV that they do not incur any costs in their activities other than their own labour. Chapter IV indicates that gum collection is of a secondary importance, seldom contributing more than 20 % to the total household annual income. One area, which might be improved, however is market information at all levels.

In Sudan, it has been reported by several authors that the gum is auctioned at competitive prices and the buyers do not have contacts with the producers (Adamson and Bell, 1974; Seif el Din and Zarroug, 1998). The government in each gum season fixes the minimum price. After the purchase from the auction, the middlemen clean and grade the gum by hand before selling it to the Gum Arabic Company at Port Sudan. The government levies

a 40 % export tax to the Gum Arabic Company when the gum is loaded on to a vessel at Port Sudan for export. Each of the appointed agents in the countries of gum destination gets 1.5 % of the selling price as discount or commission. The company retains 0.5 % for financing research and promotional activities (Seif el Din and Zarroug, 1998).

Seif el Din and Zarroug (1998) were however, concerned by a growing belief that the monopolistic exportation by the Gum Arabic Company should be deregulated so that any Sudanese person could enter the business. As Harris (1979) observed, monopolistic markets can be used as a powerful means of underdevelopment in which the few are able to reap excessive profits at the expense of producers and consumers. It was also noted by Omer and Wasila (1993) and Seif el Din and Zarroug (1998) that smuggling outside the country through Chad, Kenya, Nigeria, Uganda and Ethiopia is extremely profitable as payment of the 40 % export tax is evaded and they may also obtain more than the fixed government price.

5.4.2.2 Variations

The gum price variations were analysed at the collectors' level since the final buyers and exporters maintained secrecy in their business so this information could not be obtained. The mean gum arabic price paid by the middlemen to the collectors can be analysed in two ways: between years and between districts using Figure 5.4 and 5.5 below, in which data were available for the year 1998 – 2001 period.

Between years

Figure 5.4 below indicates that the prices were highly affected by inflation whose indices were improving year after year. The prices in constant 2001 terms were over and above the prices in real terms in 1998 and the gap kept improving until they were the same in 2001. In these discussions, the results are based on the prices in constant 2001 terms. Figure 5.4 below shows that the nominal price of gum at the collectors' level rose steadily from 1998 to 2000, but fell slightly in the following year. When expressed in real

terms (constant 2001 values), however, prices only showed a small improvement over the first 3 years and dropped more significantly to 2001. The actual figures for each year averaged TShs 290 kg⁻¹ (with a range from TShs 260 to 350), 310 (280 to 360), 330 (300 to 380) and 284 (260 to 330). The sharp fall in the price offered in 2001 was due to a shock following a rise in the license fee to TShs 150 from TShs 100 kg⁻¹ paid in the previous years even though few paid it. The license fee was paid by the middlemen but the effect was to the final price received by the collectors.

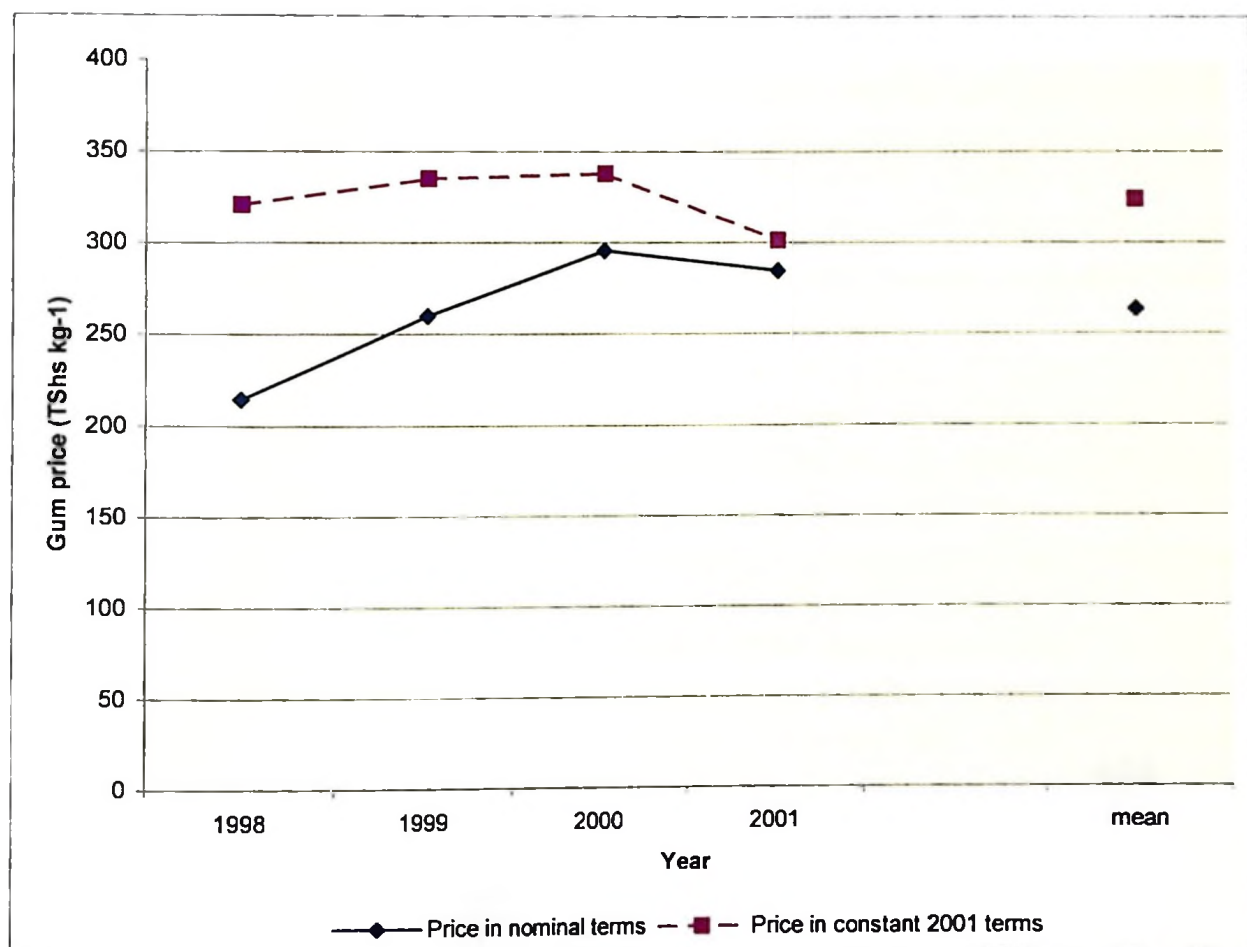


Figure 5.4 Gum arabic price patterns during 1998 – 2001.

Between districts

The variation in gum prices between districts can be seen from Figure 5.5. Shinyanga Rural district had the most favourable prices with a mean of TShs 350 kg⁻¹, followed by Igunga (TShs 320 kg⁻¹). These two districts had their prices well above the overall mean price of TShs 304 kg⁻¹ for all of the eight districts.

Third on the list is Meatu district with a mean price of TShs 302 kg⁻¹, which almost equalled the overall mean for the districts. Other districts in order are Maswa (TShs 297 kg⁻¹), Babati (TShs 296 kg⁻¹), Kiteto (TShs 293 kg⁻¹), Singida (284 kg⁻¹) and Iramba (TShs 275 kg⁻¹). The reasons for the variations between districts appeared to be gum quality and transport costs (as discussed in Chapter III). The analysis of variance, however, indicated that there were no significant differences in the gum prices between the districts ($p = 0.06$).

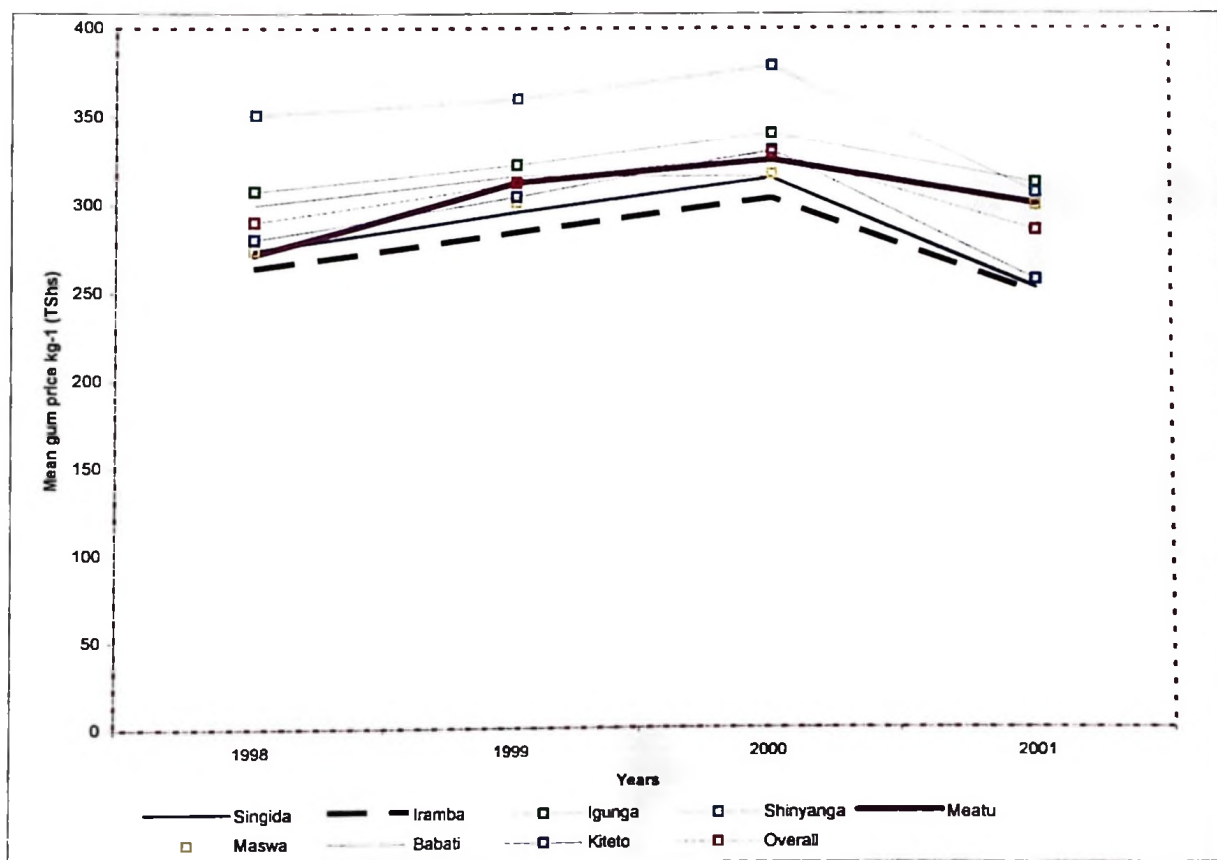


Figure 5.5 Gum arabic price pattern during 1998 – 2001 across districts in Tanzania

5.4.3 Descriptive analysis of the marketing concepts for gum arabic in Tanzania

5.4.3.1 Firms at each level of the chain

In the gum market chain, there were estimated to be 22,870 collectors in the whole country, all located in remote rural areas, selling the gum to eight intermediaries (refer section 5.4.1 above). The middlemen were prominent merchants in the gum areas owning, among other businesses, retail shops, petrol stations and transport services. These intermediaries were supplying the gum to three final buyers and exporters of all gum in the country, all located in Dar Es Salaam with branches in towns near the gum collection areas. The final buyers were prominent importers and exporters of other products as well as millers in the country.

5.4.3.2 Barriers to entry

Engagement in the collection of gum activities by the collectors was open and free to anyone, nevertheless, determined by the motivation to withstand the harsh field conditions and the negative social image perceived by society against the collector (refer Chapter III). It is because of the latter reason that these activities were dominated by women and children.

Entry to the business by the middlemen and final buyers and exporters was controlled by licences, fees payable to the local and central governments (Chapters III and IV). These people were relatively much wealthier than the gum collectors; had own transport facilities (vehicles), had much more financial capital, were much more educated and were much more knowledgeable on gum marketing. The middlemen and final buyers and exporters also had to have a network of contacts and associates in the field and in the markets. Nevertheless, the final buyers and exporters were much more advantaged in terms of the above mentioned aspects than the middlemen, therefore controlling the whole marketing chain.

5.4.3.3 Extent of competition

Given the fact that there are many collectors, but, with only 8 middlemen, each of whom is probably the only buyer with each particular area, there is closer matching of market power when middlemen sell on, although the power probably lies with the small number of final buyers, and that the exporters are selling onto a world market, in which they are minor players, albeit probably trading with close partners in that market (Figure 5.6), then:

- Competition is strongest at collector-middleman level, where, because of local monopsony, collectors are probably price takers.
- At middleman-final buyer level, it is oligopoly selling versus oligopsony buying, but probably middlemen are largely price takers as the 3 buyers have most of the power.
- Exporters probably are price takers although somewhat less so, if negotiating with close partners or company branches.

Comparing the extent of competition between participants in the chain for gum marketing and marketing of other crops in Tanzania, it can be argued that in the gum marketing, there is no fair competition due to oligopsony. In coffee for instance, TCB (2002) documented that 20 exporters participated during season 2001/02 in which 17 % of the total supply of the product was brought into the market by licensed private traders while the balance was brought by cooperative societies, farmer groups and individual farmers.

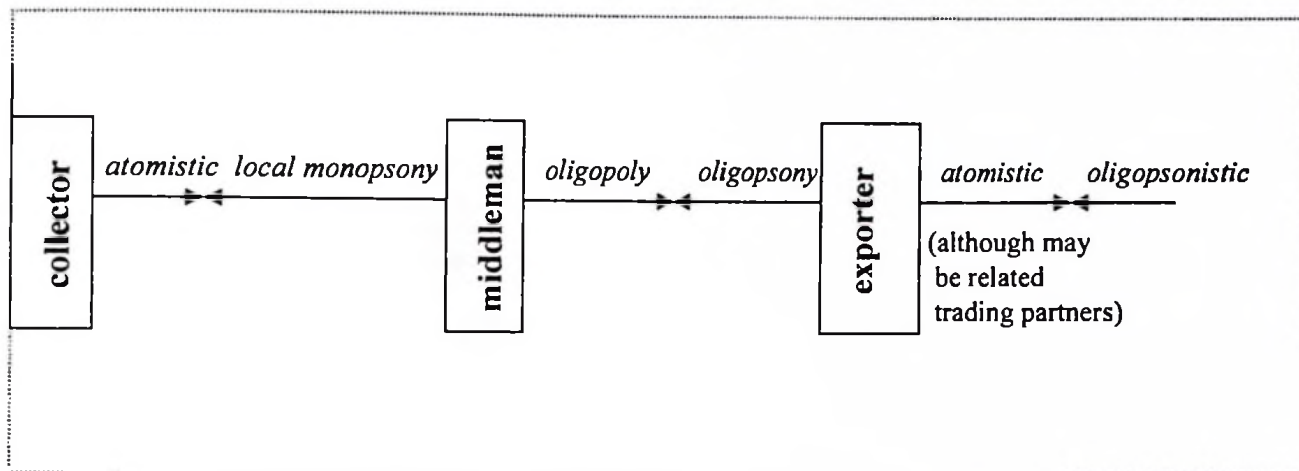


Figure 5.6 Gum arabic market powers in selling and buying in Tanzania

5.4.4 Numerical analyses of marketing aspects of the gum arabic trade in Tanzania

The numerical analyses of were conducted to measure marketing performance. Mathews *et al.* (1964), Rich (1970), Abbott (1987) and Harris (1993) recommended three generally accepted indicators through which analysis of marketing performance could be made, namely:

- Cost analysis, including all expenses incurred to provide marketing services
- Sales analysis, including, volumes of sales and profitability
- Productivity analysis, related to sales revenues and to costs.

In this study, all the three aspects above were combined and employed in the marketing performance analysis. This was achieved using analyses of costs, marketing margins and marketing efficiency. Figure 5.7 and Table 5.3 below present summaries of the results.

5.4.4.1 Costs analysis

The costs involved in the procurement and delivery of gum to Dar Es Salaam, and some processing done by the middlemen and final buyers and exporters, and exportation, for 10 tonnes (TShs 8,011,500) as determined in Chapter IV and presented in Table 4.7, and

Table 5.3 below were used in the analysis of the cost breakdown and are presented in Figure 5.7 below.

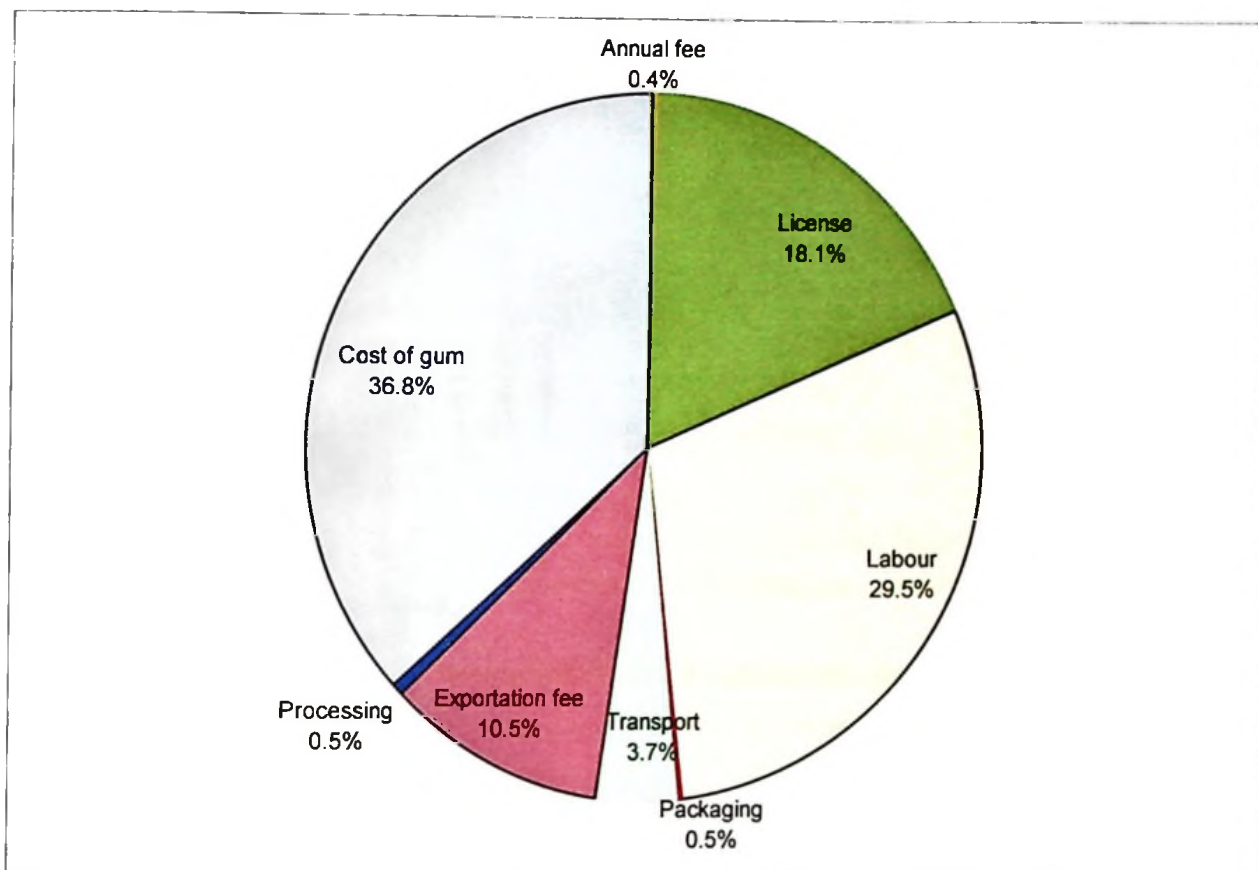


Figure 5.7 Cost breakdown for 10 tonnes of gum arabic in Tanzania

From the figure, it can be seen that the raw material makes up 37 % of the final price, labour 30 % and license up to 18 %. Note that any grading or processing is only a minor element showing how little the activity is done to improve the quality of the product. So the value added to the product in the whole chain is basically gathering together and transport plus taxes. The license fee of TShs 150 kg⁻¹ charged was being complained of by the middlemen and exporters (see Chapter III) although this is probably seldom paid.

Beshai (1984) judged the price elasticity of demand for gum arabic to be low and that of supply to be high. Improvement in the prices, which could be achieved through gum processing, would therefore result in increased gum production and supply. Adamson and Bell (1974), for example, attempted to relate the prices of the various grades of gum arabic in Sudan, assuming the price of Kordofan cleaned gum to be £ x tonne⁻¹ (During

this time, the approximate price was £ 485.20, extracted from Figure 5.1 using Fx converter (2003)):

Grade	Relationship (tonne ⁻¹)
Natural	£ x - 3.0
Cleaned and sifted	£ x + 3.5
Hand-picked selected	£ x + 14.0

Despite complaints of high transport costs by the middlemen and exporters, it can still be concluded that the transport costs were within the limits operating in Africa. This is according to the assessment carried out by von Braun *et al.* (2002), in which it was revealed that, in one third of all African countries transportation costs accounted for over 25 % of the total value of exports. Moreover, for Uganda, this was over 70 %. This problem was also noted by Scarborough and Kydd (1979), Coulter *et al.* (1999) and Becker and Engel (2000) as one of the most binding in developing countries.

The observations on transport costs for gum in Tanzania partly suggests the relatively high value : weight ratio of gum *vis-à-vis* other agricultural commodities in developing countries as noted above. From this study, it can nevertheless, be concluded that labour and license fee were the most binding cost items as far as gum production in Tanzania is concerned.

Table 5.3 Summary of analyses of numerical marketing concepts for gum arabic in Tanzania

Concept analysed	Results				
	Collectors	Middlemen		Final buyers and exporters	
		With tax	Without tax	With tax	Without tax
a. Number of establishments	22,870	8	8	3	3
b. Gum price, TShs kg ⁻¹	304.05	475.00	475.00	458.70 (807.50)	458.70 (807.50)
b ₁ Selling				475.00	475.00
b ₂ Buying	-	304.05	304.05	475.00	475.00
c. Quantity of gum marketed, metric tonnes	4,030	4,030	4,030	4,030	4,030
d. Absolute Marketing Margin, TShs kg ⁻¹ (b ₁ - b ₂)	304.05	170.95	170.95	-16.30 (332.50)	-16.30 (332.50)
e ₁ In relation to selling price (%) (d/b ₁)	100	36.0	36.0	-3.6 (41.2)	-3.6 (41.2)
e ₂ In relation to buying price (%) (d/b ₂)	-	56.2	56.2	-3.4 (70)	-3.4 (70)
f ₁ Labour	242.53	0.68	0.68	0.75	0.75
f ₂ Licence fee	-	150.00	-	-	-
f ₃ Registration fee	-	0.06	0.06	0.02	0.02
f ₄ Packaging	-	4.00	4.00	-	-
f ₅ Transport	-	3.85	3.85	28.10	28.10
f ₆ Exportation fee	-	-	-	87.21	-
f ₇ Preliminary processing	-	2.00	2.00	2.00	2.00
f ₈ Total (f ₁ + f ₂ + + f ₇)	242.53	160.59	10.59	118.08	30.87
g. Net Marketing Margin, TShs kg ⁻¹ (d - f ₈)	61.52	10.36	160.36	-134.38 (214.42)	-47.17 (301.63)
h. Gross Marketing Ratio (d/b ₁)	1.00	0.36	0.36	-0.04 (0.41)	-0.04 (0.41)
i. Net Marketing Ratio (g/b ₁)	0.2	0.02	0.34	-0.29 (0.27)	-0.10 (0.37)
j. Return on Costs [g/(b ₂ + f ₈)]	0.25	0.02	0.51	-0.23 (0.36)	-0.09 (0.60)

Figures in parentheses have been computed using the alternative gum price reported by FAO (1995b) for Sudan's grade II gum talha

5.4.4.2 Marketing margins

Goodwin (1977) defined marketing margin as “the difference between the prices at which the same quantity of product would sell between different levels”. Analyses of the marketing margins as presented in Table 5.3 above were split into Absolute Marketing Margin, Relative Marketing Margin and Net Marketing Margin computed using formulae shown in the table as described by Briz and de Felipe (1997), and these indicated the following results:

Absolute Marketing Margin (AMM)

The table shows that during the study period, the collectors enjoyed the highest AMM of TShs 304.05 kg⁻¹ followed by the middlemen (TShs 170.95 kg⁻¹) and the final buyers and exporters suffered a loss of TShs 16.30 kg⁻¹ if a weighted mean price of TShs 458.70 kg⁻¹ was used. Nevertheless, this group would enjoy the highest margin of TShs 332.50 kg⁻¹ if the price of TShs 807.50 kg⁻¹ (FAO, 1995b) was used. The apparently high AMM for the collectors is because this group does not buy the gum but collects it.

Relative Marketing Margin (RMM)

RMM in relation to selling price

In these analyses again, for the same reason as given in the AMM above, the collectors enjoyed the highest margin (100 %), followed by the middlemen (36.0 %) and lastly the final buyers and exporters (-3.6 and 41.2 % for the weighted mean price and the alternative price respectively).

RMM in relation to buying price

Only the middlemen and the final buyers and exporters of gum were considered in this analysis since the collectors did not participate in buying gum. The middlemen enjoyed a higher margin (56.2 %) than the final buyers and exporters who again suffered a loss of 3.4 % under the weighted mean price but would have enjoyed a higher margin of 70 % under the reported world market price (FAO, 1995b).

Net Marketing Margin (NMM)

In this measure which takes into account the costs involved, the collectors seemed to enjoy the highest margin (TShs 61.52 kg⁻¹) ahead of the middlemen (TShs 10.36 kg⁻¹) whereas the final buyers and exporters suffered a loss of TShs 134.38 kg⁻¹ under the weighted mean price of TShs 458.70 kg⁻¹. However, under the alternative world market price of TShs 807.50 kg⁻¹ for grade II gum talha reported by FAO (1995b), the final buyers and exporters would have been enjoying the highest margin of TShs 214.42 kg⁻¹.

If taxes are avoided (licence fee for the middleman and exportation fee for the exporter), which seems to be the case for most of the licence fee and for 75 % of the exportation fee, the figures improve to TShs 160.36 kg⁻¹ for the middlemen and TShs -47.17 kg⁻¹ and TShs 301.63 kg⁻¹ for the exporters if the current official and the grade II gum talha prices are used respectively.

5.4.4.3 Marketing efficiency

The efficiency in the marketing of gum arabic between the different levels in the chain was analysed using Gross Marketing Ratio (GMR), Net Marketing Ratio (NMR) and Return on Costs (RoC) tools whose formulae and results are shown in Table 5.3 above.

Gross Marketing Ratio (GMR)

Under this assessment criterion, the collectors had the highest value (1.00) followed by the middlemen (0.36) whereas the final buyers and exporters lowest value (-0.04) under the weighted mean price of TShs 458.70 kg⁻¹. However, under the alternative world market price of TShs 807.50 kg⁻¹, the final buyers and exporters would have performed slightly better than the middlemen (0.41).

Tax evasion has no effect on the GMR, since the selling price and AMM which are used in its calculation are also not affected.

Net Marketing Ratio (NMR)

The collectors were getting a NMR of 0.2 which appeared to be the highest in the chain with 0.02 for the middlemen and the least NMR of -0.29 was for the final buyers and exporters. With tax avoidance, the figures for the middlemen and exporters rise to 0.34 which is the highest and -0.10 respectively. The final buyers and exporters enjoy the highest NMR of 0.37, only if the alternative world market price of TShs 807.50 kg⁻¹ is used, and the exportation tax is evaded.

Return on Costs

The collectors seemed to be enjoying the highest RoC of 0.25 followed by the middlemen (0.02) and the exporters were at a loss of RoC of -0.23 if the current official price was used. If there were tax avoidance, the middlemen would then be getting the highest RoC of 0.51 whereas the exporters would still be losing, however, with an improvement to RoC of -0.09. The exporters would get RoC of 0.36 and 0.60 if the alternative price was used and the tax was paid in the former case but evaded in the later.

From the above observed results, the following conclusions can be drawn:

- Each firm in the chain appears to be making a positive net marketing margin but, in the case of exporters, this happens only if they are obtaining a higher price for the product and are avoiding most of the exportation fee, both of which portray a picture that is close to the truth. Goodwin (1977) and Abbott (1987) noted that nobody would be eager to operate under circumstances in which the total costs of operations are not covered. It can be strongly argued here that most of the gum trade in the country was undercover, done by under-invoicing both the values and volumes of the gum exports, as noted by Maliyamkono and Bagachwa (1990) for Tanzania's agricultural exports. In so doing, the majority of the gum export was neither licensed nor exportation fee paid as depicted in Chapter IV, Table 4.6.
- The gum collectors were the most disadvantaged group in the marketing chain, getting the lowest NMR and RoC, which is a good measure of firm's marketing profitability. As noted by Abbott (1987), in an environment of low wages and high unemployment, one may accept very low net income for lack of an alternative. Though this group seemed to obtain a high RMM in relation to selling price, the collectors were not involved in any buying of the gum. Further analysis shows that this group incurred 99.6 % of the total labour costs and this constituted 30.4 % of the total costs, in the whole chain of marketing the gum arabic in Tanzania consequently, the NMR and RoC were the lowest.
- Given their lack of bargaining power, the collectors obtain the lowest NMR and, probably, RoC. However, the middlemen seem to enjoy a greater return than the exporters. This may be because of differences in the relative market power in buying and selling as shown (see Figure 5.6 above).

5.4.5 Estimating supply shifts over time

An attempt was made to devise a hypothetical supply/demand picture of gum arabic at the field level to predict what would happen to supplies if the overall price changed, and the payment system changed with a higher price for gum arabic and a lower price for *Acacia drepanolobium* gums. The underlying assumption was a horizontal demand of gum in a particular year, externally determined in the world market and supply as a function of rainfall-tree productivity, opportunity cost of collector's time and proximity to supply.

Since supply was in the previous chapters found to be dependent upon price, time (changes in the *Acacia* stocking levels) and weather conditions, particularly rainfall, then it could be expressed in the following simple equation:

$$S = f(p, t, r)$$

Where: S = gum supply,
 p = gum price,
 t = time, in years,
 r = rainfall,

However, it was not possible to carry out a multiple regression analysis of gum supply against price, time trend and rainfall pattern during the study period because of the limited number of observations for the exogenous variables, since the degree of freedom for the variable observations did not meet the minimum requirements. However, these parameters were used to plot Figure 5.8 below. Figure 5.8 indicates that there was a downward trend in the supply of gum arabic to the market, despite general improvements in real prices during the study period with the biggest shock to the supply shown by the gap between the 1999 and 2000 supply curves.

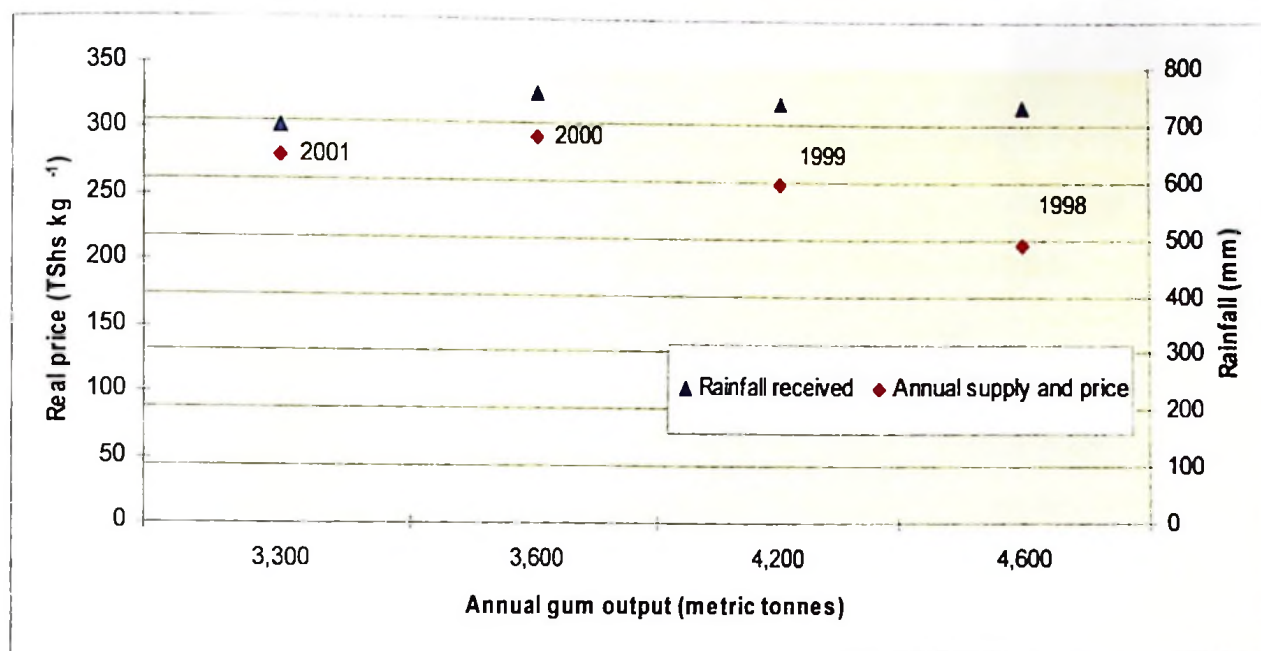


Figure 5.8 Tanzania annual gum output versus real price.

The figure suggests that the effect of price on gum supply, was completely overwhelmed by the negative influence of the time trend and rainfall. The negative effect indicated by the time trend could be the influence of deforestation, making supplies more difficult to obtain.

Rainfall statistics during the study period indicated that the study areas received an average annual amount of 729.8, 735.3, 750.5 and 692.8 mm in 1998, 1999, 2000 and 2001 respectively. An attempt to explain the wider gap between the 1999 and 2000 supply curves could be made from the rainfall statistics since relatively high rainfall might be expected to reduce supplies. This may be because the opportunity cost of collectors' time is higher when they get good income from agriculture in good rainfall years. However, since the rainfall was not significantly higher in 2000, this might not be the major influence. One major reason for the big decline in the supply might be the rise in world oil prices as Energy Information Administration (2003) reported that the prices tripled during 1999-2000. The effect of this is on the increased transport (procurement) costs which is a disincentive to both the middlemen and the final buyers and exporters.

It could still be argued that price could be used to boost the gum supply, as shown in the graph presented in Figure 5.9 below. The current price, a is characterised by low valuation of gum, collection is carried out where easiest/closest and gum trees seem to be of low value with regard to their future gum productivity as compared to their current value of the wood and are therefore felled for other requirements. In this situation, the supply trend is downward (shifting to the left), indicated by the arrows pointing to the left. This is the typical current situation characterizing Tanzania's gum supply.

If prices were improved, more potential collectors would be joining the business, and collection would extend even further afield and in areas that are more difficult until the price received is outweighed by the cost of the extra collection. However, it is assumed that there would still be downward trend in gum availability due to deforestation. Eventually, further improvements to the price would raise the value of the gum *vis-à-vis* the wood, and other products to the point (price b) at which the trees would become protected. At this price, the supply curve would be stable, if rainfall remains constant.

Under an even higher price (c), more and more potential collectors would be expected to come in, and the gum trees would also become very valuable and therefore the existing ones would be protected and more planted for gum production. In this price scenario, there would be an upward trend in gum supply indicated by the arrows pointing to the right.

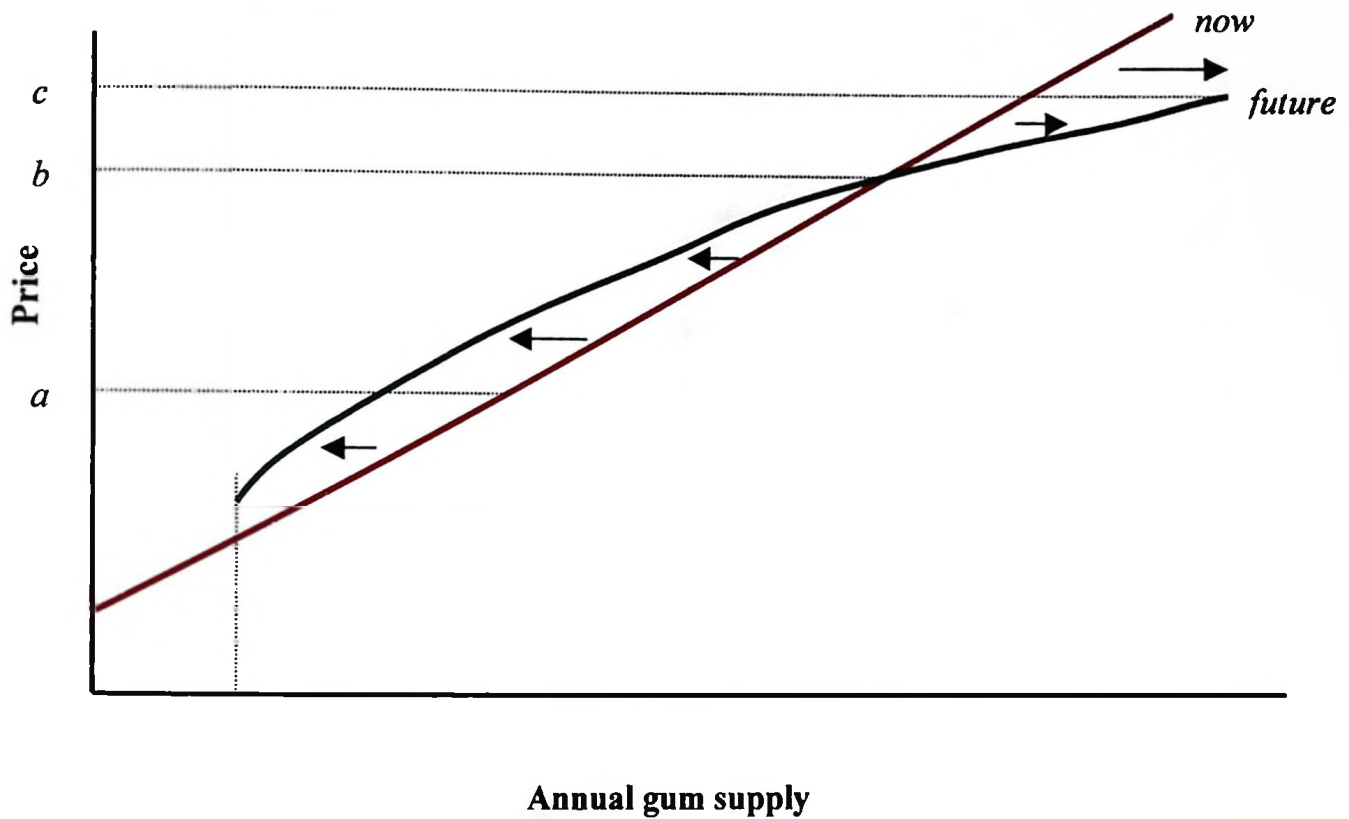


Figure 5.9 Hypothetical gum supply curve for Tanzania under different price regimes.

Similarly, if quality of gum were rewarded by a differentiated price, there would be less collection of gum from *Acacia drepanolobium* nearby but more *A. senegal* further afield at prices *b* and *c*. The prices would eventually encourage protection and planting of *A. senegal* trees, encourage formation of growers associations and might also change the lifestyle of collectors from the current nomadic to permanent settling. However, there might also be additional felling of *A. drepanolobium* as users switch from the use of *A. senegal* and consequently, a more rapid depletion of the resources on this species.

5.5 Conclusions and recommendations

5.5.1 Conclusions

From this section of the study, it can be concluded that gum arabic marketing in Tanzania is characterised by spatial local monopsony and oligopoly, lack of transparency and apparently illegal practices of participants, particularly the final buyers and exporters. This trade is purely a private enterprise activity largely controlled by the final buyers and exporters of the product, who are currently only three. The role of the government is only in the collection of revenues in the form of fees, from the middlemen and the final buyers and exporters which is also not adequately carried out as there appears to be a great deal of avoidance of official channels in the trade. The collectors are the most disadvantaged group receiving the minimum payment in the whole chain.

Marketing of gum arabic in the country is highly disorganised and introduction of collectors' associations would provide greater bargaining power. However, this is likely to meet bottlenecks, as the collectors are small-scale, highly scattered over fairly large areas, mobile, consider the activity to be secondary and have the lowest formal education.

There is a serious lack of a clear definition of gum arabic at all levels in Tanzania, making its collection and handling haphazard. In addition, very little cost is incurred in gum processing, an activity that has significant potential in the improvement of the prices offered in the whole chain. There are indications that the re-exporters of gum carry out processing of the product and benefit from the added value. Certainly, as Table 4.6 shows, even with current official production, if gum from *Acacia senegal* were to be sorted out, the potential revenue would much exceed that currently gained.

Pricing mechanisms could be employed to boost the supply of the country's gum and also provide incentives for the protection, conservation and or planting the *Acacia senegal* trees, when the value of the gum makes retaining the trees worthwhile. This could also

help reducing the nomadic mode of life by raising the living standards of the rural people around the gum resources.

5.5.2 Recommendations

From this study, the following recommendations can be made:

- Government interventions are important in the formulation of a bureau for gum quality checks and grading and the export trade in general. But the government should act as a helper rather than as quality police officer in the following aspects;
 - Conducting informal training on the right gum tree species identification and collection to the collectors,
 - Supplying market information and encouraging competition by helping other businesses to get involved
- More research on gum marketing in Tanzania is needed, particularly on the market prices offered by the exporters and on alternative pricing strictness and the reasons why these have not been adopted.
- A clear definition for gum arabic needs to be given to the all stakeholders for significant improvement of gum grades, therefore markets, and prices.
- There is a need to find out whether there are markets for gums from other *Acacia* species from Tanzania.
- More research on the likely effects on other species and vegetation if price differentiation with regard to grades were to be introduced.

CHAPTER VI

GENERAL CONCLUSIONS AND RECOMMENDATIONS

6.1 General conclusions

6.1.1 Gum yield

6.1.1.1 Amounts, range and influences

From the gum yield studies, it can be concluded that gum arabic yield per tree is extremely variable, with most of the trees producing gum below 360 g tree^{-1} and 30 % producing nothing at all. Nevertheless, the mean gum arabic yield per tree (246 g) is close to the reported average in Sudan and Kenya (250 g) and higher than that reported for Mauritania (100 g). The gum yield is positively influenced by tree size particularly diameter, peaking at around 12 cm. The environmental factors of importance are temperature, fire intensity and stem crowdedness.

6.1.1.2 Stocks of *Acacia senegal*, influence and potential production of gum

Vast *Acacia senegal* natural woodlands were identified in Dodoma Rural, Singida Rural, Iramba, Igunga, Shinyanga Rural, Maswa, Meatu, Bukombe, Geita, Babati and Kiteto districts. Other occurrences were in Kilosa district (Morogoro) in Mikumi National Park and Lindi district. The overall mean population density of *Acacia senegal* was estimated as $225 \text{ stems ha}^{-1}$ and is marginally influenced by altitude and also temperature. The highest densities are expected in areas with average elevations, highest mean annual temperatures and lowest mean annual rainfall. The biological potential production of gum arabic in the country stands at $424,000 \text{ tonnes year}^{-1}$. It must be borne in mind that although there is a vast biological potential for production of gum, the physical potential may be less because of limitations on what is collectable. Furthermore, this physical potential is further limited to what might be termed its economic potential – that which is

worth collecting and trading from an economic point of view along the chain. Given the population of the gum collectors and other conditions, the annual harvestable target can be considered at about 4,000 tonnes of pure gum arabic.

6.1.2 Actual gum production

6.1.2.1 Amounts and quality

It can be concluded from the survey of actual gum arabic production that the annual production for the country is about 4,000 metric tonnes. This figure is four times higher than the official national statistics and earlier published reports of 910 and 1,000 tonnes respectively, suggesting that the bulk of the gum is traded unofficially. It is evident, however, that the gum from Tanzania is mixed with gum from other *Acacia* species, the bulk being from *Acacia drepanolobium* and traded in admixture without grading at all. The gum therefore does not qualify for the name gum arabic but rather gum talha.

6.1.2.2 Collectors, methods and constraints

All gum from Tanzania is collected from trees in natural stands and not by tapping, mainly by women, children and male livestock herders in rural areas around the gum resources. Compared to non-collectors, the collectors are disadvantaged in terms of per capita income, level of education, house type, farm size and also occupation. The occupation of gum collection is highly labour-intensive and considered secondary and inferior. Other constraints to the gum industry in the country include low prices offered, market uncertainties and the high rate of deforestation which dwindles the gum resources. Nonetheless, under deliberate government interventions, most of these constraints can be subjugated.

6.1.3 Importance of gum arabic

6.1.3.1 Actual and potential contribution

From the study on the economic importance of gum arabic in Tanzania, it can be concluded that the product is important to the subsistence economy of about 23,000 people most of whom are rural based, using it for food, medicine and glue. The gum is also economically important to the collectors, the middlemen, the final buyers and exporters and local and central governments.

6.1.3.2 Constraints

There is little attention paid by the governments to tapping the potentials of this resource as very little is collected as revenue. Results indicate that during the study period of four years, TShs 4,512,157 (only 0.25 %) had been collected as revenue by local governments instead of TShs 1,818,220,005.

Also, no use is made of the gum by the country's industries as all requirements are met by imports.

6.1.4 Marketing of gum

6.1.4.1 Marketing structure, margins and profitability

The marketing chain for gum arabic in Tanzania is composed of gum collectors (22,870), middlemen (8) and final buyers and exporters of the product (3). The collectors are atomistic suppliers to local monopsonistic buyers (middlemen) who themselves are oligopolistic suppliers of gum to oligopsonistic buyers (final buyers and exporters). The final buyers and exporters assume a role of atomistic suppliers into an oligopsonistic world market for gum arabic.

The profit margin kg^{-1} of these actors is estimated as TShs 61.52, between 10.36 and 160.36 and between -134.38 and 301.63 for the collectors, middlemen and final buyers and exporters respectively. The profitability of gum marketing is realised by selling: any amount by the collector, from 0.2 tonnes by the middlemen and from 0.1 tonnes by the final buyers and exporters.

6.1.4.2 Constraints and improvements to supply

Study of gum marketing concludes that there is a serious lack of a clear definition of gum arabic at all levels in Tanzania. This leads to haphazard collection of gum from low-grade botanic sources and little processing and grading is carried out before export. The business is purely a private enterprise, highly disorganised and controlled by the final buyers and exporters and, to an extent, the middlemen. The collectors are the most disadvantaged group, receiving the lowest return in the whole chain.

Despite the above situation, introduction of gum collectors' associations for improving the occupation through improving bargaining power, a means of improving the position of the collectors would seem to meet bottlenecks, as they are highly scattered, mobile, consider the activity to be secondary and have the lowest formal education.

Improvements in the price given to the collectors however, might help curbing the downward trend in the country's gum arabic supply by attracting more collectors, and encouraging conservation and planting of more *Acacia senegal* trees. Establishment of *A. senegal* plantations as a source of gum is economically feasible at current price of TShs 500 kg^{-1} to collectors, with an estimated Land Expectation Value of TShs 814,529, Net Present Value of TShs 469,089 and Internal Rate of Return of 63 % at a rotation age of 9 years and discount rate of 10 %.

6.1.5 Overall conclusion regarding hypotheses

The yield of gum arabic can be measured and estimated using dbh and height. Environmental factors of importance are temperature, fire and stem crowdedness but with the constraints of the limited data on these factors, they can only explain some of the variation in yield. The actual production of gum arabic is much less than its potential and appears to be constrained by the marketing structure inefficiency and deforestation.

6.2 General recommendations

From this study, the following general recommendations can be made:

6.2.1 Improvements of quality of gum arabic and its collection methods

It is strongly recommended that for improvements in the quality of gum arabic from the country to be made, firstly, a clear definition of gum arabic be given to all stakeholders. This is important for collection, processing and marketing of the gum to be made by identity of the botanic source.

Secondly, it is recommended that tapping of trees be conducted in order to ensure constant quality of gum as this method also gives a more consistent and better-formed gum than collection from wounds caused by other injuries. Yet, tapping greatly saves the time that is spent searching for collectable gum trees.

The above two recommendations can be implemented through extension services in which the collectors, middlemen and exporters will be educated concerning which trees should be selected and how grading can be carried out. The collectors should also be given demonstrations of tapping methods.

Thirdly, it is also recommended for the government to get involved in helping with gum market information and perhaps research with the interested parties in order to cultivate their interest in gum.

Fourthly, payment methods should be reflective of the gum quality to encourage production of high quality gum and to value the resources. There will be no point doing the other things if there is no incentive to improve quality. But, a price structure cannot be enforced by governments. Discussions and research to show the effects of different price structures to convince parties that this is more profitable for all, need to be carried out. This would also then only work if markets for the quality could be found and Tanzania's gum be marketed forcefully with high quality, reliable and regular supplies.

6.2.2 Improvements in the marketing of gum arabic

The marketing of gum arabic from Tanzania needs to be improved at all levels in the chain. This can be achieved through:

- Improvement in the infrastructure, particularly roads, to cut down the costs and facilitate gum procurement
- Provision of adequate periodic market information on gum market performance trends such as buyers, prices, quality requirements and demands
- Finding out why there are so few middlemen and final buyers and exporters and then enhancement of fair internal gum market competition by inviting participation of more middlemen and exporters, which might lead to selling by auctioning.

6.2.3 Marketability of gums from other *Acacia* spp.

There is a need to find out whether there is a market for gum from other acacias, particularly *Acacia nilotica* (gum babul). From the inventories of species associated with *A. senegal* it has been observed that there is enough growing stock of *A. nilotica* trees in many of the gum-producing areas.

6.2.4 Contribution of gum arabic in Tanzania

The study recommends collection and trade in gum to be closely monitored in order to have more reliable local and national statistics and appropriate returns through taxation and duties. This will also enhance improvement in the contribution of forestry to the recorded revenues of both local and central governments. The government should also create conducive environments for utilization of the gum by the local industries thereby saving foreign exchange used for importing the raw material requirements.

Processing of gum from Tanzania should be given consideration by the stakeholders in order to improve the prices offered and therefore the government revenues and living standards of the rural people. This can be achieved through sensitization programmes by the government. Special consideration should be put towards improving the share of income from activities that goes to the collector, as this might encourage higher supply of gum and yet, of better quality.

Taxes should be enforced, but these should not be too high as to be a disincentive to production, sales and exporting.

6.2.5 The future of the industry

It is recommended by this study that conservation of the existing *A. senegal* resources and establishment of gum plantations are carried out by all stakeholders. It is unlikely

that these would happen naturally: the collectors, middlemen and exporters therefore need to be encouraged, perhaps via research or development projects.

These methods, in conjunction with tapping and improvements in the payment systems, would also greatly improve the production and quality of gum arabic from Tanzania.

6.2.6 Further investigations

More research into the causes and physiology of gum production is needed since the mechanisms inducing gum biosynthesis and gummosis are still not fully understood. This will facilitate manipulation of conditions favourable for optimum gum production, from the tree characteristics to the environmental factors and their effects on the production life span of the tree.

The other area of utmost importance for further investigation is the gum arabic quality and its influencing factors. As has been observed in this study, there has not yet been any study of the chemical properties of *Acacia senegal* gum from Tanzania. Such studies will enhance comparisons with reported properties of the gum from other countries.

It should be noted that any solutions or interventions need to be holistic since for them to work, lots of other things have to be right; for example, better tapping techniques, better information, better infrastructure, better market arrangements overseas and better prices are needed – having only one of these would not work.

6.3 Main contributions of this work to knowledge

Such wide ranging research on gum arabic in Tanzania has never been carried out before, so the findings herein form new knowledge to science. The main contributions of this work could be summed up as follows:

1. The biological potential annual production of gum arabic in Tanzania is estimated at 424,000 tonnes if all trees were tapped. The production is positively influenced, mainly by the tree size, ambient temperatures and fire. The actual annual production of gum stands at around 4,000 tonnes out of which only 34 % is collected from *Acacia senegal* so, could be qualified as gum arabic. The official records however, indicate an annual production of about 900 tonnes, the balance of about 75 % therefore is not captured in the official statistics, nor the revenues therefrom. The actual production is influenced mainly by the availability of gum trees, gum prices and weather, so could mainly be improved through pricing mechanisms and planting and conserving the existing gum resources.
2. The population of gum collectors is estimated at 22,870 whose identity could be summarised as: women (44 %), children (31 %) and men (25 %). These are generally the socio-economically disadvantaged group living in rural areas, characterised mainly by a semi-nomadic way of living. The population of middlemen is 8, living in centres and towns around gum collection areas. All three final buyers and exporters, who mainly control the marketing chain of gum live in Dar Es Salaam, at least 800 km away from the middlemen. The gum marketing chain has been analysed and described.
3. The methodologies used in these studies were not new, but were applied in novel ways to suit the conditions. The yield prediction equations, for instance, have been developed to provide guidance on what levels one might expect from a certain tree size, as have the supply and the *Acacia senegal* plantation models, all of which suit the Tanzania conditions.
4. Through the findings and the recommendations made in these studies, this work all as a whole has opened the way for researchers and policy makers to take and run with it further.

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APPENDICES

Appendix I

Table 1 Summary of the sample gum tree characteristics in each district

District	Dbh (cm)			Height (m)			Branches		
	Range	Mean	Sd	Range	Mean	Sd	Range	Mean	Sd
Dodoma	2.0 – 32.0	6.7	4.4	1.5 – 18.0	3.2	2.7	2 - 10	4	1.8
Singida	2.0 - 16.5	5.3	2.7	1.5 – 6.0	2.6	0.6	2 - 9	4	1.2
Iramba	2.0 – 16.0	5.0	2.4	1.5 – 6.0	2.6	0.8	2 - 8	6	1.5
Igunga	2.0 – 20.0	5.7	3.3	1.0 - 4.5	3.0	0.9	2 - 8	5	1.5
Shinyanga	2.0 - 16.5	5.1	2.7	1.5 – 5.0	3.5	1.1	3 - 9	5	1.4
Maswa	1.0 - 12.0	5.1	2.4	1.0 – 12.0	2.7	0.9	2 - 8	5	1.6
Meatu	2.5 – 32.0	6.8	4.4	1.5 – 8.0	3.7	1.5	3 - 8	4	1.0
Babati	2.0 – 13.0	5.0	2.3	2.0 – 12.0	2.8	0.7	2 - 7	5	1.4
Kiteto	2.0 – 10.0	4.8	1.9	2.0 – 5.0	2.5	0.6	2 - 8	5	1.4
Bukombe	2.0 – 12.0	5.9	2.2	1.5 – 6.0	3.5	1.2	2 - 9	5	1.1
Geita	2.0 – 20.0	5.9	3.0	1.5 – 5.0	3.3	1.5	2 - 7	5	1.3

A summary of the sampled gum tree characteristics in each district is given in Appendix I, Table 1.

Table 2 Matrix of correlation between gum arabic yield and the assessed factors

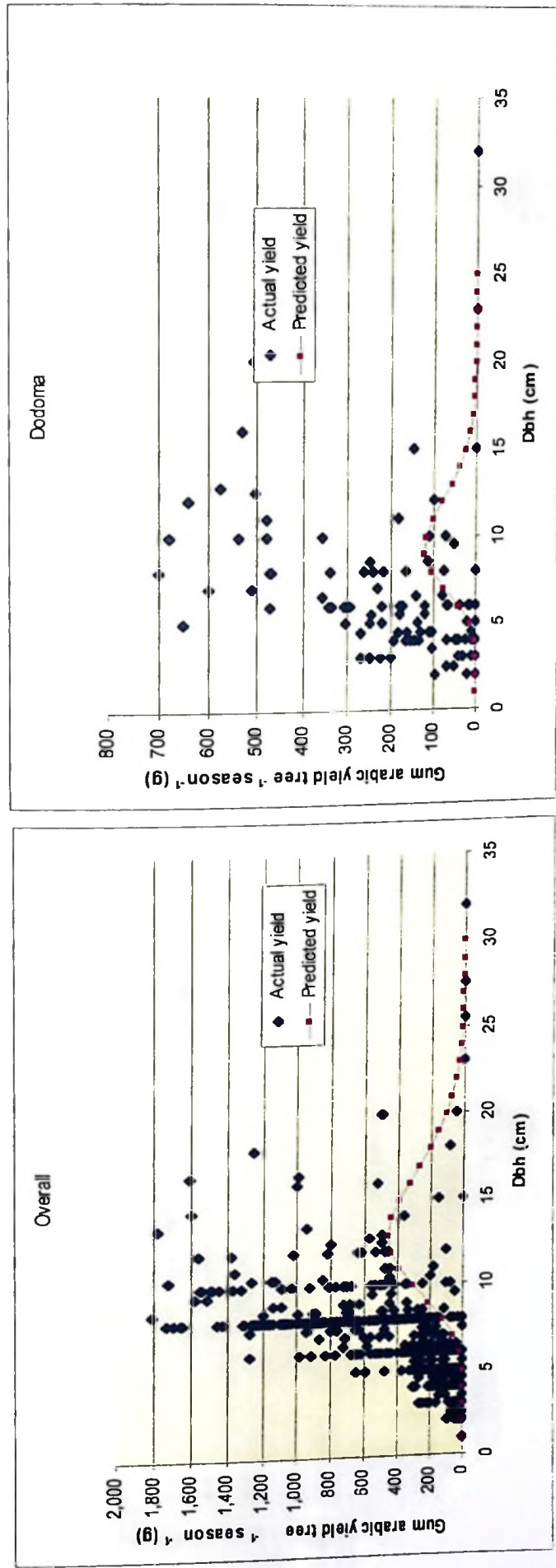
	masl	In.masl	masl^2	Slope	In.slope	slope^2	f2	f3	stems	In.stem	stem^2	dbh	In.dbh	dbh^2	ht	In.ht	ht^2	Branches	In.branch	branch^2	Yield	In.yield	yield^2
masl	1.00																						
In.masl	1.00	1.00																					
masl^2	1.00	1.00	1.00																				
Slope	0.03	0.03	0.03	1.00																			
In.slope	0.02	0.02	0.02	0.97	1.00																		
slope^2	0.02	0.03	0.02	0.91	0.79	1.00																	
f2	0.01	0.00	0.01	0.13	0.18	0.04	1.00																
f3	0.08	0.08	0.09	0.03	-0.01	0.10	-0.46	1.00															
stems	0.16	0.15	0.17	-0.04	0.01	-0.11	0.14	-0.17	1.00														
In.stem	0.12	0.11	0.13	-0.11	-0.05	-0.19	0.14	-0.21	0.93	1.00													
stem^2	0.19	0.18	0.20	0.01	0.05	-0.06	0.13	-0.10	0.94	0.76	1.00												
dbh	-0.03	-0.02	-0.03	0.07	0.06	0.09	0.02	0.12	-0.05	-0.06	-0.04	1.00											
In.dbh	-0.03	-0.03	-0.04	0.05	0.04	0.07	0.01	0.10	-0.02	-0.02	-0.01	0.91	1.00										
dbh^2	-0.03	-0.02	-0.03	0.08	0.07	0.08	0.03	0.10	-0.07	-0.09	-0.05	0.89	0.64	1.00									
ht	-0.10	-0.10	-0.10	0.05	0.05	0.03	0.06	0.06	0.07	0.06	0.08	0.74	0.64	0.71	1.00								
In.ht	-0.12	-0.12	-0.12	0.04	0.05	0.02	0.05	0.06	0.12	0.12	0.10	0.72	0.72	0.57	0.92	1.00							
ht^2	-0.06	-0.06	-0.06	0.06	0.06	0.05	0.05	0.04	0.00	-0.01	0.02	0.61	0.43	0.70	0.89	0.65	1.00						
Branches	0.10	0.10	0.10	0.06	0.06	0.06	0.04	0.05	-0.01	0.01	-0.02	0.03	0.00	0.01	0.06	0.04	0.09	1.00					
In.branch	0.10	0.10	0.10	0.05	0.05	0.04	0.05	-0.02	0.01	-0.01	0.02	0.00	0.00	-0.01	0.05	0.04	0.07	0.98	1.00				
branch^2	0.09	0.09	0.09	0.09	0.06	0.07	0.05	-0.01	0.01	-0.02	0.03	0.01	0.01	0.01	0.07	0.04	0.11	0.98	0.93	1.00			
Yield	-0.02	-0.02	-0.02	0.01	0.00	0.02	-0.01	0.20	-0.01	0.00	-0.03	0.55	0.60	0.31	0.35	0.45	0.15	0.01	0.02	0.00	1.00		
In.yield	0.00	0.00	0.00	0.00	0.03	0.02	0.04	-0.06	0.16	0.00	-0.01	0.50	0.67	0.21	0.29	0.43	0.09	-0.02	-0.02	-0.02	0.61	1.00	
yield^2	-0.03	-0.03	-0.03	0.01	0.01	0.02	-0.01	0.17	-0.01	0.01	-0.03	0.43	0.43	0.26	0.27	0.34	0.12	0.00	0.01	-0.01	0.93	0.40	1.00

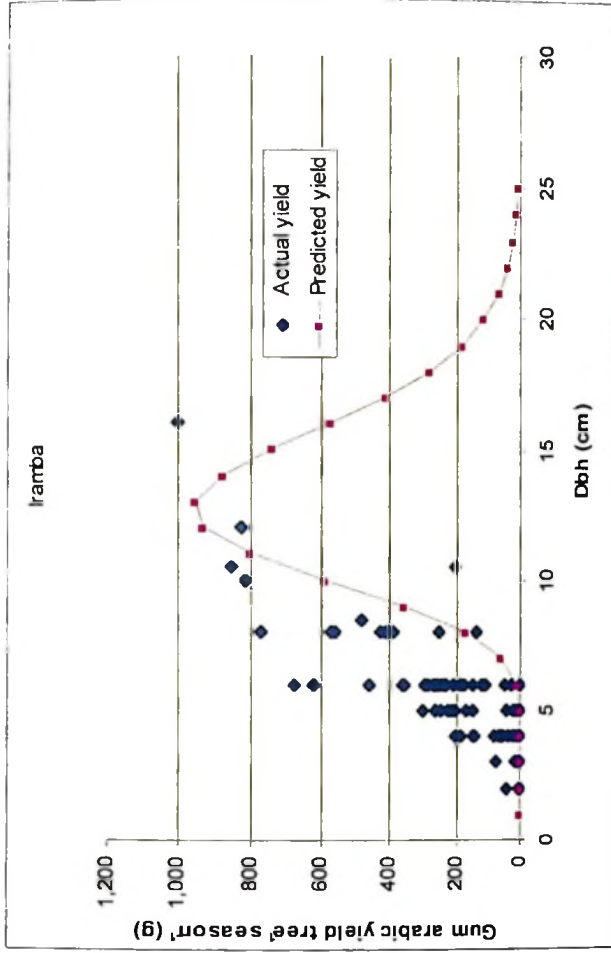
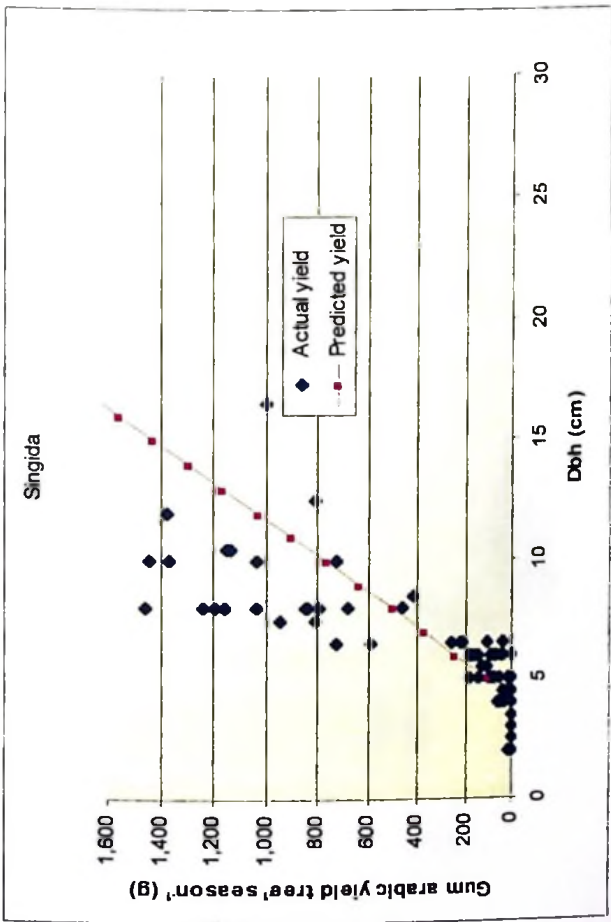
Table 3 Summary of regression analyses results for gum yield and tree diameter and height in each district.

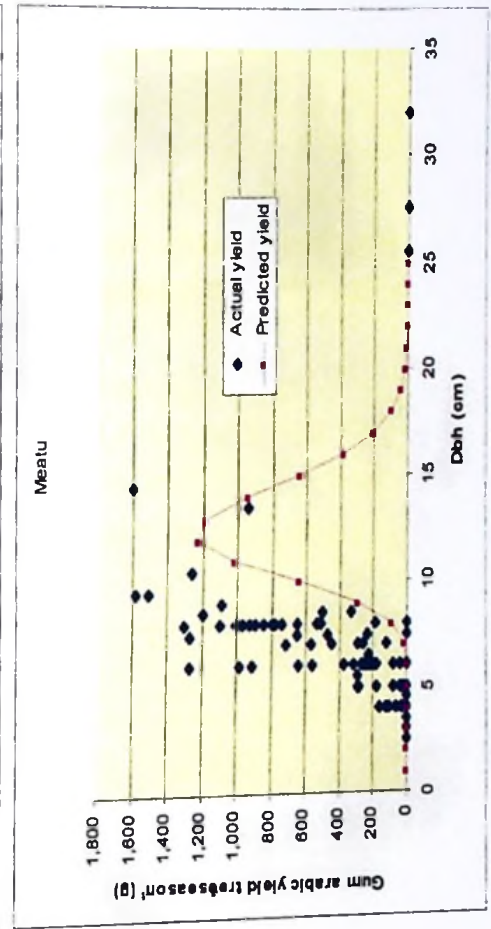
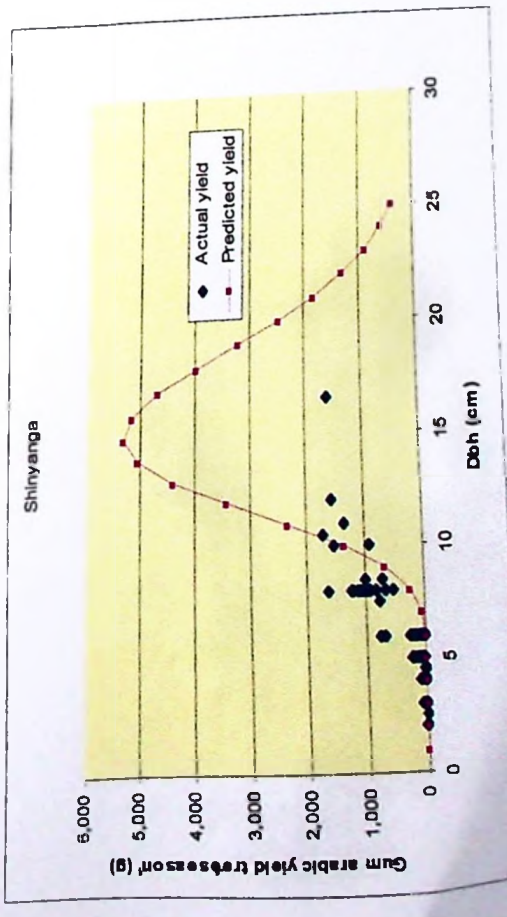
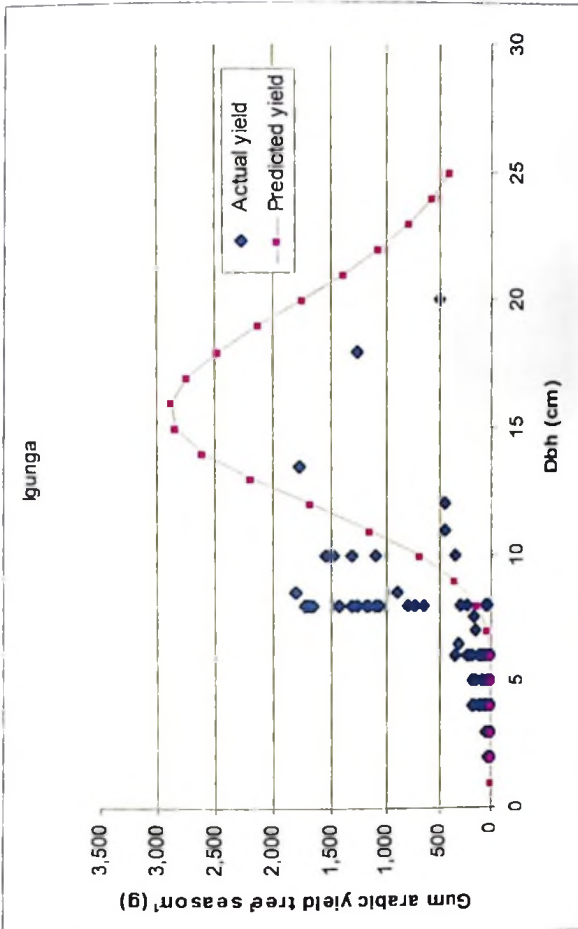
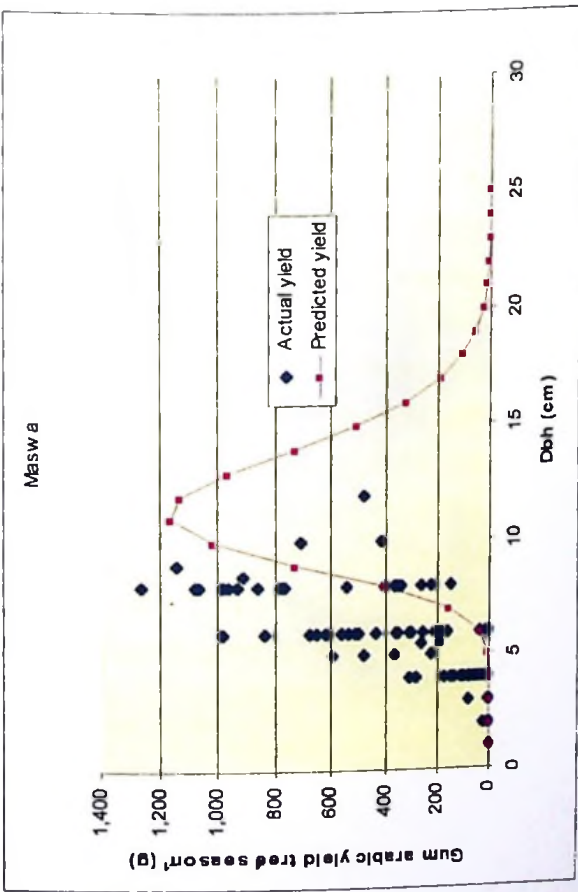
Regression coefficients									
District	Diameter					Height			
	Constant	Dbh	lnDbh	Dbh ²	R ²	Constant	Ht	lnHt	R ²
Dodoma	-6.15	-1.18	9.8			0.15	-2.12	9.65	
	-2.14	-0.24	(1.96)		0.21	-1.22	-0.38	-2.1	0.25
	p<0.01	p<0.01	p<0.01			p=0.90	p<0.01	p<0.01	
Singida	-419.27	131.99		-0.42		-17.68	-6.91	37.29	
	-93.19	-29.63		-2.07	0.66	-2.74	-6.97	-19.68	0.29
	p<0.01	p<0.01		p=0.84		p<0.01	p=0.32	p=0.06	
Iramba	-15.49	-1.31	15.32			-8.16	-5.09	24.51	
	-1.84	-0.58	(2.87)		0.52	-1.91	-3.45	-9.58	0.24
	p<0.01	p=0.03	p<0.01			p<0.01	p=0.14	p=0.01	
Igunga	-15.62	-0.95	13.97			-14.98	-3.77	25.76	
	-1.65	-0.38	(2.17)		0.60	-2.37	-3.56	-11.13	0.35
	p<0.01	p<0.01	p<0.01			p<0.01	p=0.02	p=0.02	
Shinyanga	-17.21	-1.11	15.66			-11.55	1.82	4.91	
	-1.82	-0.55	(2.81)		0.61	-2.56	-3.05	-9.94	0.26
	p<0.01	p=0.04	p<0.01			p<0.01	p=0.55	p=0.62	
Maswa	-14.37	-1.56	16.08			-9.29	0.67	10.07	
	-1.33	-0.59	(2.55)		0.67	-2.07	-2.73	-6.4	0.43
	p<0.01	p=0.01	p<0.01			p<0.01	p=0.81	p=0.12	
Meatu	-31.28	-2.38	26.93			-20.64	-7.28	38.65	
	-3.62	-0.29	(2.92)		0.47	-4.78	-1.62	-8.08	0.20
	p<0.01	p<0.01	p<0.01			p<0.01	p<0.01	p<0.01	
Bukombe	-20.73	-0.92	16.18			-11.41	-1.94	16.18	
	-3.11	-0.89	(4.65)		0.56	-3.24	-2.44	-9.15	0.22
	p<0.01	p<0.01	p<0.01			p<0.01	p=0.43	p=0.08	
Geita	-15.89	-1.15	14.79			-9.83	-3.37	20.48	
	-1.9	-0.4	(2.32)		0.51	-1.61	-0.96	-3.65	0.35
	p<0.01	p<0.01	p<0.01			p<0.01	p<0.01	p<0.01	
Babati	-14.87	-0.2	10.51			-16.72	-8.87	41.74	
	-2.18	-0.74	(3.57)		0.46	-1.91	-4.34	-11.96	0.51
	p<0.01	p=0.79	p<0.01			p<0.01	p=0.04	p<0.01	
Kiteto	-13.92	2.59	-0.25			-18.19	-9.93	46.03	
	-2.56	-1.21	(5.26)		0.46	-2.33	-5.58	-15.49	0.38
	p<0.01	p=0.04	p=0.96			p<0.01	p=0.08	p<0.01	

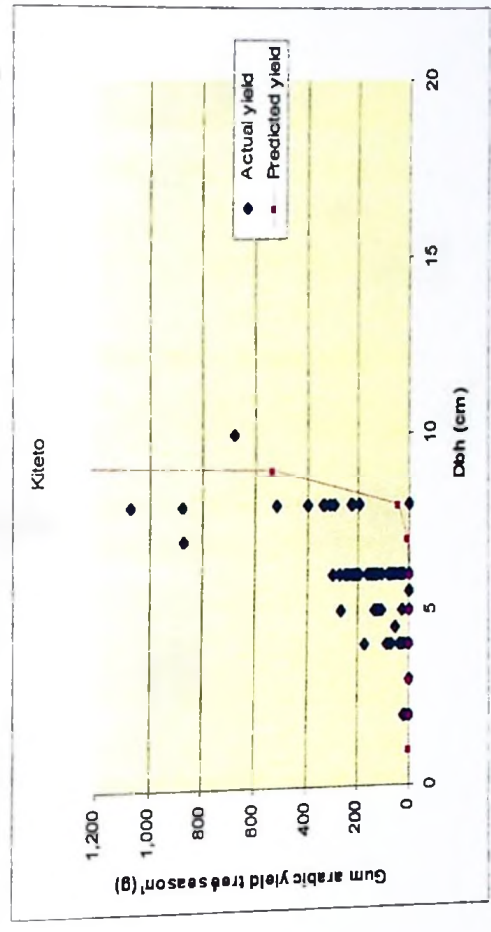
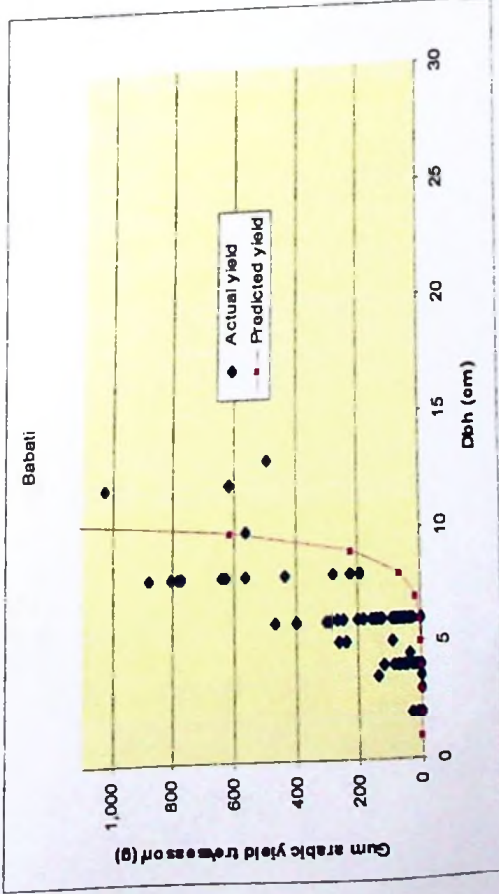
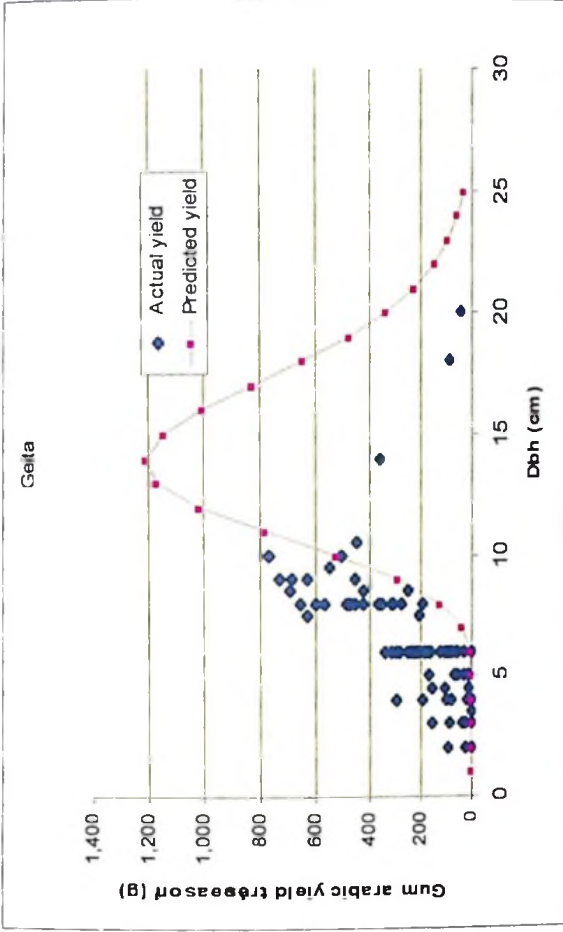
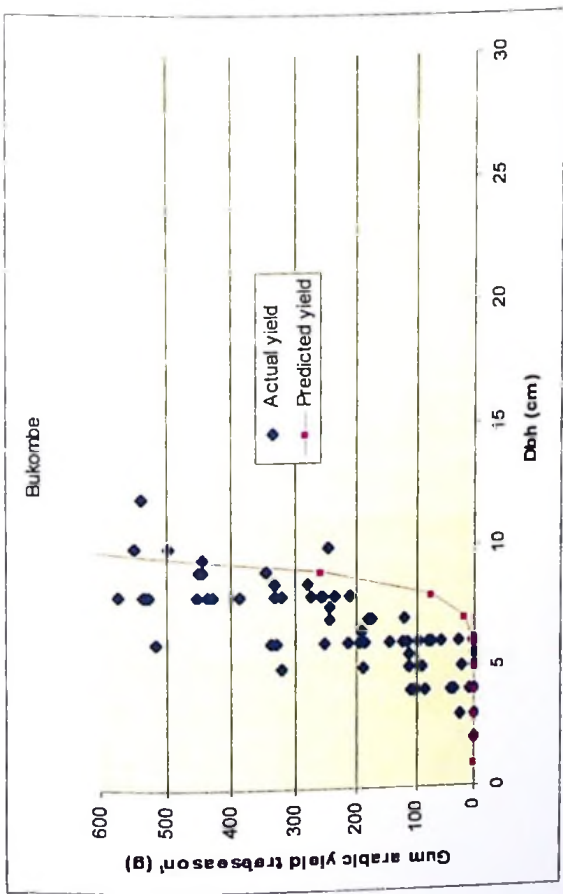
Figures in parentheses indicate t – statistics, cells in bold have p < 0.05.

Figure 1 Actual gum yield scatter plots and predicted yield curves against tree diameter in each district









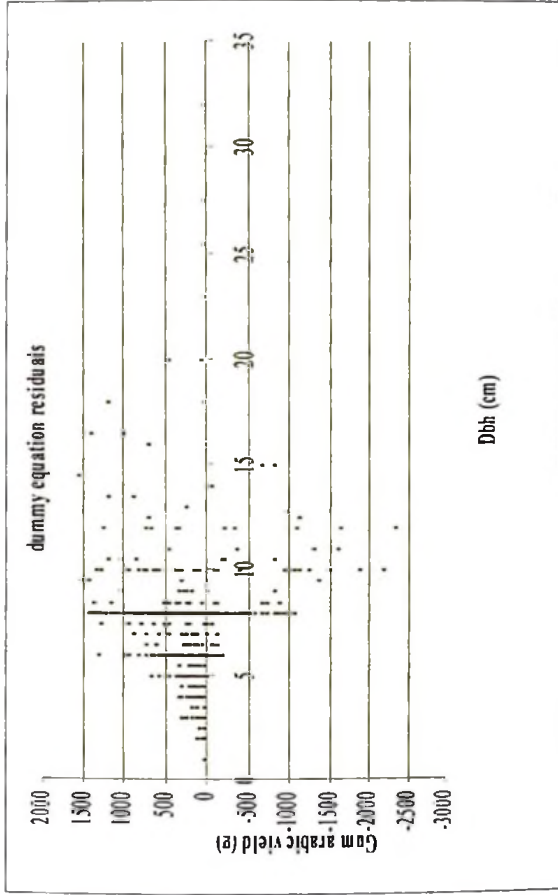
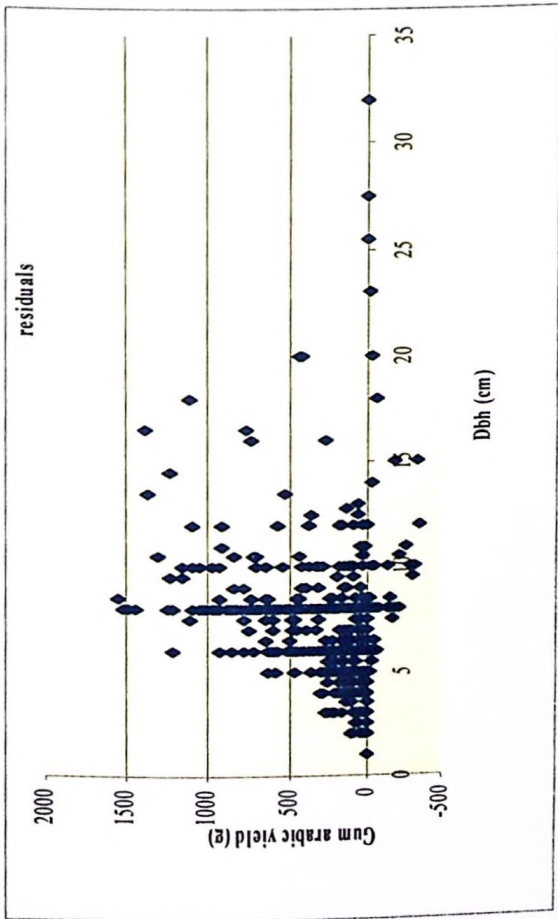
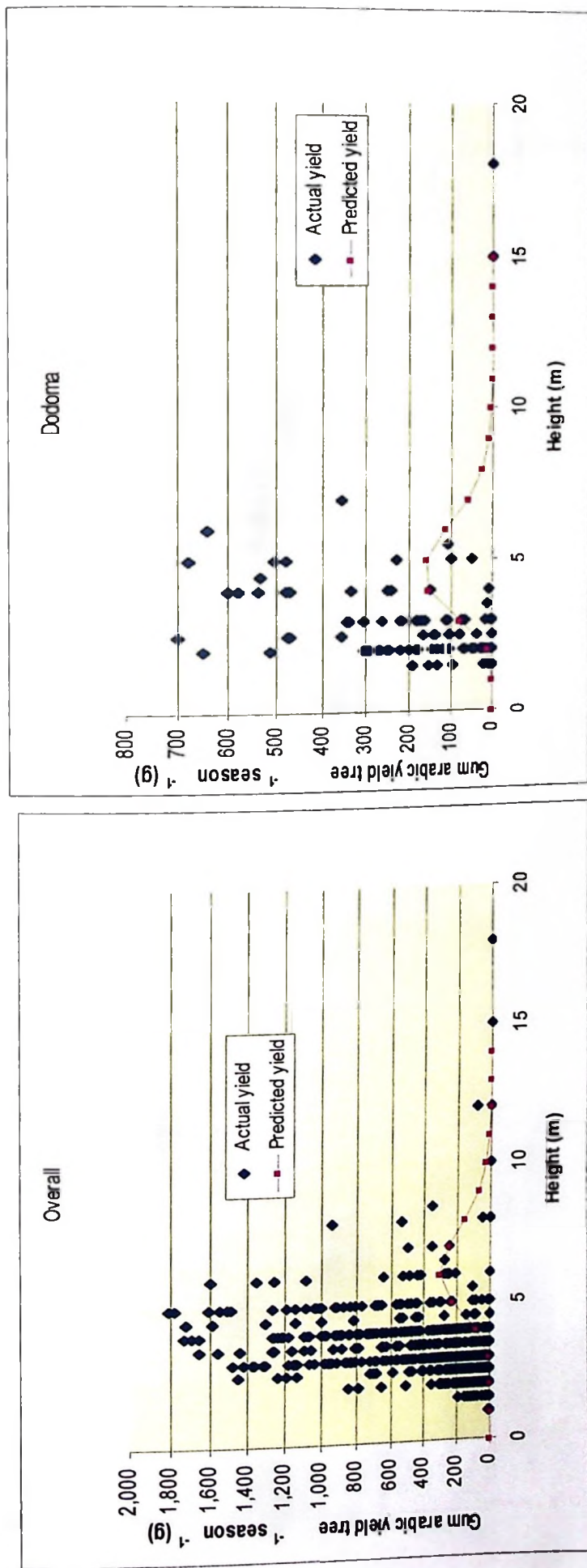
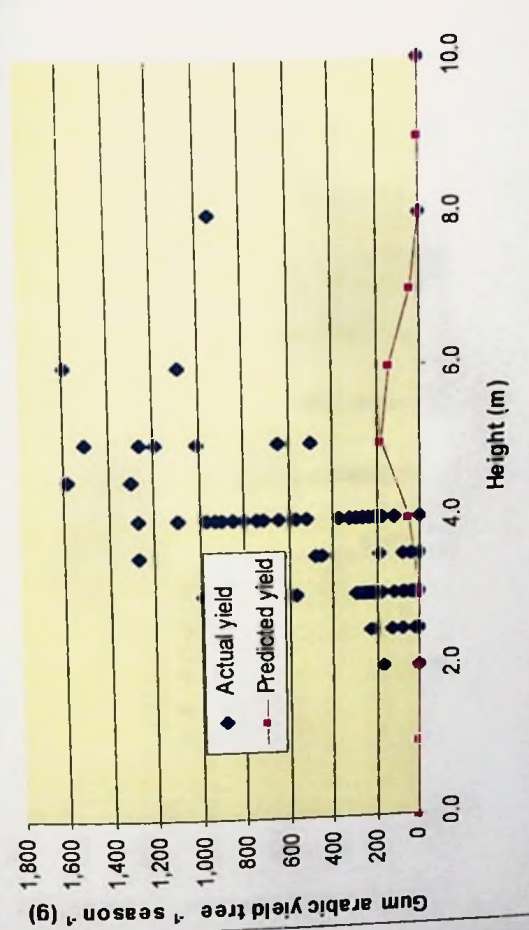


Figure 2 Actual gum yield scatter plots and predicted yield curves against tree height in each district

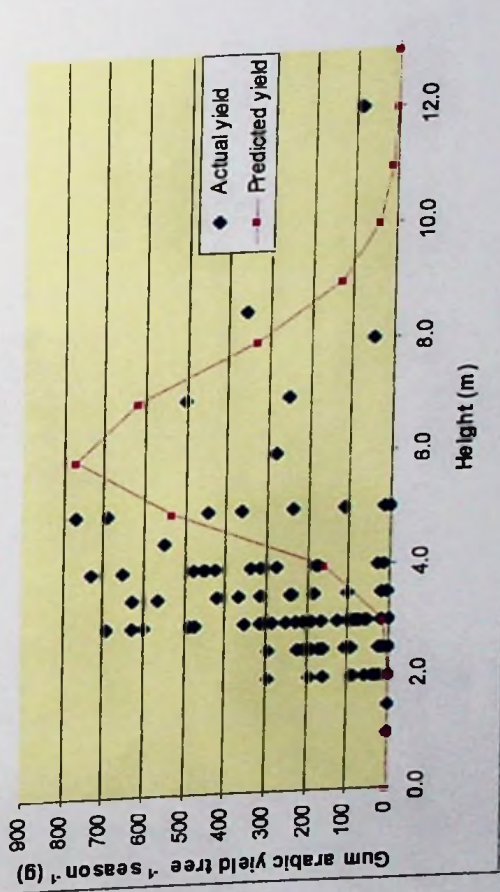




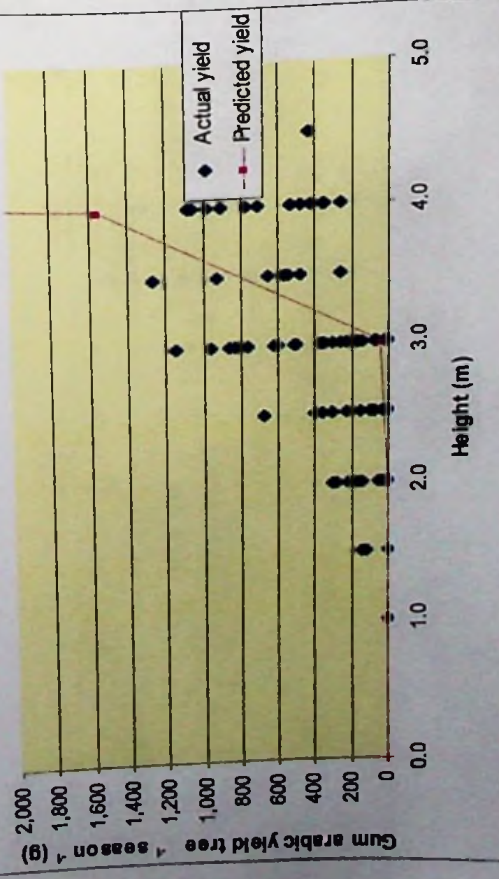
Mesatu



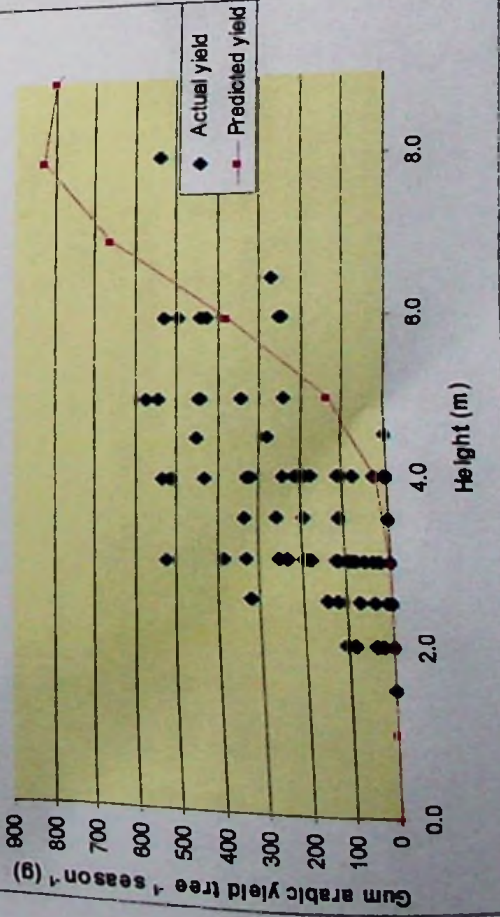
Gelta

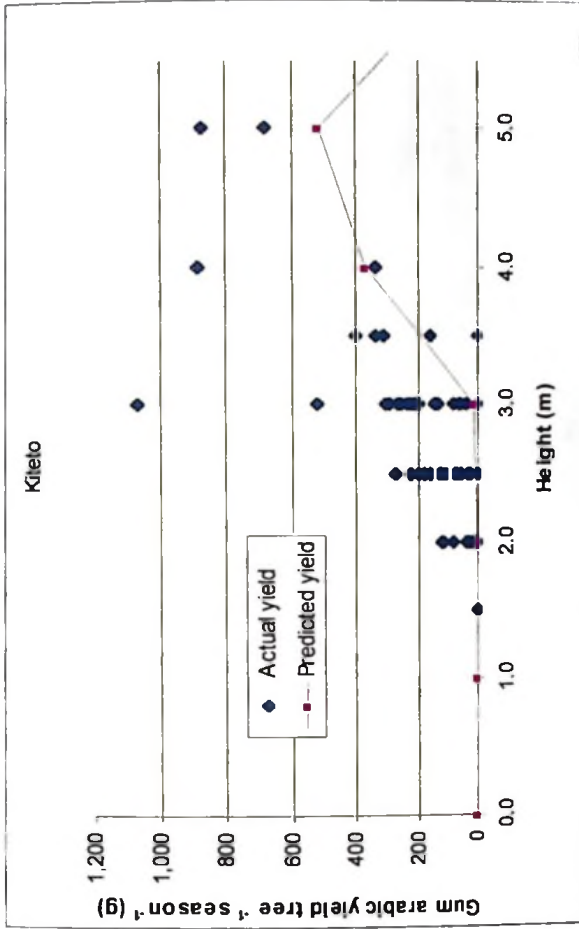
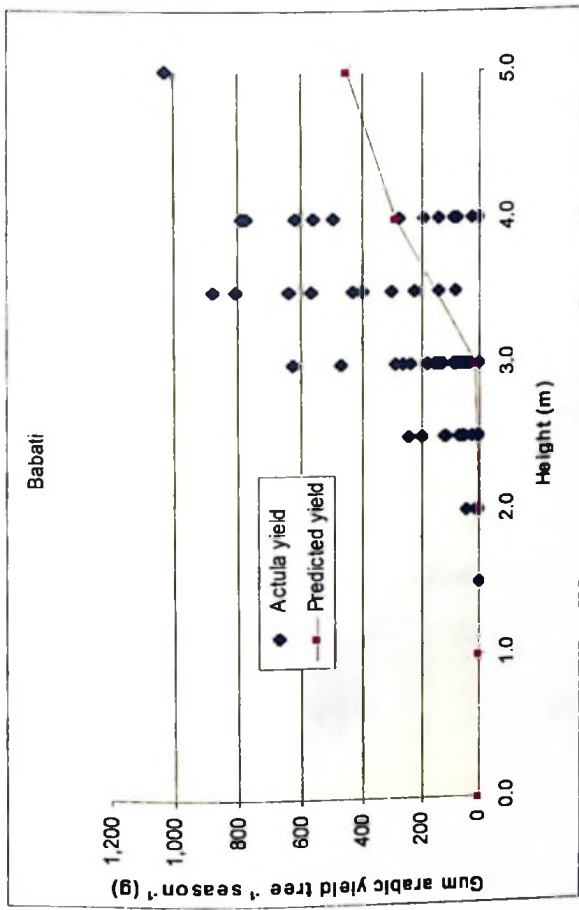


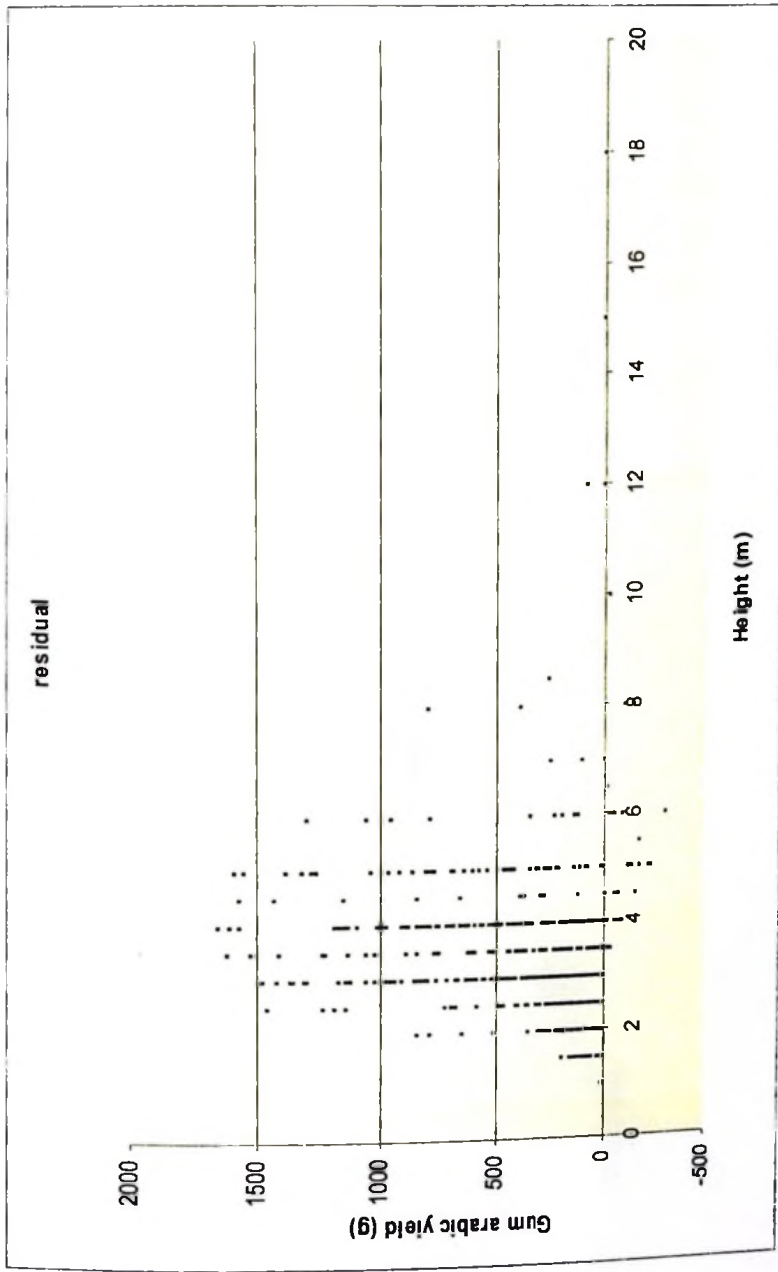
Maswa



Bukombe







Appendix II

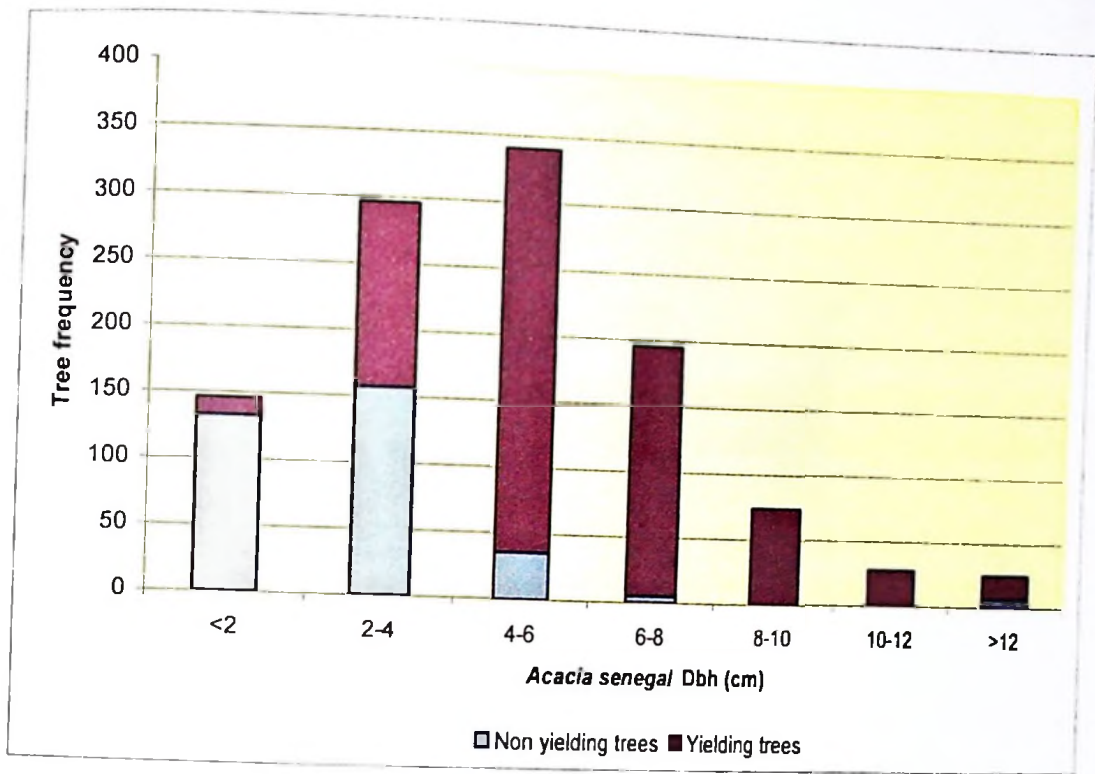


Figure 1 Distribution of gum yielding and non-yielding trees by diameter classes

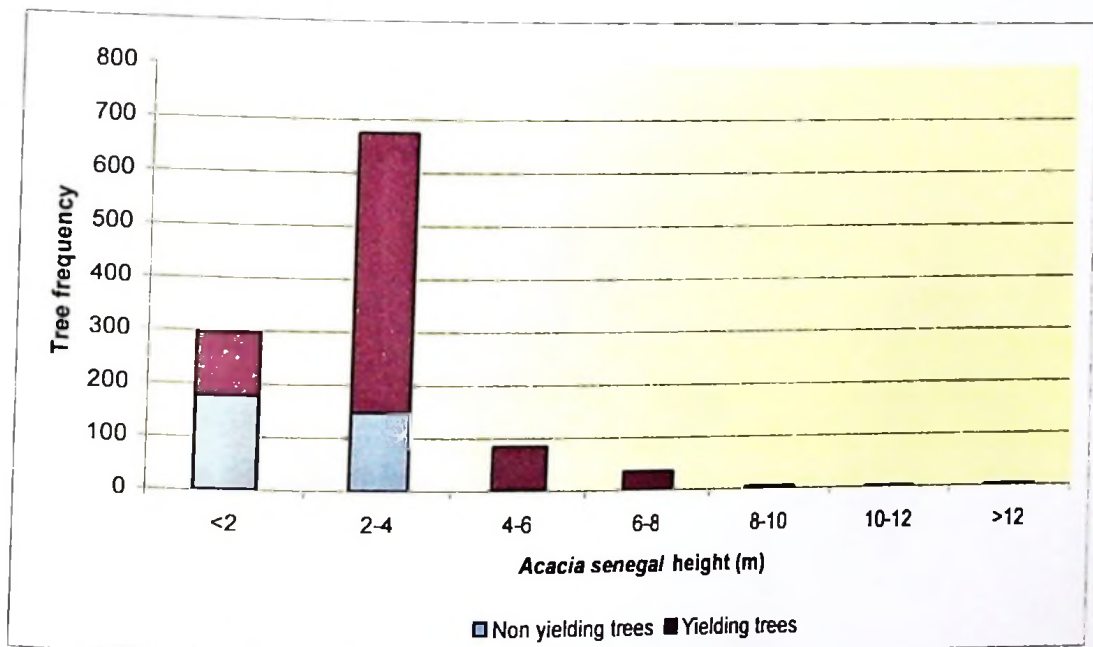


Figure 2 Distribution of gum yielding and non-yielding trees by height classes

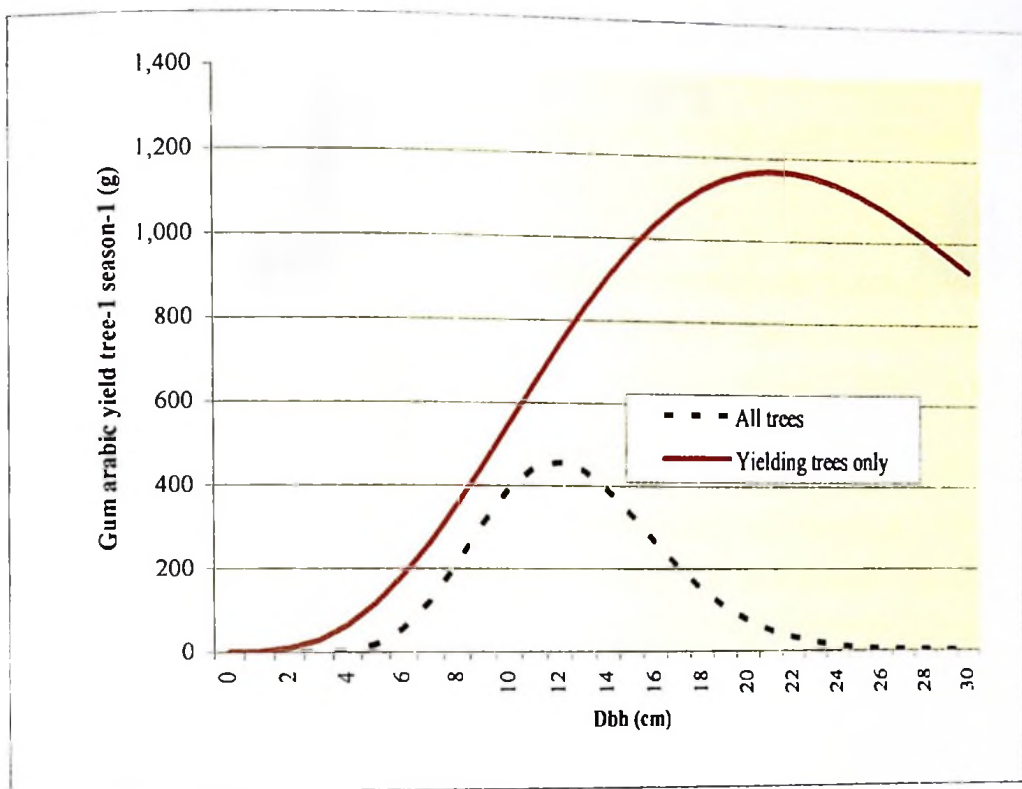


Figure 3 Overall mean gum yield per tree against diameter considering yielding and all sampled trees

Table 1

Logistic Regression

Case Processing Summary

Unweighted Cases ^a		N	Percent
Selected Cases	Included in Analysis	1103	100.0
	Missing Cases	0	.0
	Total	1103	100.0
Unselected Cases		0	.0
	Total	1103	100.0

a. If weight is in effect, see classification table for the total number of cases.

Table 1.1 Effect of diameter (dbh)

Block 1: Method = Forward Stepwise (Wald)

Omnibus Tests of Model Coefficients

	Chi-square	df	Sig.
Step 1 Step	542.177	35	.000
Block	542.177	35	.000
Model	542.177	35	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	807.248	.388	.550

Classification Table^a

Observed			Predicted		Percentage Correct
			YIELD		
			0	1	
Step 1	YIELD	0	191	141	57.5
		1	54	717	93.0
Overall Percentage					82.3

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step	DBH			252.696	35	.000	
1	DBH(1)	.000	99.631	.000	1	1.000	1.000
	DBH(2)	7.311	70.450	.011	1	.917	1496.512
	DBH(3)	8.286	70.454	.014	1	.906	3969.695
	DBH(4)	8.766	70.450	.015	1	.901	6409.404
	DBH(5)	8.286	70.454	.014	1	.906	3969.695
	DBH(6)	9.354	70.450	.018	1	.894	11544.522
	DBH(7)	10.812	70.452	.024	1	.878	49621.192
	DBH(8)	11.068	70.450	.025	1	.875	64056.448
	DBH(9)	10.301	70.453	.021	1	.884	29772.715
	DBH(10)	11.619	70.450	.027	1	.869	111151.5
	DBH(11)	18.405	75.675	.059	1	.808	9.8E+07
	DBH(12)	18.405	74.723	.061	1	.805	9.8E+07
	DBH(13)	11.601	70.457	.027	1	.869	109166.6
	DBH(14)	12.807	70.451	.033	1	.856	364715.8
	DBH(15)	18.405	74.723	.061	1	.805	9.8E+07
	DBH(16)	18.405	77.885	.056	1	.813	9.8E+07
	DBH(17)	18.405	83.357	.049	1	.825	9.8E+07
	DBH(18)	18.405	72.922	.064	1	.801	9.8E+07
	DBH(19)	18.405	79.882	.053	1	.818	9.8E+07
	DBH(20)	18.405	86.283	.046	1	.831	9.8E+07
	DBH(21)	18.405	77.173	.057	1	.811	9.8E+07
	DBH(22)	18.405	99.631	.034	1	.853	9.8E+07
	DBH(23)	18.405	122.022	.023	1	.880	9.8E+07
	DBH(24)	18.405	122.022	.023	1	.880	9.8E+07
	DBH(25)	18.405	99.631	.034	1	.853	9.8E+07
	DBH(26)	18.405	122.022	.023	1	.880	9.8E+07
	DBH(27)	18.405	122.022	.023	1	.880	9.8E+07
	DBH(28)	9.203	70.464	.017	1	.896	9924.238
	DBH(29)	18.405	99.631	.034	1	.853	9.8E+07
	DBH(30)	18.405	99.631	.034	1	.853	9.8E+07
	DBH(31)	18.405	99.631	.034	1	.853	9.8E+07
	DBH(32)	18.405	90.950	.041	1	.840	9.8E+07
	DBH(33)	.000	122.022	.000	1	1.000	1.000
	DBH(34)	.000	122.022	.000	1	1.000	1.000
	DBH(35)	.000	122.022	.000	1	1.000	1.000
	Constant	-9.203	70.449	.017	1	.896	.000

a. Variable(s) entered on step 1: DBH.

Block 1: Method = Forward Stepwise (Wald)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	241.541	18	.000
	Block	241.541	18	.000
	Model	241.541	18	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	1107.885	.197	.279

Classification Table^a

Observed			Predicted		Percentage Correct
			YIELD		
			0	1	
Step 1	YIELD	0	180	152	54.2
		1	126	645	83.7
Overall Percentage					74.8

a. The cut value is .500

Variables in the Equation

	B	S.E.	Wald	df	Sig.	Exp(B)	
Step 1	HEIGHT		164.237	18	.000		
	HEIGHT(1)	4.408	15.763	.078	1	.780	82.099
	HEIGHT(2)	5.432	15.729	.119	1	.730	228.705
	HEIGHT(3)	5.962	15.726	.144	1	.705	388.525
	HEIGHT(4)	6.772	15.726	.185	1	.667	873.235
	HEIGHT(5)	7.539	15.726	.230	1	.632	1879.437
	HEIGHT(6)	8.331	15.731	.280	1	.596	4151.867
	HEIGHT(7)	8.878	15.729	.319	1	.572	7169.984
	HEIGHT(8)	8.839	15.760	.315	1	.575	6896.321
	HEIGHT(9)	10.168	15.758	.416	1	.519	26058.330
	HEIGHT(10)	12.399	27.238	.207	1	.649	242649.2
	HEIGHT(11)	8.765	15.760	.309	1	.578	6403.727
	HEIGHT(12)	12.399	27.238	.207	1	.649	242649.2
	HEIGHT(13)	12.399	20.302	.373	1	.541	242649.2
	HEIGHT(14)	7.298	15.768	.214	1	.643	1477.783
	HEIGHT(15)	12.399	27.238	.207	1	.649	242649.2
	HEIGHT(16)	.000	27.238	.000	1	1.000	1.000
	HEIGHT(17)	6.200	15.789	.154	1	.695	492.594
	HEIGHT(18)	.000	27.238	.000	1	1.000	1.000
	Constant	-6.200	15.726	.155	1	.693	.002

a. Variable(s) entered on step 1: HEIGHT.

Table 1.3 Effect of number of branches

Classification Table^{a,b}

Observed		Predicted		
		YIELD		Percentage Correct
		0	1	
Step 0	YIELD	0	332	.0
		1	771	100.0
Overall Percentage				69.9

a. Constant is included in the model.

b. The cut value is .500

Variables in the Equation

	B	S.E.	Wald	df	Sig.	Exp(B)	
Step 0	Constant	.843	.066	164.745	1	.000	2.322

Appendix III

Table 1 The effect of dummy variables on gum yield predicted using tree diameter in each district

<i>Parameter</i>	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>
Intercept	-15.96	0.75	-21.30	<0.01
Dummy for Igunga	-0.76	0.66	-1.16	0.25
Dummy for Shinyanga	-0.66	0.66	-1.01	0.31
Dummy for Maswa	0.47	0.67	0.71	0.48
Dummy for Babati	-1.70	0.66	-2.57	0.01
Dummy for Geita	-0.94	0.64	-1.47	0.14
Dummy for Bukombe	-2.21	0.68	-3.25	<0.01
Dummy for Meatu	-2.67	0.66	-4.05	<0.01
Dummy for Singida	-2.48	0.66	-3.78	<0.01
Dummy for Iramba	-0.51	0.66	-0.78	0.44
Dummy for Kiteto	-3.30	0.66	-5.00	<0.01
Dbh	-1.47	0.11	-13.10	<0.01
lnDbh	16.52	0.67	24.56	<0.01

Figures in bold indicate significance at $p = 0.05$

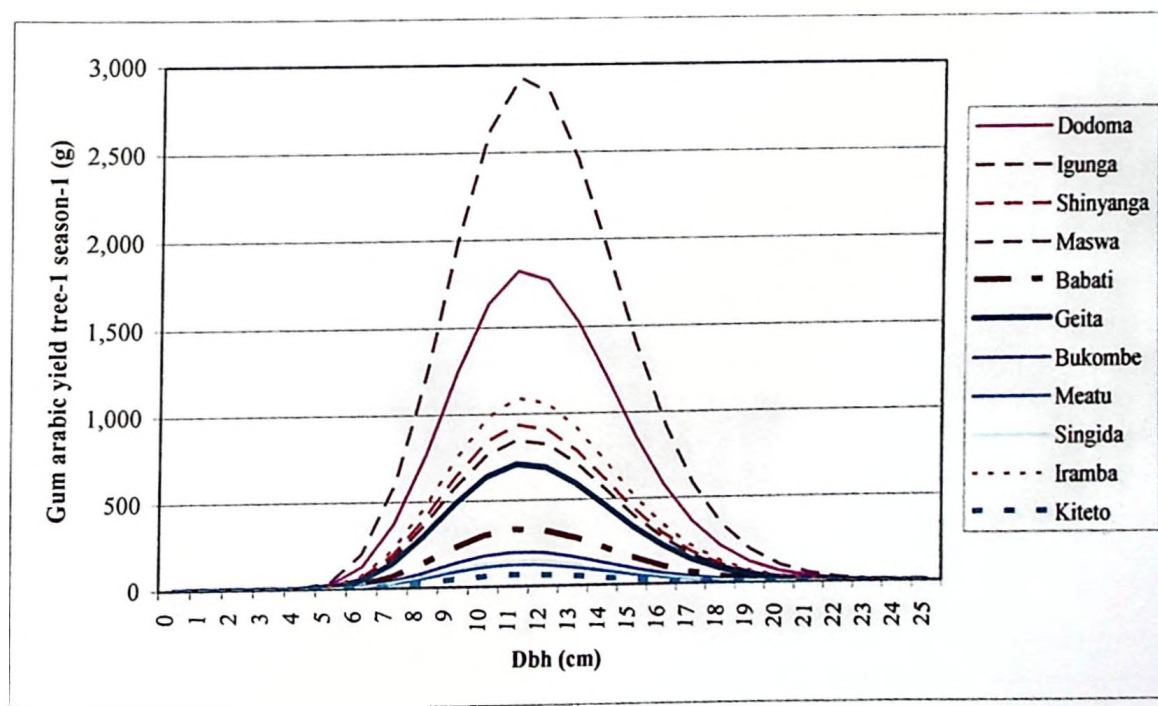


Figure 1 The effect of dummy variables on gum yield predicted using tree diameter in each district

Appendix IV

Questionnaire form for key informants

A. General

Region: Dod/Sin/Tab/Shy District: Village:

Respondent Identification: M/F Age: <20/21-30/31-40/>40

Occupation: Educ. level: None/Primary/Secondary/Tertiary

Type of house: I/II/III*

<u>No. of people in the household:</u>	Infants	Children	Adults
Male
Female

A resident of the area since

B. Gum arabic

1. Name of collection sites and distances

.....
.....
.....
.....
.....

2. When and why did you start business in gum arabic?
..... How many
collectors/middlemen are you and the trends?

.....
Do you have any association?
.....

3. Kind of business: tapping-collecting/middleman. Amount involved per season and trends in the past 20 years (if applicable)

1982	1987	1992	1997
1983	1988	1993	1998
1984	1989	1994	1999
1985	1990	1995	2000
1986	1991	1996	2001

4. Reasons for trends above

.....
.....
.....

* I = Block/Brick with Iron roof, II = Mud/Pole with Iron roof, III = Mud/Pole with grass thatched roof

5. Buyer(s) and address

.....
.....
.....
.....
.....
.....

6. Distance to the markets

.....

7. Prices and trends for the past 20 years (if applicable)

1982	1987	1992	1997
1983	1988	1993	1998
1984	1989	1994	1999
1985	1990	1995	2000
1986	1991	1996	2001

8. Reasons for trends above

.....
.....
.....

9. Can the production be increased? Y/N Why? Give all reasons in the order of their importance

.....
.....
.....
.....

10. Where do you get labour Gender

11. How much do you pay for labour? Other costs involved ?

.....
.....

12. What are the seasons for your business and why?

.....
.....

13. Tapping/collection of gum: Do you know the different *Acacia senegal* varieties?
From which do you usually collect
.....
.....

Tools used and availability
.....
Average production per tree

14. Processing and grading of gum:
.....
.....

15. Is there any regulation governing your business?
.....
.....

16. How much do you pay to the government (local/central) for the business?
...../.....

17. How do you compare gum business to others?
.....
.....

18. Can you estimate your total income per year? (including other business)
.....
.....

19. What is gum arabic used for
.....
.....
.....

20. Any other addition:
.....
.....

C. Other economic activities

Farming: Land area How obtained?
.....
Crops grown and incomes generated
.....
.....

Appendix V Questionnaire form for gum final buyers and exporters

A. General

Region: Dod/Sin/Tab/Shy District:.....Town/city:

Name of firm and address:

.....
.....

Other business apart from gum arabic: (and their percentage contribution to the total firm's revenues)

.....
.....
.....
.....

No. of gum business employees: Males Females

B. Gum arabic

1. When and why did you start business in gum arabic?
..... How many gum arabic exporters are you in the country and the trends? Do you have any association?
.....

2. Amount involved (local market and exports) per season and trends in the past 20 years (if applicable)

1982	1987	1992	1997
1983	1988	1993	1998
1984	1989	1994	1999
1985	1990	1995	2000
1986	1991	1996	2001

3. Reasons for trends above
.....
.....
.....

4. Buyers and addresses:
Local:
.....
.....
.....
.....

Exports

.....
.....
.....
.....

5. Prices and trends for the past 20 years (if applicable)

1982	1987	1992	1997
1983	1988	1993	1998
1984	1989	1994	1999
1985	1990	1995	2000
1986	1991	1996	2001

6. Reasons for trends above

.....
.....
.....

7. Can the production be increased? Y/N Why? Give all reasons in the order of their importance

.....
.....
.....
.....
.....

8. Who are your major market competitors?

.....
.....
.....

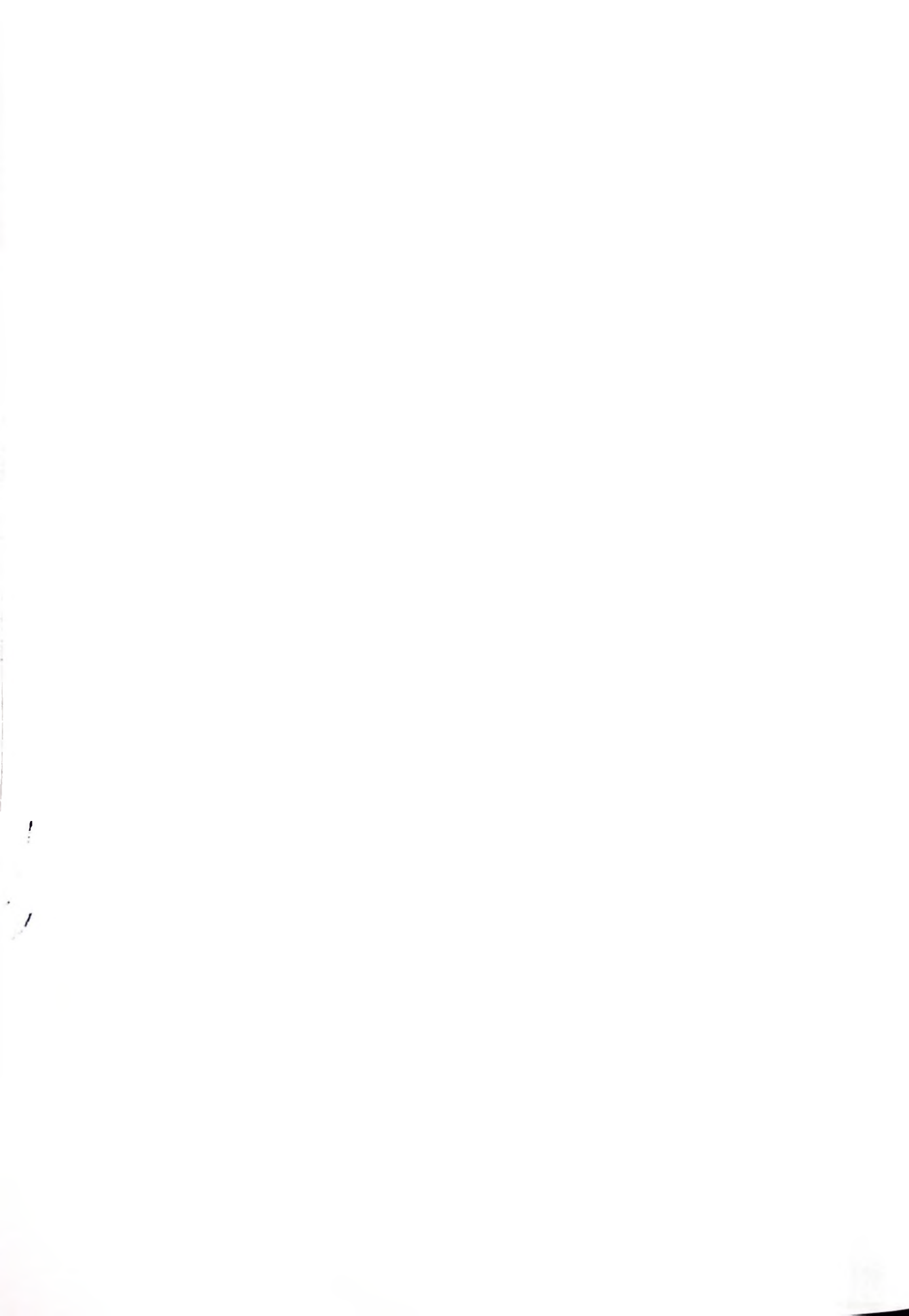
9. What are the seasons for your business and why?

.....
.....
.....

10. Do you know the different gums from *Acacia spp* and their varieties? From which do you usually trade in and their prices

.....
.....
.....
.....

11. Among the gum producing regions which one do you prefer most and why?
.....
.....
12. Processing and grading of gum:
.....
.....
.....
13. Is there any regulation governing your business?
.....
.....
.....
14. How much do you pay to the government (local/central) for the business?
...../.....
15. What is gum arabic used for?
.....
.....
.....
.....
.....
16. Any other addition:
.....
.....
.....



6. Reasons for trends above
.....
.....
.....
7. Can the production be increased? Y/N Why? Give all reasons in the order of their importance
.....
.....
.....
.....
.....
8. Where do you get labour Gender How much do you pay for labour ?
.....
9. What are the seasons for your business and why?
.....
.....
.....
10. Is there any regulation governing your business?
.....
.....
11. How much do you pay to the government (local/central) for the business?
...../.....
12. Have you ever engaged yourself in gum activities? Why?
.....
13. How do you compare gum business to others?
.....
.....
14. What is gum arabic used for
.....
.....
.....
15. Can you estimate your total income per year? (Including other business)
.....
.....
16. Farming: Land area How obtained?
.....
.....
17. Any addition

Appendix VII

Table 1 Factors influencing engagement in the gum collection activities

Case Processing Summary

Unweighted Cases ^a		N	Percent
Selected Cases	Included in Analysis	1259	100.0
	Missing Cases	0	.0
	Total	1259	100.0
Unselected Cases		0	.0
Total		1259	100.0

a. If weight is in effect, see classification table for the total number of cases.

Block 1: Method = Forward Stepwise (Wald)

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	464.807	1	.000
	Block	464.807	1	.000
	Model	464.807	1	.000
Step 2	Step	202.978	1	.000
	Block	667.785	2	.000
	Model	667.785	2	.000
Step 3	Step	141.470	1	.000
	Block	809.255	3	.000
	Model	809.255	3	.000
Step 4	Step	22.976	1	.000
	Block	832.231	4	.000
	Model	832.231	4	.000
Step 5	Step	10.007	1	.002
	Block	842.237	5	.000
	Model	842.237	5	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	1280.537	.309	.412
2	1077.559	.412	.549
3	936.089	.474	.632
4	913.113	.484	.645
5	903.106	.488	.650

Classification Table^a

Observed			Predicted		
			OCCUPAT		Percentage Correct
			0	1	
Step 1	OCCUPAT	0	456	173	72.5
		1	143	487	77.3
	Overall Percentage				74.9
Step 2	OCCUPAT	0	498	131	79.2
		1	111	519	82.4
	Overall Percentage				80.8
Step 3	OCCUPAT	0	527	102	83.8
		1	105	525	83.3
	Overall Percentage				83.6
Step 4	OCCUPAT	0	523	106	83.1
		1	100	530	84.1
	Overall Percentage				83.6
Step 5	OCCUPAT	0	529	100	84.1
		1	100	530	84.1
	Overall Percentage				84.1

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1	INCOME	.000	.000	267.342	1	.000	1.000
	Constant	3.391	.214	250.801	1	.000	29.702
Step 2	HHSIZE	.561	.045	154.775	1	.000	1.752
	INCOME	.000	.000	271.192	1	.000	1.000
	Constant	-1.480	.412	12.922	1	.000	.228
Step 3	GENDER	-2.074	.188	121.739	1	.000	.126
	HHSIZE	.584	.049	141.064	1	.000	1.793
	INCOME	.000	.000	201.826	1	.000	1.000
	Constant	-.691	.458	2.277	1	.131	.501
Step 4	GENDER	-2.043	.191	114.121	1	.000	.130
	HHSIZE	.622	.052	145.737	1	.000	1.863
	INCOME	.000	.000	210.074	1	.000	1.000
	FARM	.362	.076	22.599	1	.000	1.436
	Constant	-2.132	.560	14.522	1	.000	.119
Step 5	GENDER	-2.112	.193	119.402	1	.000	.121
	HHSIZE	.636	.052	148.425	1	.000	1.889
	DURATION	-.409	.131	9.789	1	.002	.664
	INCOME	.000	.000	202.834	1	.000	1.000
	Constant	.359	.077	21.909	1	.000	1.431
		-1.241	.628	3.910	1	.048	.289

- a. Variable(s) entered on step 1: INCOME.
- b. Variable(s) entered on step 2: HHSIZE.
- c. Variable(s) entered on step 3: GENDER.
- d. Variable(s) entered on step 4: FARM.
- e. Variable(s) entered on step 5: DURATION.

Appendix VIII Table 1 Economic analysis of managing a gum arabic plantation

Year	Costs (TShs ha ⁻¹)										Revenue (TShs ha ⁻¹)							Max LEV	Max NPV	
	Notional land rent	Nursery	Land prepn	Planting	Weeding	Protection	inter cropping	Gum tapping	Clear felling	Total	Base crops	Gum	Net (excp Wood)	NPV (excp Wood)	Wood	Net (wood)	NPV (wood)			NPVtot
0	3,000	31,250								34,250	0	0	-34,250	-94,367	0	0	0	-94,367		
1	3,000	0	15,000	5,000	15,000	5,000	2,000	0	1,847	45,000	9,922	12	-35,066	-66,128	38,881	37,035	33,668	-32,460	-357,065	
2	3,000	0	0	0	15,000	5,000	2,000	0	2,309	25,000	8,192	2,082	-14,726	-78,298	107,251	104,942	86,729	8,431	48,580	
3	3,000	0	0	0	0	5,000	3,000	0	2,886	11,000	5,819	16,439	11,259	-69,839	196,599	193,713	145,540	75,700	304,402	
4	3,000	0	0	0	0	5,000	3,000	0	3,607	11,000	3,257	44,398	36,655	-44,803	296,117	292,510	199,788	154,985	488,932	
5	3,000	0	0	0	0	5,000	3,000	9,018	4,509	20,018	788	74,556	55,326	-10,450	396,127	391,618	243,164	232,714	613,894	
6	3,000	0	0	0	0	5,000	0	11,272	5,636	19,272	0	98,917	79,645	34,507	489,940	484,304	273,377	307,885	706,926	
7	3,000	0	0	0	0	5,000	0	14,090	7,045	22,090	0	115,889	93,799	82,641	573,823	566,778	290,847	373,488	767,164	
8	3,000	0	0	0	0	5,000	0	17,613	8,806	25,613	0	126,821	101,208	129,856	646,294	637,488	297,393	427,248	800,851	
9	3,000	0	0	0	0	5,000	0	22,016	11,008	30,016	0	133,565	103,549	173,771	707,354	696,346	295,319	469,089	814,529	***
10	3,000	0	0	0	0	5,000	0	27,520	13,760	35,520	0	137,622	102,102	213,135	757,848	744,088	286,878	500,013	813,749	
11	3,000	0	0	0	0	5,000	0	34,400	17,200	42,400	0	140,021	97,621	247,351	799,025	781,825	274,025	521,375	802,726	
12	3,000	0	0	0	0	5,000	0	43,000	21,500	51,000	0	141,420	90,420	276,161	832,249	810,749	258,330	534,491	784,436	
13	3,000	0	0	0	0	5,000	0	43,000	21,500	51,000	0	142,225	91,225	302,586	858,840	837,340	242,548	545,134	767,431	
14	3,000	0	0	0	0	5,000	0	43,000	21,500	51,000	0	142,680	91,680	326,728	879,992	858,492	226,068	552,796	750,400	
15	3,000	0	0	0	0	5,000	0	43,000	21,500	51,000	0	142,931	91,931	348,736	896,736	875,236	209,525	558,261	733,966	
16	3,000	0	0	0	0	5,000	0	43,000	21,500	51,000	0	143,064	92,064	368,772	909,943	888,443	193,351	562,123	718,487	
17	3,000	0	0	0	0	5,000	0	43,000	21,500	51,000	0	143,130	92,130	386,999	920,331	898,831	177,829	564,828	704,138	
18	3,000	0	0	0	0	5,000	0	43,000	21,500	51,000	0	143,159	92,159	403,575	928,483	906,983	163,129	566,704	690,983	
19	3,000	0	0	0	0	5,000	0	43,000	21,500	51,000	0	143,168	92,168	418,645	934,869	913,369	149,343	567,988	679,012	
20	3,000	0	0	0	0	5,000	0	43,000	21,500	51,000	0	143,166	92,166	432,345	939,866	918,366	136,509	568,854	668,174	
21	3,000	0	0	0	0	5,000	0	43,000	21,500	51,000	0	143,160	92,160	444,799	943,772	922,272	124,627	569,426	658,395	
22	3,000	0	0	0	0	5,000	0	43,000	21,500	51,000	0	143,153	92,153	456,119	946,822	925,322	113,672	569,791	649,591	
23	3,000	0	0	0	0	5,000	0	43,000	21,500	51,000	0	143,145	92,145	466,410	949,203	927,703	103,604	570,014	641,675	

24	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,138	92,138	475,764	951,060	929,560	94,374	570,138	634,563
25	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,131	92,131	484,268	952,508	931,008	85,928	570,196	628,174
26	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,126	92,126	491,997	953,637	932,137	78,211	570,209	622,435
27	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,122	92,122	499,024	954,517	933,017	71,168	570,193	617,277
28	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,118	92,118	505,412	955,203	933,703	64,746	570,158	612,641
29	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,115	92,115	511,219	955,738	934,238	58,894	570,113	608,470
30	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,113	92,113	516,498	956,154	934,654	53,564	570,061	604,717
31	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,111	92,111	521,297	956,478	934,978	48,711	570,008	601,337
32	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,110	92,110	525,659	956,731	935,231	44,295	569,954	598,291
33	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,109	92,109	529,625	956,928	935,428	40,276	569,902	595,544
34	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,108	92,108	533,230	957,081	935,581	36,621	569,851	593,065
35	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,107	92,107	536,508	957,200	935,700	33,296	569,804	590,828
36	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,106	92,106	539,488	957,293	935,793	30,272	569,760	588,807
37	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,106	92,106	542,196	957,366	935,866	27,522	569,718	586,981
38	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,106	92,106	544,659	957,422	935,922	25,022	569,680	585,329
39	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,105	92,105	546,897	957,466	935,966	22,748	569,645	583,835
40	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,105	92,105	548,932	957,500	936,000	20,681	569,613	582,483
41	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,105	92,105	550,782	957,527	936,027	18,801	569,584	581,259
42	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,105	92,105	552,464	957,548	936,048	17,092	569,557	580,150
43	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,105	92,105	553,993	957,564	936,064	15,539	569,532	579,146
44	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,105	92,105	555,383	957,577	936,077	14,126	569,510	578,236
45	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,105	92,105	556,647	957,586	936,086	12,842	569,489	577,411
46	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,105	92,105	557,795	957,594	936,094	11,675	569,470	576,663
47	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,105	92,105	558,840	957,600	936,100	10,614	569,453	575,984
48	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,105	92,105	559,789	957,605	936,105	9,649	569,438	575,369
49	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,105	92,105	560,652	957,608	936,108	8,772	569,424	574,810
50	3,000	0	0	0	5,000	0	43,000	21,500	51,000	0	143,105	92,105	561,437	957,611	936,111	7,974	569,411	574,303

Discount rate 10% Base crop revenue 10,500 IRR 63%
 Gum price 500 Maximum NPV 570,209
 Timber price 4,500 Maximum LIEV 814,529

SPE
 TP978
 T34
 M3