# NON-TIMBER FOREST PRODUCT (NTFP) EXTRACTION IN ARID ENVIRONMENTS: LAND-USE CHANGE, FRANKINCENSE PRODUCTION AND THE SUSTAINABILITY OF *BOSWELLIA SACRA* IN DHOFAR (OMAN)

by

Mohamud Haji Farah



A Dissertation Submitted to the Faculty of the

GRADUATE INTERDISCIPLINARY PROGRAM IN ARID LANDS RESOURCE SCIENCES

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

2 0 0 8

THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

As members of the Dissertation Committee, we certify that we have read the dissertation

prepared by Mohamud Haji Farah

entitled Non-Timber Forest Product (NTFP) Extraction in Arid Environments: Land-Use Change, Frankincense Production and the Sustainability of Boswellia sacra in Dhofar (Oman)

and recommend that it be accepted as fulfilling the dissertation requirement for the

Degree of Doctor of Philosophy

_____ Date: November, 2005
Charles F. Hutchinson

_____ Date: November, 2005
Stuart E. Marsh

_____ Date: November, 2005
Michael E. Bonine

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copies of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

_____ Date: August 10, 2008
Dissertation Director: Charles F. Hutchinson

STATEMENT BY AUTHOR

This dissertation has been submitted in partial fulfillment of requirements for an advanced degree at the University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.



SIGNED: Mohamud Haji Farah

# ACKNOWLEDGMENT

All praises be to Allah for giving me the health, patience and strength to achieve this milestone. I would like to express my deepest gratitude to my precious family members, relatives, friends, colleagues, mentors, advisors and teachers for their help, valuable advice, constructive suggestions, and priceless feedback that were instrumental in shaping this document.

Special thanks to my wife Nura Dualeh for her unwavering support, love and kindness throughout my career. Thanks for the optimism, positive outlook and encouragement that lifted my spirits. Thanks to Karima Dualeh who during her battle with cancer taught me about courage, compassion and staying the course. Thanks to my biggest mentor and hero (my brother Hassan) for taking me under his wing and giving me the opportunity to jump-start my quest for education in America.

I specially thank the Fulbright Association for the graduate research grant that enabled me to carry out this research project. I also thank Sultan Qaboos University's College of Agriculture for hosting me, the Ministry of Agriculture and Fisheries, Range and Forestry Department, Ministry of Regional Municipalities & Environment, Ministry of Water Resources, the Public Authority for Marketing Agricultural Products, and Amouage Corporation for providing valuable data, logistics and technical support in Musqat and Salalah.

I wish to express my deep gratitude to my committee members, mentors and colleagues. My committee chair, advisor, mentor and teacher Dr Charles Hutchinson for helping me explore and identify the thread that weaves the parts together to tell this story. Dr. Stuart Marsh for his guidance, and his ever-present financial, academic and moral support. Dr Michael Bonine and Dr. Peter Ffolliott for their edits and feedback. Dr. Barron Orr, Dr Barbara Eiswerth, and Hugo Rodgriguez for the friendship and support; Dr. Maria Teresa Velez for financial assistance and encouragement; and Mark Borgstrom for timely data assistance. Special thanks to my Tucson family, so broad and loving, for their unwavering support during the completion of this project.

In Oman thanks go to Dr Jama and the extended Galal family – especially Ahmed Jama Galal, for giving my son, Hanad, and I a home away from home. Special thanks also go to Ahmed Alkatheri, government administrator author, for giving me insight into the cultural and traditional etiquette in Dhofar. Finally, I would like to thank Ali Al-Shahri, Mohamed Al Mashekhi, the Salalah hiking group, the Somali elders, Omani elders, guides and harvesters in Dhofar for their hospitality and generosity.

# DEDICATION

I dedicate this work to my family, especially my mother Haji Jookho who did not have the privilege of attending school and my father Haji Farah who was a self-educated man. My parents instilled in me the importance of school. Though they have both passed away, they continue to guide, inspire and motivate me to ensure that their investment and faith lives on in a life committed to God, family, service, community and the pursuit of knowledge.

I also dedicate this to my sisters Maryan and Khadra, brothers Hassan and Ahmed and their extended family; Haji Ahmed Kayse Dualeh the first Somali college graduate and his wife Haji Qamar. Special thanks to my wife and friend Nura and my children Hanad, Hassan and Habon. I could not have done this without your constant encouragement and patience.

Special dedication to those who passed away may Allah bless their souls.

Hussein Bilal Adan

Shire Mahamud Adan

Khadaro Jama

Hurre Hassan Muse

Farah Salah Abdi

Karima Ahmed Kayse

TABLE OF CONTENTS

TABLE OF CONTENTS- Continued

TABLE OF CONTENTS- Continued

# LIST OF FIGURES

LIST OF FIGURES- Continued

# LIST OF TABLES

**ABSTRACT**

Frankincense, a much revered non-timber forest product (NTFP) known as *luban* in Oman, is a gum-resin extracted from *Boswellia sacra (meqerot)*. In Oman, *B.sacra* is endemic to ecological zones in and around Dhofar's southern mountain ranges of Jabal Samhan, Jabal Qamar and Jabal Qara. Hojar (Samhan Nejd), Nejd (Qara Nejd), Shazr (Qamar Nejd) and Sha'b are the four *B.sacra* ecological zones. A suffix (i) after the name (i.e. Hojari or Samhan Nejdi) is indicative of the *luban* produced in or associated with the respective zone. Traditional Omani *B.sacra* ownership, management, organization, and frankincense extraction are based on a land parcel system known as *menzela*. The 1970's oil boom attracted rural labor to urban and oil operation centers in Dhofar and other provinces, thus creating a labor shortage that had a profound transformative impact on frankincense production. This transformation caused frankincense extraction to evolve from an Omani-controlled system to a Somali-dominated hybrid system. Migrant Somali harvesters predominantly control the production and processing of frankincense in the field. Similarly, wholesalers occupy the next rung up the production ladder are the most powerful players in the frankincense industry.Dhofar has a long history of non-timber forest product (NTFP) extraction. From April to mid-June 1999, *luban* production in the Hojari/Nejdi zone of the study area was estimated at 8,710 kg with a seasonal projection of 24,840kg-30,360kg. *B.sacra*, a single or multiple stem shrub restricted to wadis in arid environments in or around the Dhofar Mountains, can be found at elevations from 60m above sea level in Wadi Adonib on the coastal plains to 1,770m above sea level in Wadi Kharish (a branch of Wadi Qobyr) in jabal Samhan). Land-use and landcover changes in

Dhofar are threatening the fragile stability of *B.sacra* habitats. Frankincense trees on easily accessible flat or gently sloping terrain are susceptible to stress and mortality from harvesting, grazing and mining, while trees on cliffs and steep slopes are less vulnerable to the effects of these land-use activities.

# CHAPTER 1. INTRODUCTION

## *EXPLANATION OF THE PROBLEM AND CONTEXT*

Millions of people worldwide, especially in developing countries, depend on the harvest of non-timber forest products such as gum, resins and latex for their livelihood (FAO web 2005; Lacuna-Richman 2004). Frankincense is utilized in traditional (Farah 1994; Groom 1981; Miller and Morris 1988) and conventional medicine (Inder, Ashok et al. 2001) to treat numerous ailments. Even though migrant Somali harvesters are seen as new comers to frankincense extraction in Oman, there was a long active trade in frankincense between Somalis and Arabs in the 1800s (Miles 1982) and some Somalis invariably came to Oman for the sole purpose of collecting *luban* (Groom 1981).

Although patterns of Oman's frankincense extraction, ownership and organization have persisted relatively intact for a long time, changes since the late 1970s have transformed these indigenous systems. The changes that have taken place in Oman's frankincense extraction industry will have long term management implications for the structure and organization of the luban industry. To better understand the nature and potential impact of these changes, this study seeks to answer several critical questions:

1. What motivates poor workers from Somalia to illegally enter Oman to make a living in *luban* harvesting?
2. How do they secure financial resources and gain access to rent frankincense groves?

3. What are the strategies they use to influence the *luban* market and what is the impact of their activities on the management, organization and structure of frankincense extraction activities in Oman?

To answer these questions, I examine the relationships and interactions among three groups who play a significant role in the *luban* industry. The groups consist of (1) indigenous (Omani) *Boswellia sacra* owners, (2) merchants and wholesalers (contractors) and (3) Somali frankincense collectors (harvesters).

A Food and Agricultural Organization of the United Nations (FAO) report indicates that non-timber forest products (NTFP) are widely traded in the international markets with a total world trade value estimated at US$ 11 billion (FAO 1995) . Oman has a long history of NTFP extraction from the Boswellia shrublands in the governate of Dhofar, but most economic analyses of forest resource extraction studies have focused on tropical forests with overwhelming importance given to timber benefits (Tewari 2000). Although the forest reference might be misleading when the focus is clearly on arid shrublands in Dhofar, the term (NTFP) was chosen to emphasize the similarity of the extraction process and its value to household and regional economies that are dependent on forest and woodland resources. Although frankincense is a commercial product widely traded in local and international markets, the economic significance, production, processing and marketing of frankincense, and its contributions to sustaining livelihood in arid

environments like Dhofar, is not well understood and is insufficiently researched. In order to address these issues, I sought to:

1. Identify frankincense producing areas and evaluate the roles of primary and secondary stakeholders.
2. Assess the level of production and methods of production.
3. Document the processing and marketing of frankincense.
4. Investigate NTFP contribution to household livelihood.
5. Address the sustainability of this resource given the current extraction rate.

Multiple and often competing or conflicting land use activities affect the way natural resources are utilized, managed and conserved. Increased livestock numbers and human settlements in Dhofar are putting a strain on the delicate balance between vegetation resources and their users, thereby threatening the fragile *B.sacra* habitats in the province. There are various studies on the effects of livestock grazing in Dhofar (Chatty 1996; Al Kathiri 1996; Seif El Din 1990; El Samani 1990; Jensen 1986; GRM,1982;), but there are no studies targeted on the effect of livestock browsing and frankincense (*luban*) harvesting on *B.sacra*. Similarly, the effects of gravel mining activities near *B.sacra* fields have not been addressed, not much is known about *B.sacra* stand age structures and seed germination, and there are no studies on the state of *B.sacra* regeneration and conservation in Oman.

*B.sacra* habitat degradation associated with land-use change is a major concern in the Sultanate of Oman. Given this concern and the limited research on the topic, this research project has sought to:

1. Document the current distribution of *B.sacra* in Dhofar.
2. Investigate land-use activities affecting *B.sacra*
3. Assess the impact of human and animal activities on the regeneration of *B.sacra*.
4. Address the prospects for the propagation and conservation of *B.sacra*.

*STUDY AREA*

This study was conducted in the province of Dhofar located in the Sultanate of Oman. Dhofar is the southern-most province in Oman bordering Yemen on the west, Saudi Arabia on the north and the Indian Ocean on the south. The province covers an area about 99210 square kilometers approximately between latitudes 16º north and 21º north, and longitudes 51º east and 56º east. Dhofar is the largest of eight provincial regions. It represents about 32% of Oman's total area, and consists of nine administrative districts, six of which are concentrated in the three mountain ranges along the southern coastal area of the province.

Dhofar has rich vegetation diversity and species richness which is floristically more similar to those found in the island of Socotra (Yemen) and the drier regions of Northeast Africa than those found in northern Oman (Miller and Morris 1988). Most of this rich flora is restricted to a mountain range belt and adjoining area about 40 km at its widest

extent and approximately 240 km long extending from Hasik to Oman's border with Yemen. The mountains of Dhofar form a raised plateau reaching an elevation of 2,000 m in the south and dipping to the north beneath the sand dunes of Rub' al Khali (Guba and Glennie 1998). As the Dhofar mountain-range slopes north, aridity increases and the vegetation becomes sparse (Phillips 1966 p170), while the seaward-facing southern aspect is characterized by cliffs, slopes and wadis covered in thickets of drought–deciduous woodlands (Gallagher 1977). The dry leeward side of these mountains known to the locals as Nejd and pockets of fragmented habitats on the coastal plain (*sahil*) are the principal frankincense zones.

The Dhofar plains are comprised of aeolian sand and alluvial limestone gravel, and are traversed by a network of wadis that drain from the mountains (Ghazanfar 1998). The coastal plains consist of the Salalah Plain bounded by Jabal Qara, the Rakhyut Plain bounded by Jabal Qamar, and the Sadh Plains bounded by Jabal Samhan.

## CHAPTER 2. PRESENT STUDY

The methods, results and conclusions of this study are presented in the papers appended to this dissertation. The following is a summary of the most important findings in these papers.

### *METHODS*

Two types of interviews, formal and informal interviews, were used to capture and understand various aspects of frankincense extraction and associated management practices which included surveys of the major stakeholders. These consisted of formal interviews using questionnaires, and unstructured informal interviews with various stakeholders, ranging from government agents, tribal elders, local communities and harvesters. In addition, rapid rural appraisal was used to identify local ecological zones, frankincense habitats and to capture differences among local stakeholders and markets.

Other methods used included weighing randomly chosen sacks of frankincense in the field. These direct measurements were done biweekly to coincide with the end of each harvesting cycle and prior to *luban* shipment. The purpose of these measurements was to quantify the weight equivalence of a sack of frankincense in kilograms (kg).

Incision sampling was carried out to determine the number and impact of harvester administered incisions on trees of different heights during the frankincense extraction season. Grazing transects were taken in each sampled wadi to determine the intensity of grazing on *B.sacra*. Radiocarbon dating was carried out on *B.sacra* trees with different heights. This was done to study *B.sacra* age structure and to determine if there was an age - height relationship between tall trees favored by harvesters and less desired short trees. Germination trials were carried out to determine how seeds from different ecological zones respond to various propagation treatments and how that might be useful for the propagation and regeneration of *B.sacra* and its potential for the conservation and management *B.sacra*.

*RESULTS*

Frankincense (*luban*) extraction has gone through a transformation. *B.sacra* ownership and control remain in Omani hands but the production and processing systems are dominated by migrant Somali harvesters. As young Omanis move away from seeking employment in harvesting frankincense, migrant harvesters move in to fill the void and establish a niche. Consequently the *menzela* (land parcel) based management structure and organization has given way to a hybrid system that retains some aspects of the Omani *menzela* system but is heavily influenced by the infusion of Somali knowledge. Similarly the legendary system of transporting frankincense to Salalah, Mirbat and Sadh through the use of camel caravans has been replaced with the contemporary use of donkeys and trucks.

The only harvesters working in Samhan Nejd (better known as Hojar) were illegal migrant Somalis consisting of 43 individuals organized into three working groups. This number represents only 4.5% of the estimated number of Omani harvesters that occupied the zone before the 1970s. Although this practice is banned, some migrant harvesters continue to collect seeds in the field for sale to clandestine sources.

Somalia and the U.A.E are Oman's largest frankincense trading partners. Somalia is the principal exporter of frankincense into Oman and the U.A.E. is the largest importer of Omani frankincense. Omani wholesalers of Somali heritage (resident Somali Omanis) have become major players in the frankincense industry, especially in the import/export sector.

Camel grazing poses the greatest threat to *B.sacra* especially in easily accessible areas and wadis with gentle slopes. The most severe form of grazing occurs in wadi Dowkah and wadi Adonib. Short trees within camel reach are more vulnerable to severe over grazing. By contrast, tall trees (>2m) are favored for frankincense extraction and receive more incisions from harvesters than short trees (<2m) by a factor of eight. Therefore, taller trees with bigger girth are more susceptible to over harvesting damage from incisions. Radiocarbon dating results did not correlate well with tree height. Seven samples (36.8%) were dated as post-atomic bomb era (55 yrs or younger) and the remaining 12 samples (63.2%) ranged from 68-457 years old. The lack of on site owner

supervision, combined with the absence of government agents and guidelines, poses a serious threat for the successful management of *B.sacra* habitats.

## CHAPTER 3. CONCLUSIONS

Frankincense extraction in Oman has undergone a major shift in the organization, structure and management systems of the frankincense industry. The evolution of frankincense extraction from an entirely Omani-controlled process to a hybrid system controlled by stakeholders consisting of Omani owners, Somali-Omani wholesalers/merchants, and Somali harvesters is still evolving but is stacked in favor of harvesters, transporters and wholesalers with a common Somali lineage.

Frankincense producing trees are under the control of the Al-Kathiri, Al-Mahra and Al-Qara tribes of Oman's Dhofar region. Ownership will remain with the tribes for the foreseeable future and the size of each *menzela* will continue to decline with each sequence of inheritance which results in increased fragmentation. Eventually, it appears that individual ownership parcels will become too small and economically unfeasible to rent or exploit.

Even though there are legitimate grounds for government and public concern about the potential effects of over-harvesting in frankincense-producing habitats, Somali harvesters will use their frankincense extraction skills and their social capital to strengthen their networking with resident Somali-Omani kinsmen in order to maintain a foothold in Dhofar's *luban* production industry. As long as their skill and experience are needed by Omani nationals willing to hire them, and as long as frankincense remains a sought-after

product, Somali harvesters will exploit their niche in the production and processing of frankincense in the field through rental or sharecropping arrangements.

Somali-Omani wholesalers/merchants are familiar with both the Somali and Omani cultures and customs and they maintain social capital links with both Omani owners and Somali-harvesters. Moreover, their access to Somali *luban* products gives them an added advantage to continue playing a leading role in Oman's frankincense industry.
The store of knowledge of frankincense management and production that is currently held by the older generation of Omanis will most likely disappear as the younger generation is drawn to other forms of employment. Given the lack of interest among young Omanis in the *luban* extraction industry, a significant portion of the art of managing the structure and organization of frankincense will die with the elders who possess this knowledge.

The diffusion of the Somali harvesting knowledge system is taking hold in Dhofar. As long as there are no direct Omani supervision and monitoring management systems in the field, Somali harvesters will use their human and social capital to acquire the necessary physical and financial resources required to gain unfettered access to the natural capital (frankincense). Obtaining and maintaining frankincense usufruct rights enables Somali harvesters to play a leading role in frankincense extraction.

Frankincense/*luban* is a NTFP that plays an important role in the economy and culture of Dhofar. *Luban* production and processing is sustainable because the number of harvesters is too small to have a detrimental impact. In addition, the owner's threat to suspend group harvesting rights to those who engage in harmful gum-resin extraction methods is an effective management tool that fosters self- monitoring among harvesters. Because harvesters depend on frankincense to maintain their livelihood, work parties exercise considerable self-policing that encourages sustainable low impact harvesting methods in order to protect group usufruct rights.

There are large tracts of protected reserves Jabal Samhan Natural Reserve (JSNR) that contain about 60% of the two most important *luban* habitats (Hojari/Nejdi) but these areas lack active management plans. JSNR was set up by Sultan Qaboos by Royal Decree 48/97 (in 1997) and could prove to be instrumental in the sustainable conservation and management of *B.sacra* and other natural resources in the reserve.

Documenting migrant workers and providing them work authorization papers will legalize the harvesting process and stabilize the NTFP workforce, thus reducing abuse by and against harvesters. Similarly, standardized resin classification and certification at the wadi of origin or "forest gate" will enable local harvesters to authenticate and enhance the grading, marketability and profitability of their frankincense. If current low harvester numbers and minimal human settlements, coupled with restricted grazing trends in JSNR

are maintained, the extraction of this NTFP for its economic value appears to be sustainable

*Luban* production is sustainable within its current configuration. However some of the things that might make it more socially just (i.e., formalizing the immigration status of Somali harvesters) and potentially more profitable to all involved (i.e. better grading/documenting origin/overseas markets) could threaten sustainability because it would (a) make it more profitable, and hence (b) increase pressure by encouraging more (legal) Somali tappers.

*B.sacra* is under threat on several fronts but there are some promising developments that may contribute to the long-term regeneration, management and conservation of this arid land resource. For example, the Royal decree responsible for the establishment of the 4500 km² JSNR will at least maintain the woodlands in their current composition, especially if the decree is complimented with an active management strategy.

Successful nursery propagation of *B.sacra* could play a significant role in the rehabilitation of fragmented *B.sacra* habitats and in the continuation of *B.sacra* regeneration. This study's propagation trials demonstrated the promise and possibility of more active management of *B.sacra*, while radiocarbon dating illustrated the opportunity to describe the age structure of *B.sacra* stands instead of relying on untested harvester

claims. In addition, dating will play an important role in understanding and determining frankincense production levels that might be sustainable.

The distribution of *B.sacra* in Oman is generally restricted to dry environments on the rainshadow side of Jabal Qamar, Jabal Qara and Jabal Samhan. However, this study found scattered *B.sacra* trees growing within the drought deciduous acacia woodlands on the humid southern aspect facing the Indian Ocean. The trees on the seaward facing slopes are small in stature and too sparse to be viable for *luban* extraction.

*B.sacra* is found along an elevation gradient from 60 meters above sea level in the *Jarbeeb* to 1770 meters above sea level in Jabal Samhan. The vegetation's primary area of occurrence is within wadis. Bigger trees that often reach a height of 6 meters or more are found in the bottom of stream channels while smaller trees of 2 m to 3 m are found on wadi slopes. Although radiocarbon dating is an approximation, it showed that the age of sampled trees had no correlation with tree height thus disproving the belief among harvesters and locals that taller trees with larger girth are the oldest.

*B.sacra* growing in gently sloping easily accessible terrain such as those in Adonib, Dowkah, Iyun and other areas in the Jarbeeb are the most vulnerable to bark-stripping and overgrazing. These grazing activities contribute to vegetation stress and vulnerability and inhibit the ability of *B.sacra* to regenerate. In extreme cases, this form of grazing often results in the mortality of the plant.

Although *B.sacra* trees get some respite from grazing during the rainy season (*Khareef*). This relief is only temporary because the high animal population density tends to quickly exhaust available forage. As palatable forage or browse is exhausted (Al Kathiri 1996), camels in *B.sacra* habitats resort to browsing on less desired alternatives such as *B.sacra*. Locals indicate that increases in livestock population and human settlements are quickly depleting grazing resources and disrupting the traditional rest rotation and migration patterns of the past.

Government incentives, remittances from family members working in urban centers, and improved personal incomes are enabling more nomadic families to provide supplementary animal feed and water in permanent or semi permanent locations. Unfortunately, this practice effectively limits the range that livestock will travel to graze during the dry season or any other time when forage availability is reduced. Increasing the length of time livestock remain on any one site intensifies resource utilization and contributes to the general overgrazing trend in Dhofar.

The JSNR lacks active management strategies that serve to enforce and/or implement the conservation legislation decreed by Sultan Qaboos (of Oman). Several different land use and land right activities are often exercised on the same plot of land. These overlapping rights by tribal groups, rights of government agencies and ministries and the rights of the Royal branch require a careful synergy to accommodate the competing interests of the

various stakeholders. The sensitive nature of these issues in JSNR makes managing the general area and *B.sacra* stands very challenging.

Increases in the number and density of human settlement and associated activities have altered traditional land utilization systems. The increasingly diversified and often overlapping agricultural, pastoral, urban, environmental and industrial activities are changing landscape use in Dhofar, especially in and around the southern mountain ranges. These changes influence vegetation health, in general, and the maintenance of viable frankincense habitats and stable *B.sacra* stands in particular.

Land conversion, frankincense harvesting and livestock grazing are the three major impacts affecting *B.sacra* regeneration. The interaction among these impacts and the biological system result in outcomes such as vegetation instability, fragmentation or extinction.

Land allocation for urbanization, agriculture and industrial use in the Jabal and Jarbeeb removed prime rangelands from communal use and management. These land-use changes directly or indirectly contribute to land degradation that affects *B.sacra* regeneration and survival.

Plants subjected to successive tapping over extended periods tend to experience stresses that interfere with plant reproduction cycles and *luban* yield. In extreme cases, stresses

from tapping injuries reduce *luban* production, weaken inherent plant defenses and thus render the plant vulnerable to secondary infections that induce plant mortality. Trees that are less than 2 meters in height are harvested less frequently than taller trees. Consequently tall trees are more susceptible to injuries from tapping. The higher resin production of the big trees and ease of access to them by the harvester makes those trees more vulnerable to stress and mortality from repeat harvesting. Furthermore, it appears that a "sustainable" harvest regime is dependent on a limited harvest pressure (i.e., not totally open-access), and a workforce of harvesters that have some level of skill and social cohesion. Thus, if harvester numbers and their level of expertise remain at the current level the long-term detrimental effects of resin extraction could be minimized.

Absentee landlords in active tapping areas increase the likelihood that harvesters will engage in practices that are detrimental to *B.sacra* survival, regeneration and conservation. Even though harvesters exercise considerable self policing, on-site owner or owner-proxy supervision and management is vital: remote management does not work well. Owner absence encourages harvesters to use less stringent and shorter rest rotation periods between seasonal harvest cycles. Lack of sufficient rest rotation between harvesting cycles does not allow *B.sacra* to heal from tapping injuries and contributes to overall plant stress and vulnerability to pests and disease. In addition, the persistent practice of seed collection for sale that coincides with the *B.sacra* plant reproduction cycle and sustained tapping, reduce the availability of seed, and the overall regeneration potential of *B.sacra*.

Gravel mining effects are far more devastating than any other land-use activity, and land degradation in the distressed area extends to soil removal, and lower soil moisture conditions and nutrient availability. This activity leads to plant mortality because it directly affects the soil through erosion and earth removal, it deprives the plant of nutrients and water, and increases plant stress that reduces or curtails seed production. Reducing or eliminating the available seed bank disrupts the biological cycle and contributes to diminished plant regeneration potential from seed to mature plant and back to seed.

Resource management and land use trends that have emerged over the past several decades threaten not only the sustainable use of *B.sacra*, but its very existence. Continuation of current utilization trends in Boswellia habitats with minimal and variable rainfall will lead to the fragmentation and eventual extinction of a valuable arid land resource in more vulnerable areas such as the Jarbeeb, Wadi Dowkah and Wadi Adonib.

Large *B.sacra* trees are less susceptible to mortality resulting from grazing unless debarking is involved. Larger trees have an extensive root system and significant parts of the trees are beyond the reach – both above and below ground – of livestock browsing. In the absence of debarking and activities that transform the landscape (e.g., gravel mining), stands of big *B.sacra* trees might not regenerate but could persist as stable plant communities.

**REFERENCES**

Al-kathiri, A. M. 1996. *Qabat wa Marai Jibal Muhafadat Dhofar [The mountains of Dhofar's forests and rangelands]* . Dhofar National Printing Press, Oman.

Chatty, D. 1996. *Mobile Pastoralists: Development Planning and Social Change in Oman*. Colombia University Press, New York.

El Samani, M.O. 1990. *Establishment of rangeland management programme in the Southern Region of Oman*. FAO report. OMA/87/013.

FAO 1995. *Trade Restrictions Affecting International Trade in Non-wood Forest Products: non-wood forest product 8.* http://www.fao.org/forestry/foris/webview/forestry2/index.jsp?siteId=1141&langId=1

Farah, A.Y. 1994. *The Milk of Boswellia Forests: Frankincense Production among Pastoral Somali*. Reprocentralen HCS, Uppsala

G.R.M. 1982. *Range and Livestock Survey*. Final Report, GRM International Pty Ltd. Brisbane.

Gallagher, M. 1977 The Oman flora and fauna survey 1977 (Dhofar). *Journal of Oman Studies*, 3:1 9-13.

Ghazanfar, S. 1998 Vegetation of the plains. In S. A. Ghazanfar and M, Fisher (eds.), *Vegetation of the Arabian Peninsula*, Klumer Academic Publishers, Netherlands, 175-190.

Groom, N. 1981. *Frankincense and Myrrh: a Study of the Arabian Incense Trade*. Longman, London pp 16.

Guba, I. and Glennie, K. 1998 Geology and geomorphology. In S. A. Ghazanfar and M, Fisher (eds.), *Vegetation of the Arabian Peninsula*, Klumer Academic Publishers, Netherlands, 175-190.

Inder, G., P. Ashok, et al. 2001. "Effects of gum resin of Boswellia serrata in patients with chronic colitis." *Planta Medica* 67(5): 391-395.

Jansen, J. 1986. *Nomads in the Sultanate of Oman: Tradition and Development in Dhofar*. Westview Press, London.

Lacuna-Richman, C. 2004. Using suitable projects in adding value to nonwood forest products in the Philippines: the copal (Agatha philippinensis) trade in Palwan. *Economic Botany*. 58(3):476-485.

Miles, S. B. 1872. On the neighborhood of Bunder Marayah. *Journal of the Royal Geographical Society of London*. 42: 61-76.

Miller, A.G. and Morris, M. 1988. Plants of Dhofar: *The Southern Region of Oman Traditional, Economic and Medicinal Uses*. The Office of the Adviser for Conservation of the Environment, Diwan of Royal Court, Sultanate of Oman

Phillips, W. 1966. *Unknown Oman*. David McKay Company Inc., New York.

Seif El Din, A.G. 1990. *Rangeland management programme: project no. OMA/87/013*. UNDP/FAO, Ministry of Agriculture and Fisheries, Sultanate of Oman (Daft).

Tewari, D. 2000, Valuation of non-timber forest products (NTFP): Models, problems and issues. *Journal of Sustainable Forestry* 11(4):47-69.

# APPENDIX A. THE TRANSFORMATION OF FRANKINCENSE PRODUCTION IN DHOFAR, OMAN

Farah, Mohamud H.

Office of Arid Land Studies

University of Arizona, Tucson, Arizona 85719

## A.1 ABSTRACT

This paper analyses the transformation of frankincense production in the Dhofar region of Oman. It focuses on and the roles various stakeholders, such as Omani owners of *Boswellia sacra* (the tree that produces frankincense), Somali-Omani merchants and wholesalers, migrant Somali harvesters, government and private agencies, play in that transformation. Frankincense management, ownership, inheritance and rental arrangements are often based on a land parcel system known as *menzela*. The paper looks into the transition of frankincense extraction from an Omani to Somali-dominated system. This analysis examines the traditional organization and structure of frankincense extraction, ownership and utilization using the late 1970s as baseline for the traditional Omani system. The 1970s oil boom attracted rural labor to urban and oil operation centers and had a profound impact on frankincense production in Oman. Migrant Somali harvesters in Oman played an important role by filling the labor shortage in the frankincense (*luban*) industry. Migrant harvesters used social capital assets and networks and exploited a niche to secure the financial credits required to dominate the frankincense industry. Indigenous Omanis have effective control over frankincense ownership but the

wealth of traditional knowledge the Omani elders possess is not being passed along, creating a considerable knowledge gap between the generations. Although overharvesting is minimal, the organizational and structural changes instituted by the migrant harvesters will have detrimental long term management implications for *B.sacra* and local resource managers.

## A.2 INTRODUCTION

Millions of people worldwide, especially in developing countries, depend on the harvest of non-timber forest products such as gum, resins and latex for their livelihood (FAO web 2005; Lacuna-Richman 2004). Likewise, poor migrant Somali harvesters in Dhofar, Oman, depend on frankincense –or *luban* – for 100% of their livelihood. These harvesters use a network of social linkages that stretch from the Bari region of Somalia, through Yemen and into the frankincense producing arid mountains of Dhofar in southern Oman.

Frankincense is examined here not so much as a commodity, but as the center of an economic activity that is central to a social network and the households whose livelihoods depend on its harvest. Rather than focus on the commerce of frankincense, we will consider the stakeholders in frankincense production and the network of social capital that underpins the enterprise in Dhofar today. The social capital concept deals with the linkages, social codes of conduct and social network that different groups or individuals in a group maintain within and among themselves.

Although patterns of Oman's frankincense extraction, ownership and organization have persisted relatively intact probably for a long time, changes since the late 1970s are transforming the indigenous systems. The changes that have taken place in Oman's frankincense extraction industry will have long term management implications for the structure and organization of the entire system. To better understand the nature and potential impact of these changes, this study sought to answer several critical questions:

4. What motivates poor workers from Somalia to illegally enter Oman to make a living in *luban* – frankincense – harvest?
5. How do they secure financial resources and gain access to rent frankincense groves?
6. What are the strategies they use to influence the *luban* market and what is the impact of their activities on the management, organization and structure of frankincense extraction activities in Oman?

To answer these questions, I examined the relationships and interactions among three groups who play a significant role in the *luban* industry. The groups consist of (1) indigenous (Omani) *Boswellia sacra* owners, (2) merchants and wholesalers (contractors) and (3) Somali frankincense collectors (harvesters). Although the first two groups are Omani nationals, for the purposes of this paper Omanis of Arab heritage will be referred to as Omani and Omanis of Somali heritage will be referred to as Resident Somali-Omanis. This study will also investigate the differences between the exclusively Omani pre-1970s harvesters and the exclusively Somali post-1980s harvesters to illustrate the

way they contributed to the changes in frankincense extraction, processing and management in Dhofar.

The study will also address the roles of the Omani national Public Agency for Marketing of Agricultural Products (PAMAP) and a private fragrance enterprise known as Amouage. Although both play comparatively minor roles, their potential impact in the future could be critical in the development of Oman's local frankincense industry. Other groups that play less significant roles include government resource management agencies and *luban* retailers in local bazaars (markets).

## A.3 STUDY AREA

The province of Dhofar, located in the Sultanate of Oman, is the southern-most province in Oman bordering Yemen on the west, Saudi Arabia on the north and the Indian Ocean on the south, covers an area about 99,210 square kilometers between approximately latitudes 16º North to 21º North, and longitudes 51º East to 56º East. Dhofar is the largest of the eight provinces of Oman. It represents about 32 percent of Oman's total area and consists of nine administrative districts, six of which are concentrated in the three mountain ranges along the southern coastal area of the province (Figure A1).

My primary focus is on *B.sacra* habitats in the province of Dhofar. In Dhofar, *B.sacra* is found in ecological zones on the arid leeward side of the Qamar, Qara and Samhan mountains known to the locals as Nejd. *B.sacra* is also endemic to pockets of fragmented habitat in the *Jarbeeb* (coastal plains), and in isolated sections of seaward facing slopes

south of the Kharish and Harkak mountain passes in Jabal Samhan . These mountain passes were prominent in the ancient frankincense caravan routes to the coastal ports of Mirbat and Sadh, and they are still in use and serve as the primary access routes for human and animal migration. *B.sacra* habitats are predominantly found in arid areas beyond the reach of monsoon rains (Miller and Morris 1988) and tend to be limited to the *wadi* channels that drain the higher, moister mountains.

The main focus of this study is on the people living in the various frankincense habitats and the impact of the interactions between indigenous (1) Omani, (2) Resident Somali and (3) Transient (illegal) Somali harvesters on frankincense extraction. The frankincense habitats extend from Hasik (eastern Dhofar) to Oman's border with Yemen in a swath of land approximately 60 km wide and 240 km long. The Indian Ocean marks the southern boundary of this strip of land and an east to west line centered on the city of Thumrait marks the northern-most boundary.

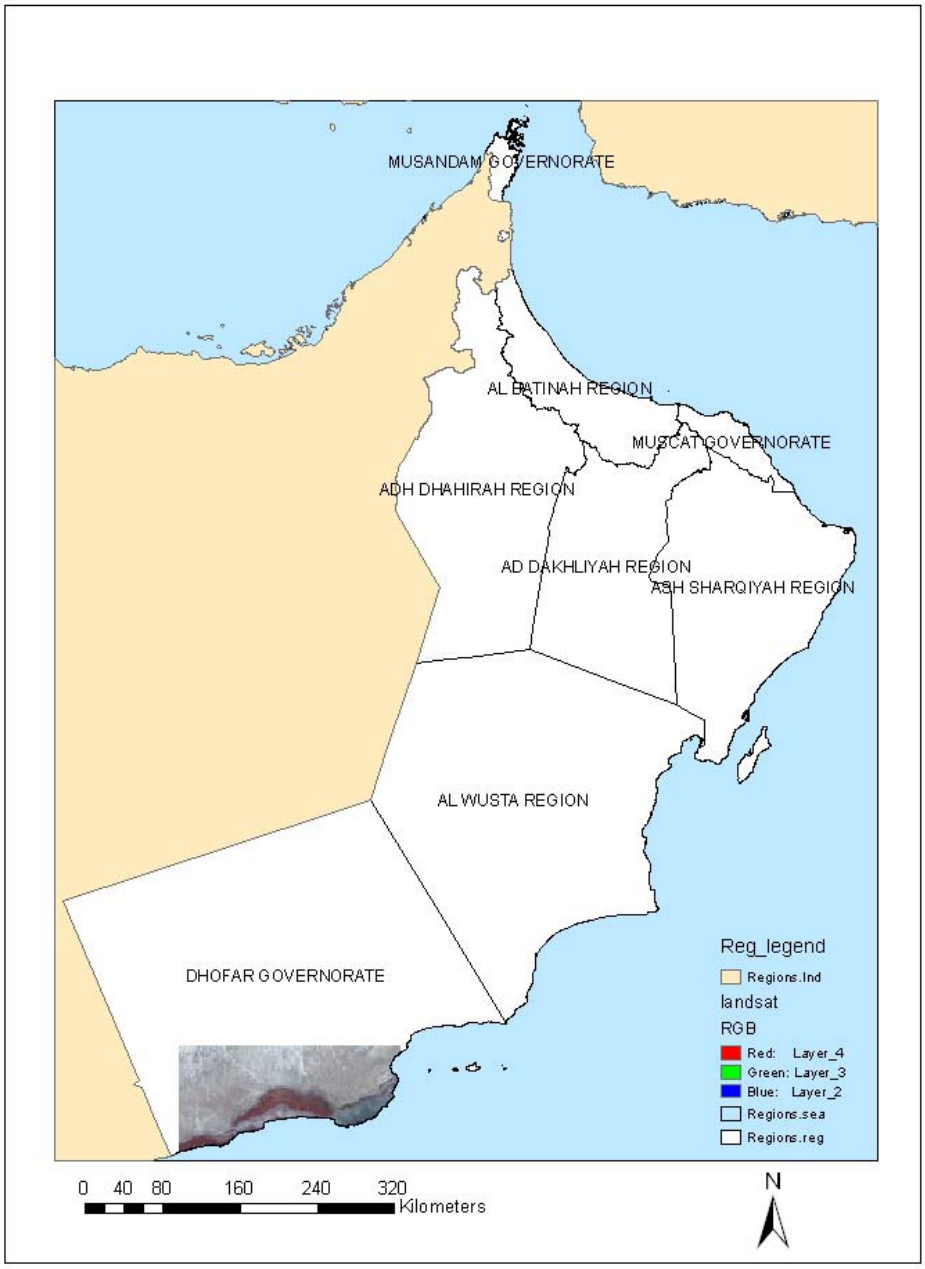


**Figure A1** The eight provinces (wilayat) of the Sultanate of Oman with a false color composite satellite image showing the Dhofar mountain range and adjoining habitat areas.

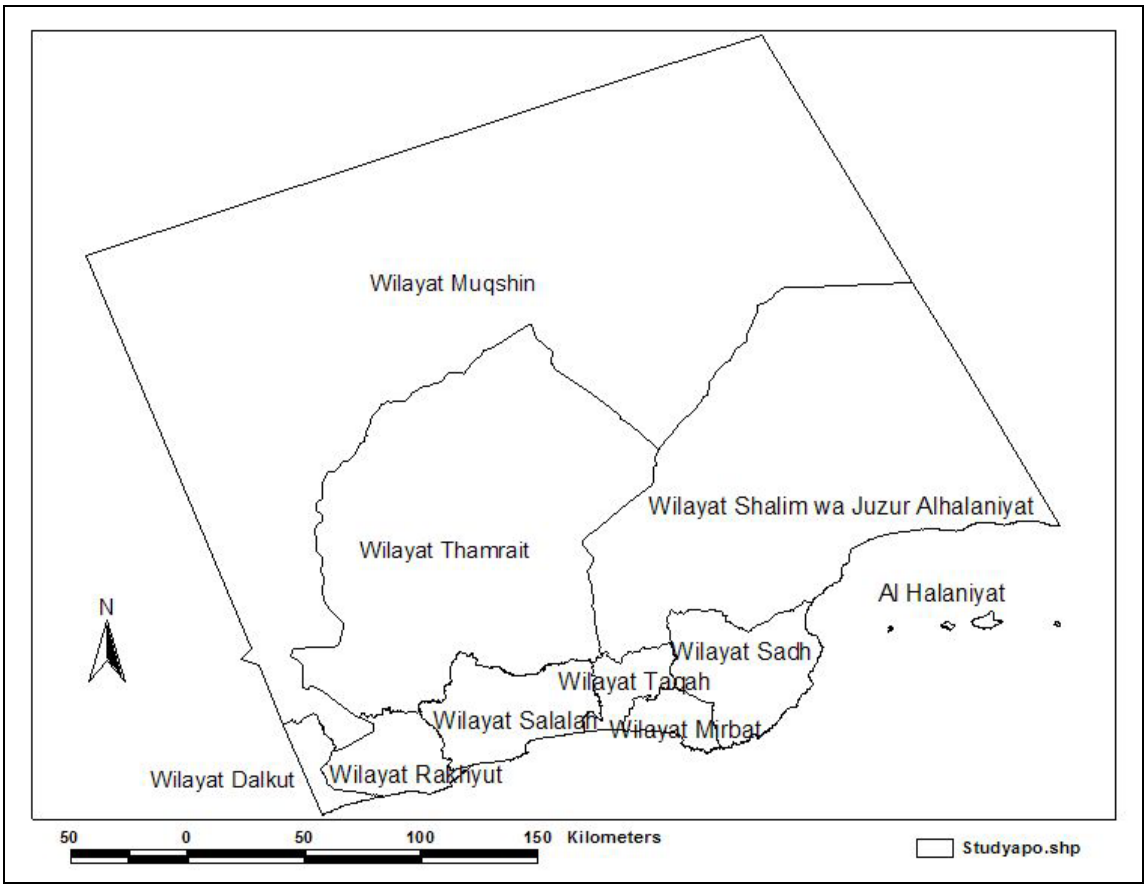


**Figure A2** Governate of Dhofar showing the nine wilayat (provincial districts) and Halaniyat Island

## A.3.1 FRANKINCENSE HARVESTING AND USES

A number of trees around the world produce resins that have been burned as incense for millennia. In greater Arabia, *Boswellia* produces a resin known as olibanum (frankincense) (Basar et al. 2001). In the new world, *Bursera* and *Protium* produces the resin copal (Case et al 2003) and *Commiphera* produces myrrh (Groom 1981). Somalis know frankincense as *beeyo* and *foox* (pronounced foh), and it is known in Arabia as *luban* (Thullin and Warfa 1986). The Indian frankincense or *salai guggul* is also known as Indian olibanum (Murthy and Shiva 1977).

Frankincense may have lost much of its past monetary value in modern times but it still has its biblical connotation (Skeet 1992), ritual value and its strong association with historical frankincense cities. Dhofar has been important over millennia for the production and trade of frankincense. Port cities and inland cities along strategic trade routes played an important role in making frankincense an item of "international" trade. The ruins of Samhuram, Hasek (Phillips 1966, Thomas 1932), Balid (Thomas 1932) or AlBalid which flourished from the 12$^{th}$ to 16$^{th}$ century (Kay 1988), as well as the legendary lost city of Ubar or Wabar (Thomas 1932) and its sister city of Ain Himran, are some of the cities in Dhofar that flourished from the trade of frankincense at different points in time dating back to 900 B.C. (Clapp 1998). As some cities fell in ruin or were abandoned, new cities emerged to take their place. Ubar was destroyed and abandoned about 300-500 A.D. in favor of cities near a water source in and around the Dhofar Mountains (Clapp 1998). A Persian conqueror destroyed an important frankincense city known as Samhuram in 625 A.D. and then moved the capital to AlBalid 25 kilometers to the west (Kay 1988). The role of cities as nodes in frankincense extraction and trade was and is critical to understanding the movement of this valuable commodity.

Although frankincense "tappers" (who extract resin from trees) and "owners" (who control access to individual trees) attribute certain mythical powers to frankincense, the trees that produce this resin are valued more for their economic importance than their ritual value. Similar phenomena have been observed among Mayan copal collectors

(Kockelman 1999; Stross 2004 web), Philippine copal collectors (Lacuna-Richman 2004; Conelly 1985) and pastoral Somali tappers in Ethiopia (Lemenih et al. 2003) and Somalia (Farah 1994). It is therefore predictable that the development of the petroleum industry in Oman and the rise of new employment opportunities in urban and industrial areas considerably reduced the reliance of indigenous pastoral Omani harvesters on frankincense extraction for sustaining rural livelihoods.

As Omanis involved in the frankincense market moved into the petroleum industry, Somalis migrated to Oman in pursuit of the economic gains from the extraction of frankincense. Somali harvesters are predominantly transient illegal immigrants, and the primary objective of these harvesters is to make money. The amount of money they make depends in large part on the quantity of *luban* they collect. Therefore, each harvester strives to produce as much resin as possible during the harvesting season, with little regard for long term sustainability. This scenario might lead to over-harvesting and over-production with negative consequences for the frankincense groves (stand of trees), the price of *luban* and, as a consequence, for the harvesters who sustain a livelihood extracting frankincense in Dhofar. The introduction of Somali harvesters has altered the structure and organization of *luban* extraction in Dhofar.

The transformation in *luban* tapping and collection in Oman might create management and land tenure problems that could potentially ruin the cordial relationships among various stakeholders. As harvesters become more vulnerable to economic factors, the

need to survive and sustain a livelihood would likely take precedence over *B.sacra* conservation. To a migrant harvester living in acute destitution and imminent danger of arrest, survival considerations are always paramount, and every peasant learns the technique of survival as part of his/her everyday experience (Rahmato 1991). The delicate balance required between deriving economic benefits from frankincense extraction and satisfying environmental management and conservation concerns oblige most Somali migrant tappers to engage in acceptable harvesting practices in order to preserve group usufruct rights. However, *B.sacra* holdings under absentee owner management are potentially more prone to overexploitation and decline than those under onsite management or periodic supervision. At a higher administrative level, resource overharvesting and its potential implications for the environment might prompt government agencies to curtail *luban* extraction. Although there are multiple issues affecting the frankincense groves, poor illegal migrant workers from Somalia tend to be blamed for a significant portion of those problems. Overgrazing is a major problem affecting all vegetation types (Al Hatrushi 1986; Al Kathiri 1996; Jensen 1986) but it is seldom associated with frankincense groves. Similarly, *B.sacra* problems linked to increased human settlements, surface mining and land tenure issues are rarely addressed in their proper context. Migrants' lack of legal documentation and representation fostered an environment where these harvesters are made the scapegoats for everything that has gone wrong with the frankincense groves.

#### A.3.1.1 RITUAL USE

Gum-resins like frankincense and copal play a major role in spiritual and sacrificial ritual offerings. Burning incense is used to ward off evil spirits and as offerings to the Gods in Guatemala's Chorti Mayans (Wisdom 1940) and Q'eqchi' Mayans (Kockelman 1999) and in Maya and Nahua (Aztec) influenced societies (Case et al. 2003). In ancient Egypt, around the third millennium B.C., frankincense was burned on all sacred and solemn occasions in the ritual of the temple, in the mummification process of princes of royal blood and of sacred animals, as well as in funeral rites (Thomas 1937). Similarly, copal was part of the funerary rites of the Mayan tomb (Case et al. 2003) in Mesoamerica. Although less significant than the historical ritual practices of purifying the soul, burning incense in religious ceremonies in Catholic churches (Wisdom 1950), Buddhists temples (Groom 1981), Orthodox churches (Tirfe 1987) and the shrines of Muslim saints (Farah 1994) illustrates the way humans around the world continue to associate incense with spirituality.

Frankincense trees are presumed to possess or house supernatural powers associated with both good and evil spirits. In ancient South Arabia frankincense was a sacred commodity and its harvesters worked under ritualistic restraints (Groom 1982) In order to appease the spirits, *luban* harvesters still perform a ritual offering such as incense burning accompanied with prayers at the beginning of the tapping season. In contrast, herders in Dhofar often burn frankincense during milking to protect the indispensable milk animals from the evil eye and from inimical spirits (Miller and Morris 1988). Some Somali harvesters believe that a plant such as *B.sacra* that continues to survive, thrive and

produce resin in harsh and desolate arid environments has sacred powers that need to be respected and when necessary pacified through the performance of incense burning rituals and prayers. Similar beliefs were widespread among Arab harvesters, and Groom (1981) speculates that this belief system might have been initially perpetuated to discourage potential trespassers from harvesting *luban* trees.

In the Americas, the flow of gum-resin from incised areas symbolizes both the blood of trees and food for deities (Stross 2005). In Somalia, the fresh white *luban* exudates are associated with milk. In other instances the gum-resin is referred to as milk (Farah 1994). Similarly, Omanis refer to the process of tapping to induce *luban* production as milking (Thomas 1932). The significance of this symbolism is important because frankincense flows from living trees to nourish the soul, just as milk flows from a living animal to nourish another body.

#### A.3.1.2 TRADITIONAL USE

Fumigation is the most widely used traditional practice using *luban* in rural and urban areas. Incense burning in places of residence, at work and in ceremonial gatherings is a ritualistic practice designed to ward off evil spirits and foster peace and tranquility. Harvesters burn incense throughout the frankincense collection season especially at the beginning and end of the harvesting season. During frankincense burning ceremonies harvesters say prayers to help sick colleagues, resolve a conflict, and shield themselves

from the evil spirits of *shaytan* (devil). Frankincense burning associated with prayer rituals extend to all facets of society, including weddings, praying for ancestors, and paying homage to saints. Fumigating clothes to get rid of bad odors (Groom 1981) is common among Somali harvesters and occasionally used in Oman's rural areas. However, readily available diversified upscale incense flavors and perfumes have reduced the significance of frankincense as a fumigating agent for clothes.

#### A.3.1.3 MEDICINAL USE

Frankincense is utilized in traditional (Farah 1994; Groom 1981; Miller and Morris 1988) and conventional medicine (Inder, Ashok et al. 2001)to treat numerous ailments. Somalis use frankincense for stomach ailments, venereal diseases, back ailments, chronic cough, polio, and chest congestion and as an external application to treat wounds (Farah 1994). In Oman, frankincense is used to treat mastitis in livestock and humans as well as hysteria and psychic disorders in humans (Miller and Morris 1988). In Somalia, these disorders are known as *saar* and the healing rituals are often performed by a high priestess known as *calaqad* or *fooxiso* (Farah 1994). Other traditional remedies include the Omani practice of using frankincense as a disinfectant to treat wounds, to relieve the nausea of pregnancy and to strengthen the teeth and gums (Miller and Morris 1988). In traditional Chinese medicine, frankincense is used to "invigorate the blood and promote the circulation of Qi," reduce swelling and promote healing (Marshall 2003). In conventional medicine frankincense has been used to treat a host of ailments such as

chronic colitis (Inder, Ashok et al. 2001), human leukemia (Shao, Ho et al. 1998), rheumatoid arthritis (Etzel 1996) and colon and liver cancer (Duan 2002).

#### A.3.1.4 COMMERCIAL AROMATHERAPY AND FRAGRANCE

Frankincense and other gum-resins like copal and myrrh are gaining popularity in alternative medicinal and non-medicinal uses. In addition to the development of some food flavors and fragrance (Baratta, Dorman et al. 1998; Svoboda, Svoboda et al. 2000; Simla, Koch et al. 2001; Kasali, Adio et al. 2002; Baser, Demirci et al. 2003), the raw gum-resin and essential oil extracts from frankincense, copal, myrrh and other plants are increasingly used in aromatherapy in Europe and North America (Bird 2003; Maddocks-Jennings and Wilkinson 2004; Buckle 2003; Marshall 2003). Although aromatherapy is considered a modern innovation in the west, it has its roots in ancient civilization dating back to the Pharaohs of the Nile (Bird 2003) and the Mayans of Mesoamerica. Essential oil derived from frankincense is also used in aromatherapy to treat depression and serve as an expectorant (Marshall 2003).

The emergence of alternative therapeutic and industrial uses of essential oil extracts and resins locally and in Western countries has generated renewed interest in gum-resins like frankincense. Local industrial innovations include the production of eyeliners (*kuhul*) and packaged frankincense in PAMAP's Musqat processing center and the use of frankincense in the Amouage brand of perfumes. In Western countries, a new generation of ointments, lotions and supplements with frankincense additives are appearing in health

food stores. Frankincense has proven to have antifungal and antioxidant properties (Baratta et al.1998), and some alternative medical practitioners use frankincense oil and resin in meditation and body healing. As the demand for frankincense increases, this development can result in higher *luban* prices at the local level that can improve the livelihood of tappers. Increased demand and high prices may lead to an influx of harvesters trying to make a living in a lucrative frankincense market. In the long run, increased harvester numbers could bring about unintended consequences including over-harvesting.

## A.4 METHODOLOGY

Two sets of interviews, formal and informal interviews, were used to capture and understand the local management practices, which included surveys of the major stakeholders. These consisted of (1) formal interviews using questionnaires, and (2) unstructured informal interviews with various stakeholders ranging from government agents, tribal elders and harvesters.

### A.4.1 FORMAL INTERVIEWS

A survey questionnaire was devised to capture various aspects of frankincense extraction such as production, transportation, processing and management; while formal interviews elicited information regarding harvester perception of *B.sacra* health and appropriate rest periods between harvesting cycles. A total of 16 harvesters were interviewed between December 1998 and June of 1999. A total of 12 harvesters were interviewed during the

April-September 1999 frankincense extraction season in the Hojari/Nejdi zone, but only 3 collectors from the Shazri/Sha'bi zone were interviewed during the October 1998-March 1999 season.

### A.4.2 INFORMAL INTERVIEWS

Informal interviews with elders, government agency officials, harvesters, wholesalers and retailers were instrumental in capturing methods of *luban* production, processing, marketing and sales. Moreover, these interviews were used to capture the different strategies the major and minor stakeholders use to influence the structure, organization and management of frankincense extraction and the impact of their interaction on the indigenous system. The information gathered during these interviews was instrumental in documenting the evolution of frankincense extraction before and after the 1970s and the way different stakeholders utilized their social, human, physical, natural and financial capital assets to enhance their role in the system to control or influence the capital assets. Informal interviews provided an insight into the structure, organization and management of frankincense ownership, land tenure and production systems in Dhofar. In addition, the interviews also revealed the increased level of interdependence among the various stakeholders. The shifting tribe-based alliances and the role of government in putting management, monitoring and conservation strategies in-place

Informal interviews with elders about ownership land parcels known as *menzela* were designed to get an estimate of the number of harvesters that worked in extracting

frankincense before the 1970's, and the traditional system of *menzela* organization and delineation before the introduction of Somali harvesters.

## A.5 RESULTS AND DISCUSSIONS

### A.5.1 CHANGES IN FRANKINCENSE EXTRACTION

#### A.5.1.1 *B.SACRA* OWNERSHIP:

Frankincense ownership in Oman is structured along tribal lineages where ownership parcels known as *menzela* are inherited and passed to the male members of the family. With each new generation, the ownership shares get smaller and smaller as parcels are subdivided among heirs in a fragmentation process (See Fig 3). The major frankincense owning tribes (Qara, Kathiri and Mahra) have complex, dynamic and hierarchical lineage and kinship structures within each tribe that extend from the first ancestor to the current living family members. This tribal structure governs the ownership, allocation and utilization of frankincense groves in a *menzela*. Since the late 1970s, the management, organization and structure of the frankincense extraction have undergone some changes. Specifically, the departure of rural Omanis for better-paying jobs in the petroleum sector has led to the introduction of migrant frankincense harvesters from Somalia. This change is threatening the long term stability of the traditional system of *luban* harvesting and management.

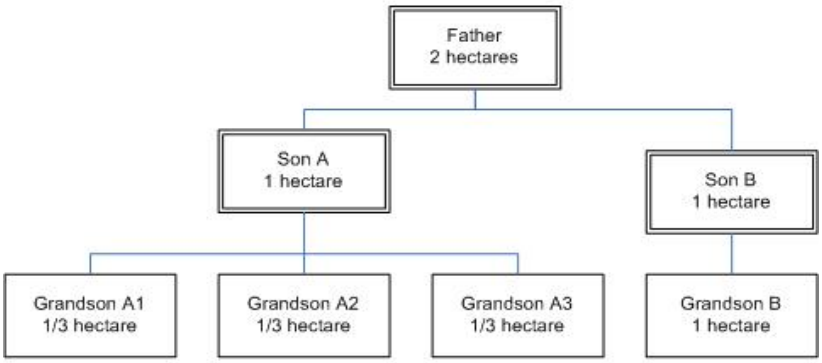


**Figure A3:** Inheritance structure of a hypothetical 2 hectare *B.sacra* parcel from the father to Sons A and B who get equal shares. As grandsons A and B inherit their fathers, individual shares are affected by the number of male siblings.

In the past, tribal territory was fiercely defended and it was almost impossible for other tribes to venture outside their traditional sphere of influence. Thus it would make sense for herders to be in control of frankincense groves endemic to their area of settlement and utilization. Tribal ownership of *B.sacra* is larger in scale and often based on *menzela* along watersheds or groups of interconnected adjacent land blocks. Intra-tribal ownership patterns of *B.sacra* are fixed. In contrast, inter-tribal ownership patterns are dynamic and can change from generation to generation. Intra-tribal parcel transfer to outside groups is extremely rare and ownership transfer of this nature is typically done at the tribal level as compensation to resolve a conflict. The primary responsibility for settling a claim in intra-tribal parcel transfer falls on the individual and moves up the tribal hierarchy system until the claim is satisfied. If the individual does not have any or insufficient parcels to satisfy the claim, the burden shifts to his family, then the next of kin, then his sub-clan and so on until the claim is satisfied. When the claim for compensation is satisfied, a

decision is made within the tribe to swap the parcel or parcels in question within the tribe before transfer. If the claim parcels are high yielding trees, individuals or groups within the tribe are given the option to swap those parcels so as to transfer their less productive parcels to settle the claim. However, a transfer of this nature was reserved for very serious offenses in order to avert tribal conflict.

Trespassing in the form of tapping *B.sacra* for *luban* extraction is a serious offence, especially when violators are individuals or groups outside the owning tribe. Retribution for such an offense can result in serious physical harm, humiliation before the tribal council or elders, and loss of property or loss of usufruct rights (Groom 1981; Farah 1994). In addition, trespassers might be required to pay monetary compensation to the owners. Although there had been strict adherence to the observation of these codes of conduct and tribal regulation (AlGhasanni 1981), the introduction of illegal Somali *luban* harvesters complicates the observance of tribal regulatory systems and increases the potential for abuse by blurring the lines of authority.

### A.5.1.2 STAKEHOLDERS AND FRANKINCENSE IN TRANSITION:

Traditional indigenous *luban* tapping, collection and marketing have undergone some fundamental changes in the organization, production and management structure of the frankincense industry in Dhofar. Indigenous *menzela*-owning Omanis, Somali-Omani (Omanis of Somali heritage) merchants and wholesalers, and migrant harvesters from Somalia are the primary stakeholders responsible for shaping the frankincense industry in

Oman. However, private agencies like Amouage, government agencies such as PAMAP, and the Ministry of Agriculture and Ministry of Municipality and Environment play a significant role with potential future benefits for frankincense owners and harvesters.

Prior to the 1970s, Omani tribes had full control over the production, distribution, marketing and export of frankincense. In addition, indigenous local tribes had total ownership of the frankincense groves, and harvesters were exclusively Omani except for a small number of Somali collectors. Miles (1872) points out the long and active trade in frankincense between Somalis and Arabs, and the movement of people and goods across the Red Sea in the late 1800's. Given these circumstances, Groom (1981) argued that some Somalis invariably came to Arabia for the sole purpose of collecting *luban* by paying rent to the Arab owners. Local interviews with Omani and Somali Sheikhs, like Sheikh Hadiya and Sheikh Ali, confirmed the historical presence and the current dominance of Somali harvesters in the frankincense extraction industry. Sheikh Hadiya is a prominent leader from the Mahra tribe and a powerful wholesaler with *menzela* holdings in Hojar. Although Sheikh Ali al-Somali doesn't own a *menzela*, he is one of the top leaders in the frankincense industry

Although Somalis have a long history of working in the Omani frankincense groves (Groom 1981), the literature on Somali harvesters in Dhofar is patchy and limited. Moreover, the recollection of oral historians is limited to events that have taken place in the last 100 years at best. At the present time, Somali-Omani ownership is limited to one

*B.sacra menzela* in Wadi Maqsail belonging to Ahmed Farah. According to second generation Somali-Omani community elders, the first generation of Somali-Omani immigrants worked and harvested frankincense in Maqsail during the early years of the reign of Sultan Saeed Bin Taymour (1932-1970). During that period, Jama Harqaf from Somalia was responsible for the distribution of frankincense. The second generation of Somali-Omani harvesters have expanded their operation to include the Shazri, Nejdi and Hojari *luban* producing zones located east of Jabal Qamar, north of Jabal Qara and north of Jabal Samhan respectively. Some of the second generation harvesters have become successful wholesalers and major stakeholders in the frankincense industry responsible for distributing some of the finest *luban* products in the market.

Group discussions with community members in Salalah revealed that as of the late 1980s, local *luban* wholesalers were predominantly controlled by second generation local Somali-Omanis. Elder local informants from Mahra, Amri and Kathiri tribal groups, ethnic Somali groups, and government officials from the Ministry of Agriculture and PAMAP confirmed the increased presence of migrant Somali harvesters in Dhofar and the transition of frankincense extraction from Omani dominated through the late 1970's to exclusively Somali in the 1998-99 harvesting season. In addition to the frankincense from Oman, Sheikh A-Alsomali a veteran *luban* importer and exporter pointed out that resident-Somali wholesalers are the liaisons and agents for the frankincense imports from Somalia. Similarly, all aspects of *luban* tapping, collection, field processing and transportation into the local markets are under the control of migrant Somali harvesters.

Field transportation is handled by Somali harvesters using donkeys while motorized transportation to the local markets is managed and operated by a Somali-Omani company. Although most indigenous Omani wholesalers buy their *luban* from field harvesters or Somali-Omani wholesalers, a small number enters directly into a sharecropping arrangement with Somali harvesters.

### A.5.1.3 COMMUNITY INTERDEPENDENCE:

Like their Mahra and Kathiri counterparts, Sehail Al-Amri and a group of elders in the Sadh plains confirmed the existence of a great level of interdependence between harvesters and the community in the past. When Omanis dominated frankincense extraction, the *luban* fields in Habjar (hojar) were teaming with people. Harvesters often bought goats, milk and ghee from the nomadic families in the area. Sometimes they brought their sick or injured to the settlements to recover. Some harvesters even died in the settlements and were buried there by their friends and relatives.

The nomadic settlements also used to provide labor during the extraction season. Some people worked in the *luban* fields during the day and spent the night at their family settlements. At times, managers (Dibbeyn Saqir) representing merchant renters hired camels and guides from the local nomadic settlements for frankincense caravans to Hasek, Sadh, Mirbat and Salalah.

The level of traditional cooperation and economic interdependence between *luban* harvesters and the nomadic communities in or near the *luban* extraction fields, before the 1970's, has disintegrated. The remoteness of most frankincense fields, as well as the cultural and language barriers between the local Omani communities and the migrant harvesters from Somalia, contributes to isolation between communities and a breakdown of the traditional system. Moreover, current migrant Somali harvesters have no legal work authorization. To minimize contact with the indigenous local community, they receive all their supply needs from the truck that hauls the bi-weekly frankincense harvest at pre-arranged pickup locations. Thus, the new harvesters' relationship with the frankincense truck has replaced the traditional harvesters' relationship with the indigenous communities. The emergence of these new interrelationships in place of the traditional methods is indicative of some of the transformation taking place in the frankincense industry.

#### A.5.1.4 Coastal Cities of Frankincense

Salalah is a magnificent coastal city, surrounding the old ruins of AlBalid, and the modern equivalent of the ancient city of Ubar. Salalah's rapid urbanization from the late 1970s through the late 1990s (Allen and Rigsbee 2000) and its rich frankincense history has propelled the city into a major tourist attraction, and enhanced the city's prominence as a major frankincense trading centre. In addition, the 1972 royal decree guaranteeing the right of each Omani to own four plots of land, and the housing loan decree of March 1974 which extended credit loans to Omanis, moved land distribution into the sphere of

government control and away from the domain of tribal elders (Allen and Rigsbee 2000). These development initiatives and the infusion of oil money in the 1970's were some of the major factors that contributed to urban expansion in Salalah.

Transport, through the development of modern road systems, airport and port facilities in Dhofar and Salalah, has contributed to the emergence of Salalah as a major frankincense trading hub, just as water played a vital role in the rise of ancient frankincense cities such as Ubar. The prominence of Salalah has also diminished the significance of Mirbat, Sadh and Hasek as major *luban* trading port-towns because harvested *luban* is channeled through Salalah. Although these three towns used to rival Salalah in the trade of frankincense, their continuing decline is indicative of the dynamic transformation of the local frankincense industry. Due to transportation access, it is cheaper, faster and easier to ship frankincense from the field to Salalah than to any of the *luban* trading port towns. The diminished role of Mirbat, Hasek and Sadh in the trade and processing of frankincense is further testament to a breakdown of the traditional frankincense-trade based on tribal affiliation between indigenous Omani owners, renters and harvesters and the camel caravan routes.

Prior to the 1970s, Omani harvesters sold their *luban* to their own merchant tribesmen regardless of their place of residence. Similarly, Omni frankincense owners gave fellow merchant tribesmen the first priority to rent their *menzelat (plural)*. The harvested *luban* was transported over camel caravan routes to merchant kinsmen in the various coastal

cities. These interdependent practices are vanishing rather rapidly because the Omani social networks relative to *luban* extraction have eroded as new generations have found employment in other enterprises (e.g., petroleum).

The emergence of the Resident Somali contractors as major players in the sale and marketing of frankincense is yet another manifestation of a new tribal/kinship affiliation between transient harvesters and Resident Somalis. The new alliance between transient harvesters, transporters and contractors with common Somali ancestral heritage gives these groups effective control of a significant sector of the frankincense market.

#### A.5.1.5 CURRENT (SOMALI) SYSTEMS

Somali harvesters are the only group extracting frankincense in Dhofar: the camel caravans strung together across mountain passes and over desert plains are a thing of the past. Indigenous Omani harvesters who tend their frankincense groves are so rare they could be considered an endangered species. Estimates elicited from unstructured interviews with local participants older than 50 years put the number of Omani harvesters in the Hojari/Nejdi at approximately 2,000 in the 1970s. By 1999, the number of transient Somali harvesters was estimated at 43 in the Hojari/Nejdi zone, and 150 in the Shazri and Sha'bi *luban* producing areas.

In addition to information solicited from local participants old enough to remember and be knowledgeable about the structure and management of the indigenous harvesting system, some scholars confirmed the presence of large harvester numbers in the past.

Phillips (1966) found that 3,000 families were engaged in the extraction of frankincense in Dhofar while Al-Ghasani (1980) put the number of Omanis in Dhofar involved in the production of *luban* at 3000 individuals. Later, Al-Kathiri (1996) reported the total number of harvesters in Dhofar consisted of 120 Somalis, thus confirming the perceived post-1970s decline in the number of harvesters. Given these numbers relative to the approximately 193 Somali migrant harvesters of the 1998-1999 season, we can infer that the potential for over-harvesting was higher under Omani management, if the number of tappers is an indicator of potential stress.

Somali tappers operating in 1999 represent only 10% of the pre-1970 Omani harvester numbers in Dhofar. When the active fields in Hojari/Nejdi zone are considered, actual Somali harvesters in Wadi Arah and Wadi Sanwyk represent 11% of the estimated number of Omani harvesters in the two wadis prior to 1970s (Figure 4). When 1998-99 harvester numbers relative to the six selected wadis are considered, they represent 4.5% of the estimated numbers in these wadis before the 1970s

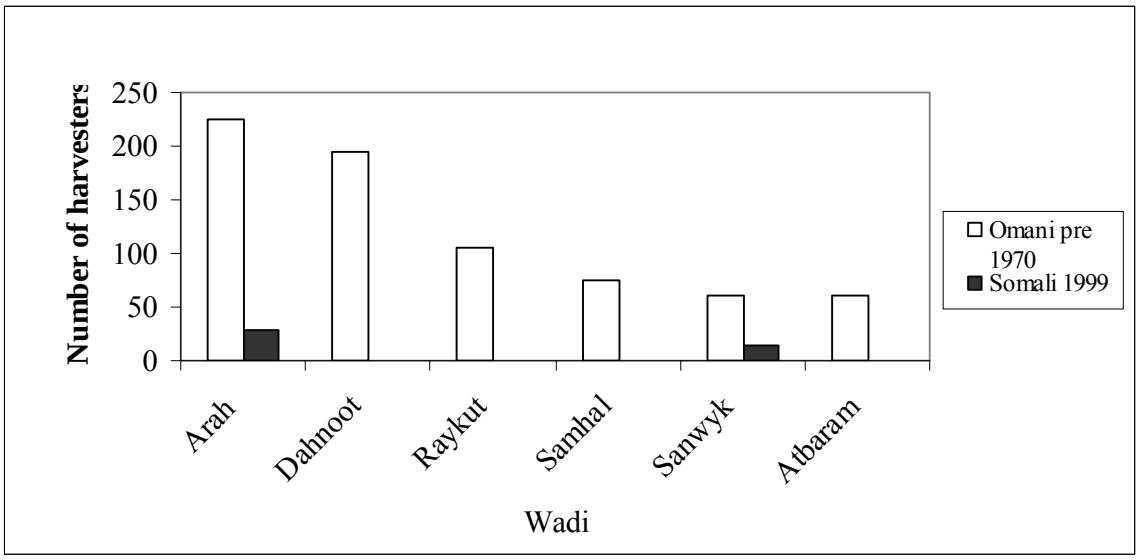


**Figure A4** Number of frankincense harvesters in the Hojari/Nejdi extraction zone.

Just as the number of harvesters and the composition of the frankincense extraction workforce has changed, new frankincense transportation methods and routes have emerged. In the past, Hojari frankincense destined for Salalah, Mirbat and Sadh was transported southward by foot or camel using a network of trails and mountain passes. The old network of camel caravan routes is no longer used for transporting frankincense. However, some of the caravan routes are utilized still for human and animal migration between highland and lowland pastures. A collection network of trucks and donkeys has replaced the camel as the ideal mode of transporting frankincense. Donkeys transport the *luban* from various locations in the extensive *luban* producing wadi network to collection points along roads. Once every two weeks, a truck distributes food, water and other essential supplies for the harvesters and collects the assembled frankincense from roadhead collection points and carries it to wholesale markets in the city of Salalah.

### A.5.1.6 INDIGENOUS INNOVATIONS

Private industries such as Amouage (fragrance company) may play a minor role today, but they have a promising future that has the potential to revitalize the frankincense industry in Oman. Amouage took the biblical story of gold, frankincense and myrrh (Groom 1981) and repackaged the three gifts of the East into one fragrance through the skill of the French Master Parfumier, Guy Robert. Frankincense-based perfumes developed by Amouage are much sought-after by Middle Eastern royalty and are making breakthroughs in international markets (http://www.amouage.com/englishweb/amouage/complexity_of_creation.htm).

D'Souza, Commercial Assistant in Amouage's Musqat plant, reported that Amouge perfumes are assembled in Musqat and some aspects of frankincense oil extraction are carried out in the Musqat plant. Current frankincense essential oil extract produced in the Amouage plant is less pure and yields about 200ml of oil per 1kg of raw frankincense. However, D'Souza illustrated that Amouage was planning to invest in more advanced essential oil processing technologies with the capability to produce highly pure essential oils from a variety of natural products. These innovations are giving impetus to the development of new frankincense-based products that are contributing to the evolution of the frankincense industry in Oman.

PAMAP can be credited with producing export oriented *luban* products and a *luban* grading system consisting of six grades that complement the traditional system which

consists of four grades (Hojai, Nejdi, Shazri and Sha'bi). The agency had the foresight to recognize *B.sacra* owners as farmers eligible for agricultural assistance. Nationwide, PAMAP helped local farmers by offering subsidies and buying agricultural produce in 6 distribution and 17 collection centers with responsibilities for the collection, grading, and packaging of agricultural products (Allen and Rigsbee 2000). PAMAP officials in frankincense buying centers of Musqat and Salalah voiced their concern that buying surplus frankincense might encourage harvesters to produce more frankincense. As a result of overproduction and potential over-harvesting concerns, in 1995 the agency curtailed buying frankincense from local producers. Despite these claims, some harvesters, wholesalers and government personnel indicated that the practice has continued, unofficially.

PAMAP's innovations in frankincense post-processing such as packaging and product development was instrumental in the certification and authentication of Omani frankincense products. Unfortunately, the Omani government's decision to liquidate PAMAP in 2001 (http://www.foodingredientsfirst.com/) will likely result in setbacks that affect some of the progress achieved in quality control, local product development and certification, and subsidies to local producers.

### A.5.2 RESOURCE OWNERSHIP AND CONTROL

#### A.5.2.1 *MENZELA*

*Menzela* are land parcels with locally recognized boundaries. Although these ownership parcels do not have any fences or survey lines to distinguish boundaries, indigenous

Omanis use a system based on local landmarks – metes and bounds – to delineate ownership boundaries. Landscape features, vegetation, wadi tributaries, watersheds and proximity to other owners are some of the landmarks used to define inter and intra ownership rights. Boundaries within a *menzela* are dynamic and are subject to change with each round of inheritance at the family level (Figure 3). Therefore, a *menzela* can have one owner or there might be multiple parcels within the *menzela* owned by a number of individuals in a family. The owning group may designate one individual, often the eldest brother, to rent, utilize and manage all the parcels. On the other hand, each individual or group of individuals might manage their share separately. In most instances, however, the male family member with the greatest financial need is given the authority to manage and extract a livelihood from the family holdings.

A *menzela* is also a collection and pre-processing location where an owner or group of owners store harvested frankincense (Al-Ghasani 1980). Caves and ledges protect *luban* from the rain and sun and serve as a base of operation and sleeping quarters for the *luban* tappers. Harvesting supplies such as food and water, tools, weights, cookware and animal feed are kept in these caves. Although the size of the work party in a *menzela* depends on the size of the parcel, informal participant discussions with community elders suggested that the number of workers in a *menzela* has a lower limit of 10 individuals and an upper limit of 30 individuals. However, Thomas (1932) reported the existence of a parcel system workable by five individuals or less known as *hawil*.

Each tribe has a naming convention associated with *menzela*t in their settlement area that becomes the accepted standard for the local tribe and outsiders to follow. The naming convention signifies the physical address of the land parcel on the landscape. The name of the *menzela* and the local based spatial location attributes are the major identifying characteristics that define the association between *B.sacra* and the tribes that own them. Even though the lands tribal groups utilize for livestock grazing might overlap in many areas or shift from time to time, *B.sacra* ownership at the tribal level is fixed. Therefore, it is common to come across land where the grazing rights are controlled by one tribe and *luban* extraction rights by another tribe.

As previously described, the number of harvesters in the *menzela* system before the 1970s oil boom in Oman and the Middle East in general was approximately eleven times higher than what it is today. Before the development of oil in Oman, frankincense harvesting and collection was a major form of employment in rural Dhofar, second only to livestock rearing. Even though *luban* owning rural households depended on their *B.sacra* holdings for a portion of their livelihood (Jansen 1986), the significant portion of rural family income came from remittances from family members working in non-luban related activities (e.g., petroleum). Similar livelihood diversification strategies can be found among pastoral groups in Somalia and Ethiopia who harvest various combinations of frankincense, myrrh and gum in conjunction with their animal rearing activities (Farah 1994, Lemenih et al. 2003). Rural households use various capital assets at their disposal to diversify livelihood activities and minimize risk (Ellis 1998, Quinn et al. 2003).

Similarly, nomadic communities in arid environments, such as those in Dhofar, diversify their livelihood through a combination of remittances from family members working in urban areas, income from animal sales, and in some instance rental or sharecropping proceeds from frankincense.

Indigenous frankincense sharecropping and the *menzela* management system are slowly giving way to a wadi management system based on *menzela* rentals operated by migrant harvesters from Somalia. With the exception of the *menzela* ownership and the enforcement of associated usufruct rights, all facets of the frankincense production systems in the Dhofar are under a management strategy introduced by Somali migrant harvesters.

#### A.5.2.2 OMANI ORGANIZATION

Indigenous Omanis organized *luban* tapping and collection around a hierarchical system organized around the *menzela*. Although a merchant in Salalah, Sadh or Mirbat might rent a group of *menzela*t, day-to-day activities in the field were organized on a *menzela* by *menzela* bases (Al-Ghasani 1980).

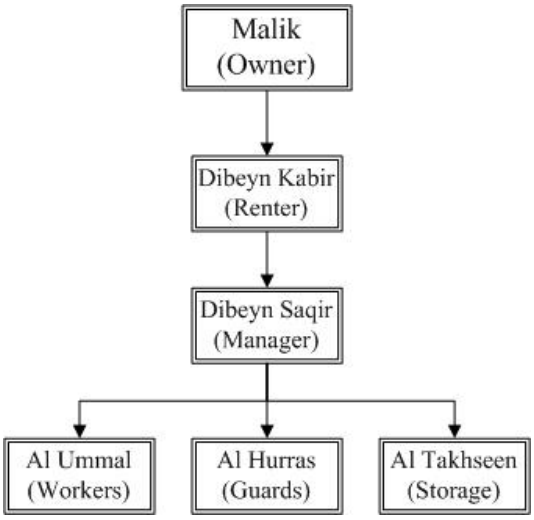


**Figure A5:** Hierarchical organizational structure of the Indigenous Omani frankincense extraction before the late 1970s. Malik (owner)-*B.sacra menzela* owning group; Dibey Kabir (DK)-local merchants who rent *menzela*t; Dibeyn Saqir (DS)-field manager representing the renter; Ummal-hired frankincense harvesters (workers); Hurras-guards and field supervisors; Takhseen- storage facilities for harvested frankincense (Adapted from Al-Ghassani 1980)

Some *menzela* owners (Malik) with the help of family members conducted harvesting; those who could afford it hired Ummal (workers) to carry out harvesting, but most owners rented their *menzelat* to Dibeyn Kabir (DK)-local merchants and wholesalers. DK would hire a Dibeyn Saqir (DS; field manager) to represent DK interest in the *menzela*. DS were operation managers responsible for hiring and firing, procuring transportation and storage facilities, bookkeeping and meeting production standards that are economically and ecologically sustainable. This hierarchical management structure features a field manager that has permanent hands-on management responsibilities during the harvest season; while the Dibeyn Saqir (DS) protects the interest of the Dibeyn Kabir (DK) in meeting profitable production goals. Similarly, the DS (manager) in conjunction with the Malik (owner) ensures that Alummal (workers) observe proper *B.sacra*

harvesting techniques. Those methods include implementing a rest rotation strategy where some trees are taken out of harvesting circulation for a specified period, and carrying out ecologically sound tapping practices that do not damage the *luban* trees. Alhurras were responsible for guarding the collected frankincense in storage and making sure that only authorized workers tap the trees. Securing proper storage facilities and guards to look after them when DS is not on the premises was vital to running a smooth frankincense extraction operation (participant info). Unfortunately, the lack of Takhseen (storage) increases frankincense exposure to natural elements which can diminish and, with time, destroy the quality of the collected *luban* (Al-Ghasani 1980). In addition to managing the day to day operation in the *menzela*, the DS was responsible for the procurement of camel caravans to the port cities of Hasek, Sadh, Mirbat and Salalah.

Luban quality is based on the ecological zone of origin, size, shape, color, and smell of the gum-resin nuggets. Depending on these characteristics, frankincense is rated into four general grades or six specific grades (Table 1). Factors that affect the quality of the frankincense consequently affect its rating in the market. *luban* dissolves when exposed to rainfall when the frankincense is left in the open or unharvested on the trunk. Exposure to rainfall can also cause *luban* to coagulate into undesired moisture laden-lumps. Exposure to high temperatures in the sun can cause the gum-resin to melt and lose its texture, thereby significantly reducing the *luban*'s quality and rating (Farah 1994). When *luban* melts in the field, it loses its shape and binds with soil, wood chips and other impurities that reduce or degrade *luban* quality, thus negatively affecting the sale and

marketing of the product. Traditionally *B.sacra* was not tapped during the monsoon (Groom 1981; Miller and Morris 1988) for three reasons. First, harvesters were by-and-large nomads who preferred to tend their animals during the rainy season. Second, if and when the rain reached the *B.sacra* groves, water soluble *luban* exudates on the trees and in the open were spoiled. Finally, the monsoon season brings stormy seas and shipping was suspended between June and September (Groom 1981). Curtailing tapping activities during the rainy season gave the frankincense groves some respite from the stresses of harvesting, and enabled the plants to recover before the resumption of harvesting and collection. This lull in harvesting gave tappers enough time to dry, process and package stored frankincense to coincide with the resumption of sea transport after the monsoon.

**Table A1** Luban grades, lowest number indicates highest grade

| Grade | General | Specific | PAMAP |
|---|---|---|---|
| 1 | Hojari | Fusoos-hojari | Hojari |
| 2 | Nejdi | Fusoos | Nejdi |
| 3 | Shazri | Hojari | Shazri |
| 4 | Sha'bi | Nejdi | Naeem |
| 5 | | Shazri | Powder |
| 6 | | Sha'bi | Raw(mix) |

Luban retailers of African descent like and local wholesalers in Salalah confirmed that most Omani harvesters, whom they referred to as Bedouin, were free- lance harvesters. These Bedouins harvested their fields and sold their *luban* to potential buyers in Salalah, Sadh, Hasek and Mirbat (field interviews). Some of the frankincense was sold to incense sellers in the market and some to wholesale merchants. The high number of Omani

harvesters in the past meant that individual shares of harvesting parcels were small relative to present harvester parcels. Moreover, the increase in the number of harvesters without a reciprocal increase in frankincense groves intensified competition among harvesters, often leading to overharvesting. While overexploitation might temporarily lead to high production levels, plant yield declines as the stress level of harvested groves rises. This explains the contention among *luban* retailers in the market that Omani harvesters used to bring smaller and less pure *luban* to market than today's migrant Somali harvesters.

The layered structure of the traditional harvesting system in Oman resulted in a hands-on management style that monitored day-to-day activities in the field. Moreover, the division of labor and administrative activities facilitated procedures that ensured accountability and the implementation of proper management and monitoring systems.

#### A.5.2.3 SOMALI ORGANIZATION

Omani *luban*-extraction practices are fairly similar to methods utilized in Somalia (Miles 1872; Thomas 1932; Groom 1981), but there are some organizational and structural differences between the two. Whereas Omani tapping and collection were organized around a *menzela* system (Al-Ghasani 1980), Somali harvesters organize their activities around a hybrid system that maintain some aspects of the *menzela*. Even though the owner and renter hierarchy of the Omani system is retained, harvesters occasionally

maintain strong relations and links with the owner. This tenuous relationship, however, does not preclude the migrant harvester from bypassing the renter and dealing directly with the owner. Harvesters run their field operation with little or no outside supervision. Hence, field operations consist of freelancing individual harvesters without managers or supervisors but bound by common social codes rooted in their tribal kinship structure. When migrant harvesters retain the owner and renter hierarchy, it is symbolic and is primarily used to access resources.

In addition to having *luban* tapping and collection based on a hybrid system, Somali harvesters in Dhofar also introduced a naming system based on incidents (broken leg place), wildlife (leopard alley) and landmarks or land features (water hole, stream) known only within Somali circles. Somali harvesters indicated that developing a naming convention helps them to subdivide a watershed into smaller components. Since harvesters are not familiar with the intricate local naming conventions, they tend to develop a parallel naming system to help them establish a spatial dimension and context relative to individual harvesting parcels.

Each transient Somali harvesting group (13-15 individuals) moves as a work unit from one subdivision to another through the area they harvest. Members of the work unit create subdivisions in which each individual lays claim to a harvesting area within the subdivision. When all individual claims for harvesting areas within each subdivision in the wadi system are allocated, each member taps his designated fields. Trespassing on

areas claimed by other members in the group is forbidden. Although these claims and parceling systems in tribal lands have no legal bases, they represent an organizational structure that fosters group cohesiveness and strengthens the mobilization of resources in times of crisis. In addition, this structure formalizes an otherwise informal utilization process and enables the work unit to function as a pseudo household unit.

Harvesters work separately but they use common sleeping quarters and they cook together most of the time. They come together in a place synonymous with *makhseys* - traditional *luban* collection place and living quarters, known to Somalis as *gole,* which is most often within close proximity to a water source. Each day's harvest is brought back to a collection point for drying and preprocessing. The group works together to guard against outsiders and the social trust is such that they look out for one another and rarely steal from each other. However, the work unit is subject to change as group composition changes and some harvesters opt out of the system and take up livestock herding or migrate elsewhere, like the Gulf States, Europe or America.

Despite the absence of a formal hierarchical organizational structure, each harvesting group has one or two designated elder figures to lead group meetings relating to conflict resolution and matters pertaining to the group. Group member participation in these meetings is mandatory and decisions made are implemented by the group. While most Somali harvesters work within the framework of their social group, the independent freelancing nature of these harvesters may give rise to undesirable harvesting and

marketing practices. For example, instead of following a procedural sale and marketing structure of *luban*, harvesters are known to circumvent the system and bypass the wholesaler to sell directly to government agencies such as PAMAP.

#### A.5.2.4 LAND TENURE

There are complex land tenure systems that govern resource utilization and ownership. The Sultanate of Oman owns all land but each tribe has some control over access to water and grazing resources in the areas they inhabit (Morris 1986). Similarly, specific tribes have total ownership of their *B.sacra* holdings (Al-Kathiri 1996) even though the land is owned by the government and access to grazing on the same plot of land might be under the control of a different tribe. Although open communal grazing access is widely practiced in Oman (GRM 1982), the open access concept is permissible or tolerated when livestock graze on *B.sacra*; however, open access *luban* harvesting is neither permissible nor tolerable (Al-Ghasani 1980).

Since their arrival in the 1980s, Somali migrant harvesters have managed to add their own version of land tenure arrangements which served to complicate the existing layered and complex land tenure system. Somali harvesters rent potential *B.sacra* fields from Omani owners or Somali-Omani kinsmen who rent from the owners. Harvesters reconfigure the rented parcels using an introduced clandestine land appropriation system, thereby dividing and subdividing rented wadis into divisions and subdivisions that fit their management and organizational needs. This enables them to create a pseudo-ownership and administrative structure with no legal tenancy within the established local

structure. Although these undisclosed activities and organizational structures have no legal bases and might at times involve multiple rental layers, they introduce increased complexity to traditional management, planning and land tenure systems. In some cases, proxy kinsmen or Somali-Omanis add a surcharge on the rent of a parcel and pass on the cost without the knowledge of the renting harvester. Although harvesters might be aware of the inflated rent they are asked to pay, the surcharge is often unchallenged to preserve the social capital linkages between the groups. Harvesters often accepted this arrangement because Somali-Omani kinsmen are the gateway to capital assets that enable harvesters to gain access to *luban* resources in Dhofar. Consequently, maintaining the social networking link with their kinfolk gives harvesters access to the physical capital, natural capital and financial capital that helps them sustain a livelihood from *luban* extraction in Dhofar.

Transient Somali harvesters maintain a temporary land tenancy system with no legal recourse or potential ownership provisions. Usufruct rights are contingent upon payment of rent and maintaining good *luban* harvesting practices.

### A.5.3 SOMALI HARVESTERS

#### A.5.3.1 MOTIVATION AND JOURNEY

Somali harvesters in Dhofar have no livestock and are rarely engaged in pastoralism. They come to Oman only to make money so they can send remittances to their families in

Somalia. Most make their livelihood harvesting frankincense in Oman but a few seek employment as livestock herders. The majority of harvesters use Dhofar as an intermediary location where they can save enough money to get them into the United Arab Emirates, Europe or North America. *luban* harvesting also gives them the freedom to work in an environment where they control their own destiny. Although their harvesting skills are variable, some are seasoned professional harvesters with a long history of *luban* extraction experience.

Somalia's civil unrest in 1988 and ultimate collapse of the state in 1991 resulted in a massive human exodus of political and economic refugees that continues even today. Some migrant harvesters came to Oman to escape political prosecution, but the overwhelming majority are economic refugees in search of a better livelihood abroad. Although the individual experiences of their journey into Oman vary, the vast majority of transient Somali harvesters migrated to Oman via Yemen and most often on foot.

Transient harvesters pay various sums of money to travel as stowaways or as part of an organized smuggling operation on board ships or *dhows* from the Red Sea shores of the Bari region to the shores of Yemen and occasionally Oman. Once in Yemen, they make their way into Oman through many means but primarily on foot. They often use the high mountain ranges along the coast that extend from Hadramout (Yemen) to Dhofar (Oman) to gain entry into Oman and the frankincense groves. When they reach Salalah, they make contact with fellow tribesmen who help them make the necessary contacts that

enable them to make a living in frankincense extraction. If illegal Somali migrants are caught in Salalah, they are subject to detention and deportation. Therefore, almost all illegal Somali migrants prefer *luban* extraction in *B.sacra* habitats where they have minimal contact with the authorities and the general public.

### A.5.3.2 SOCIAL CAPITAL

Social capital has costs and benefits (Woolcock and Narayan 2000) that can constrain individual freedom yet provide economic security within a group. Social capital has common rules and regulations that govern individual relations and group dynamics among Somali harvesters in Dhofar. Common rules, norms and sanctions are the mutually agreed upon or inherited norms of behavior that place group interests above those of individuals (Pretty and Ward 2001). In Dhofar, in some cases, social capital facilitates the extension of microcredit by the group to the poor (Anderson et al. 2001). Utilizing their social capital enables Somali harvesters to gain access to microcredit from their kinsmen in Oman. Depending on the circumstances, credit is offered to the group or the individual and is instrumental in providing monetary capital to illegal Somali harvesters.

Since illegal Somali harvesters have no access to formal lending institutions, they obtain microcredit from relatives, kinsmen and immediate family members. These proceeds are instrumental in providing the monetary capital required to rent *B.sacra* groves for the extraction of frankincense. The success and integrity of this social arrangement depends

on several factors including group trust, individual trustworthiness (Coleman 1988), and the strength of social networks (Pretty and Ward 2001). Relatives, family and kinsmen in Oman have an implicit obligation to provide some financial support for potential harvesters who are members of their social group. While belonging to a social group provides opportunities for some through social linkages, it might be perceived as an overall limiting factor when used as an exclusionary measure that limits opportunities to individuals outside the social group.

#### A.5.3.3 SECURING FINANCIAL RESOURCES

Somali harvesters have no supervisors, managers or guards and are accountable only to their group's code of conduct based on family relations, cultural and tribal linkages, and *luban* harvesting systems practiced in Somalia. Each harvester is his own boss and there is no limit to the hours he can work or the amount of *luban* he can extract. Although the absence of extraction limits and on-site supervision would tend to encourage overharvesting, the number of harvesters is too small to adversely affect the *B.sacra* habitats. Even though harvesters have no legal papers, money, natural resources in the form of frankincense grove ownership, or tools to access those resources, they still manage to find the necessary financial capital to gain access to frankincense production and control of a significant portion of the market. Harvesters effectively use their human and social capital to acquire the physical capital, natural capital and financial capital they

lack. They use their wide networks to secure rent money for harvesting the frankincense groves through a combination of credits and gifts from local renters, merchants, friends and relatives. Advances and loans from friends and relatives are repaid on prearranged time schedules or a more flexible pay-when-able basis. Credit from renters is limited and often based on a sharecropping arrangement. Loans from merchants are complex with an element of flexibility. These kinds of loans often involve cosigner(s) of a social contract between the harvester and merchant. The cosigner is trusted by both parties and facilitates the exchange and movement of money and goods. He may also be called upon to resolve conflicts between merchants and harvesters. Merchants also offer short term and long term loans payable within a specific timeframe.

#### A.5.3.4 STRATEGIES OF INCLUSION AND EXCLUSION

Each transient harvester group (13-15 individuals) works as a unit because such an arrangement enhances group security and reduces individual vulnerability. When an individual falls sick or suffers an injury that limits or curtails his ability to tend his fields, he is able to utilize his social capital to secure his livelihood and minimize his risk. In order for an individual in a group to be able to call upon his social capital assets to safeguard his livelihood and limit his risk and vulnerability, he must maintain close social ties within the group. As a result of the strong social ties and harvesting code of conduct within the group, the remaining members perform the disabled harvester's duties until he is well enough to carry out his harvesting work. In times of crisis, facilitating cooperation within and between groups requires trust and reciprocity (Coleman 1988). Harvesting units are linked based on tribal kinship structure and at time there are groups within the

group consisting of subclan members, cousins or brothers. Therefore, group members exercise a great deal of trust that all will to come to the aid of a sick or injured fellow harvester. Harvesters also believe that once an individual gets back on his feet he will return the favor. The level of trust and reciprocity enables harvesters to strengthen their social networks and put the group interest before their personal interest.

On another level, social capital serves as an exclusionary mechanism because it enables harvesters from the Bari region of Somalia to exclude other Somali harvesters from the *luban* extraction process. Omanis of Somali origin in Salalah are almost exclusively from the Bari region and share a tribal affiliation with harvesters from that area. As a result, they tend to favor their kinsmen from Bari and exclude other groups. A major advantage in favoring kinsmen is that a tribal social link gives creditors some leverage to recoup their losses when a borrower fails to meet his loan payment obligation. Moreover, fellow tribesmen in Oman have extended family/tribal members back in the Bari region who can intercede on their behalf to make sure that loans are repaid.

Merchant creditors also need the *luban* extraction services Somali harvesters provide because merchants do not have the human capital needed to carry out the backbreaking work of harvesting *luban*. Furthermore, indigenous Omanis are not interested in *luban* harvesting activities when they can make more money doing less grueling and safer work in other sectors of the economy. Therefore, the extension of credit and grants to poor Somali harvesters enables the merchant to meet his kinship obligation and also enables

him to gain access to the human capital needed to bring frankincense to the market. The mutual social link between migrants and merchants enables poor migrants to play a leading role in the production of frankincense and helps the merchants to play a major role in the *luban* wholesale market while keeping the owners satisfied with rent money. Thus the extension of financial capital to *luban* harvesters from Somalia takes a great deal of trust, and harvesters reciprocate this trust by providing the merchant with the *luban* harvest they need to control the wholesale market.

## A.5.4 WHOLESALERS AND MERCHANTS

### A.5.4.1 RENT STRUCTURE

Omani frankincense owners rent their fields to migrant Somali harvesters and local merchants/wholesalers and rarely get involved in harvesting and managing their holdings. Most rental arrangements are made through Somali-Omanis who are familiar with the local culture and customs as well as the tribal ownership structure of *luban*-producing fields. Agreements are oral and there are no written contracts between renters and owners. In the early 1970s, Sheikh Hadiya from the Mahra tribe was the first to get permission from Sultan Qaboos to bring Somali contract workers into Dhofar. The Sheikh's company brought eight frankincense harvesters on a share cropping arrangement where the Sheikh provided food, lodging, tools, transportation and a small credit allowance. At the end of the season, after all the expenses were paid out, half the profit went to the contractor and the other half went to the harvesters. The number of

harvesters was later increased to 16 individuals. Since the Sheikh has been involved in different facets of the *luban* business for most of his life, he pointed out that his land requires 32-40 harvesters to attain its optimum production capacity. The Sheikh indicated that eight workers on his land produce 90 sacks of *luban* per season, each weighing approximately 30-33 kg with a range of grade-dependent wholesale and retail value of about 2-46 USD. Doubling the number of harvesters to 16 individuals produces 200 sacks per season and 32-40 harvesters will produce 400 sacks. Any increase in the number of harvesters beyond the land's carrying capacity of 32-40 harvesters will not result increase production. During this study the Sheikh was awaiting permission to bring *luban* harvesters from Somalia.

During the 1980s, Somali-Omani Sheikhs got involved in the *luban* contract worker business. While the Mahra Sheikh was both a *luban* owner and wholesaler in his own right, most other Somali-Omanis made a rental arrangement with other tribal owners to secure frankincense harvesting rights. After securing a contract they made sharecropping arrangements with harvester kinsmen from Somalia to work the rented fields.

Some experienced Somali *luban* harvesters who are familiar with Oman, maintain social links with the local tribes and make their own rental arrangements directly with the owners instead of using a Somali-Omani intermediary. In some instances experienced harvesters act as proxy agents for newcomer kinsmen interested in trying their hand at harvesting. Proxy agents often put a surcharge on the rental amount without the

knowledge of the harvester. Although the practice is rare, on some occasions a harvester might rent a portion of his parcel to newcomers in order to recoup some of his rental cost.

Clearly, not all forms of social capital are good for everyone and formal rules and norms can also trap people within harmful social arrangements (Pretty and Ward 2001). With the exception of one individual, *luban* harvesters described here are exclusively from Somalia's Bari Region (also known as Puntland). Using the social network system of their fellow Somali-Omani kinsmen in Dhofar, *luban* harvesters from Puntland have tremendous advantage over potential harvesters from other regions in Somalia. Thus they are able to exclude other Somalis outside their home region from the extraction process. Vital information and contacts are withheld from outsiders and disclosed only to kinsmen. In some instances, outsiders are asked to pay exorbitant rents up front in order to discourage them from the tapping and collection process.

#### A.5.4.2 SHARECROPPING

Sharecropping arrangements benefit Omani owners and Somali harvesters alike so long as there is trust and honesty between the two groups. For instance, owners get skilled harvesters with *luban* extraction experience, while harvesters gain access to harvesting frankincense without making rental payments up front. Sharecropping often requires that the owner remain on the premises or make more frequent visits to the field to ensure proper production with sound ecological and environmental practices. Current rental arrangements consist of a hands-off management policy that lacks a monitoring

component. The absentee landlord neither manages nor monitors his harvested parcels which increase the likelihood of resource overexploitation. Owners, who did not consent to renting out their fields, have nevertheless had their groves harvested because they are not on-site to monitor the condition of their holdings. Trespassing incidents like these may give rise to conflict between owners because an owner who rents his parcel to transient harvesters is held accountable for the illegal action(s) of those individuals in other fields or *menzela*. Because the owner is the one who maintains a direct or indirect social link with the trespassing harvesters, the transient harvesters are considered his men as long as they have usufruct rights on the owner's *menzela*. The difficult nature of trying to resolve a conflict with transient harvesters is a major reason why owners often prefer renting their *menzela*t to resident Somali-Omanis instead of transient harvesters.

In this situation, the social capital links among Omani owners are stronger than the links they have with the transient harvesters. Thus, an Omani stands a better chance of holding a fellow Omani responsible for the actions of transient Somali harvesters. It is easier to use the local social capital networks to get hold of an Omani than a transient Somali who could vanish without a trace. This is also part of the reason why owners would prefer to rent their fields through or to Resident Somali-Omanis who then rent it out to transient Somali harvesters. Unlike their indigenous Omani counterparts, resident Somali-Omanis use and maintain strong social capital links with transient Somali harvester kinsmen. This network of social capital links between and among the different social groups is instrumental in diffusing and resolving conflicts.

The downside of sharecropping systems is the potential for overexploitation of the poor migrant harvesters. Sharecropping is done in a manner that is often stacked against the harvesters. The merchants or owners often inflate the price of the products they provide to harvesters, such as tools, food, lodging and other necessities while they keep the prices of *luban* from harvesters low. In addition, dishonest merchants and owners have also been known to use rigged scales for weighing in the field and more accurate scales in town (Farah 1994), thus accumulating incremental weight gain with every kilogram weighed. These arrangements allow the owner to make a hefty profit margin at the expense of the harvesters. In order to make up for the pricing disparity in favor of the merchant/owner, harvesters insert *luban* look-alike rock crystals in slightly moist frankincense nuggets to add weight and then dry them. Additional weight inflating techniques include drying the surface of nuggets and keeping the core moist. As a counter measure, prior to a *luban* purchase, experienced wholesalers store moist *luban* in a hot warehouse. If the *luban* is wet, the heat will cause it to lose its texture and coagulate into lumps resulting in drastically reduced market value, while *luban* that is initially dry will maintain its structure and value.

Given the small number of harvesters in Dhofar, there is less competition for frankincense, and sharecropping arrangements of the past have given way to the *menzela*

rental system. Renting absolves the owner of the day-to-day management and production logistics by shifting these responsibilities to renters and tenants.

### A.5.5 DIFFUSION OF HARVESTING KNOWLEDGE SYSTEMS

#### A.5.5.1 HARVESTING KNOWLEDGE

Local knowledge among Omanis about the production, processing and management of frankincense is limited to the older generation (50 years or older) who harvested frankincense prior to the 1970s. The older generation with extensive local knowledge is dying out and the younger generation is more interested in education and pursuing more lucrative careers in urban centers, businesses and the government sector. Younger Omanis tend to view *luban* extraction as menial work unfit for an Omani. The absence of young indigenous harvesters in the frankincense groves has severed the continuity of local knowledge transmission and has contributed to the widening knowledge gap between the two generations. The wealth of field experience and knowledge elder Omani harvesters and owners possess will die with them and will be extremely difficult if not impossible to replace.

The diminishing local knowledge base related to frankincense production and the absence of local human capital to sustain it resulted in the importation of Somali harvesters who, in turn, brought an external knowledge system based on frankincense extraction practices in Somalia. Although the Omani and Somali harvesting techniques are fairly similar, they have different organizational and management structures. Furthermore, Somali harvesters

have limited or no knowledge of indigenous ownership and usufruct rights in different *B.sacra* habitats. In the long run, the introduction and infusion of the Somali knowledge base will have management implications for the indigenous *luban* harvesting system. The loss of local knowledge pertaining to *menzela* yield, the number of workers required and the land's carrying capacity is unlikely to be regained by Omanis. Despite the Somali harvesters' skill and experience in *luban* extraction, they lack a deeper understanding of the local ecology, environment and the climatic factors that have a bearing on frankincense extraction in Dhofar. Even though the current *luban* extraction system is theoretically Omani, the components underpinning the system in 1999 were predominantly Somali.

#### A.5.5.2 BOKHOOR (INCENSE) MAKERS

Frankincense retailers in the local markets (Bazaars) are predominantly Omani women of African descent. These women have specialized expertise in incense making for highly specialized occasions such as weddings. Consequently, they do their own *luban* processing and are familiar with the quality of *luban*. All men and women *luban* retailers, who were old enough to have seen frankincense produced by local Omanis, indicate that the quality of frankincense is better today than when the Omanis harvested the fields. Similarly the misconception among most young and foreign *luban* retailers is that field production is carried out by indigenous Omanis and wholesalers are predominantly Somali-Omanis.

Older retailers also pointed out that prior to the arrival of Somali harvesters Omani sellers from the field were numerous and frankincense came in quantities that were smaller and less pure. In contrast, there are fewer suppliers today selling larger quantities of high quality frankincense. Omani harvesters were in the thousands and each individual's harvesting share would be small compared to the smaller number of Somali harvesters operating in Dhofar in 1999.

Omani *luban* retailers have expanded their incense making techniques. They possess a wealth of incense-making experience and they are often eager to show and share the fragrance of their products. However, they are protective of their secret formulas. Their skill in grading frankincense and pricing it accordingly has remained the same for many generations. They learned their trade from the older generation and they will pass it on to the next generation.

#### A.5.5.3 MANAGEMENT

Frankincense production and management activities in Dhofar come under on-site or off-site management systems, respectively representing resident and absentee landlords. *Menzela* owners rent their fields directly to harvesters or Somali-Omani intermediaries. The majority of active *luban*-field owners can be classified as absentee landlords with little or no direct supervision and monitoring of their *menzela* holdings. Even though absentee landlords rely on the word and good will of the renters, they also use the threat of suspending group usufruct rights to trees to manage their property. The threat of

collective punishment and the importance of maintaining a cordial social link with local Somali Omanis encourage Somali harvesters to employ non-destructive tapping practices.

In addition to the lack of direct owner management, government agency efforts to manage and monitor *B.sacra* in Dhofar are limited to the establishment of the Jabal Samhan Nature Reserve (JSNR). The JSNR covers the most important frankincense-producing ecological zone, but there are no active management strategies in place to assess and evaluate the various land use activities that take place there. Moreover, government agencies adopt a hands-off approach to *B.sacra* management and there is no coordination among the different stakeholders of the frankincense industry. JSNR is about 4,500 km² of predominantly rough terrain with limited road access. Therefore, implementation and enforcement of existing rules and regulations designed to conserve *B.sacra* will require a substantial increase in the number of field personnel. At present, the few rangers assigned to oversee JSNR are barely adequate in number to track and protect endangered wildlife species such as the leopard, let alone monitor natural resource management practices.

Harvesters are accused of engaging in destructive harvesting practices that are creating irreparable damage to *B.sacra* as a result of improper harvesting practices (Al-Kathiri 1996). There are no active management strategies in *luban* producing zones and *luban* owners are almost never on site to supervise or monitor activities on their frankincense fields.

Before the 1970s, whole families participated in frankincense activities and there was a hands-on approach to *luban* management where the owner, a family member or a proxy manager, monitored and supervised activities in the field. Thomas (1932) noted the presence of women collectors in an otherwise exclusively male industry. The role of Omani women in frankincense extraction and processing is currently limited to cleaning and sorting *luban* into different grades in PAMAP's Musqat center.

Although Somali harvesters are accused of causing considerable damage to frankincense trees under their management, public sentiment in rural areas, especially amongst the elders, is more sympathetic. Most believe Somali harvesters are skillful and are doing jobs that Omanis are neither interested in nor willing to carry out. However, they are also concerned that Somali harvesters spend a longer time in the field than their Omani counterparts of the past thereby subjecting the trees to extended harvesting. Longer harvesting duration in the field often translates into reduced rest-rotation cycles for tapped trees. However, Omani elders are encouraged that the extended harvesting period is counterbalanced by the low number of harvesters and the vast Hojari/Nejdi harvesting area inside the 4500 km² Jabal Samhan Nature Reserve.

Most of the alleged damage resulting from harvesting is based on the depth of the incisions made on the trunks and branches and the purported indiscriminate harvesting of trees irrespective of age and height. Harvesters prefer tapping the trees located along the

wadi base and on gentle slopes with easy access. These trees are tall, have larger girth and are tapped more frequently. The repeated harvesting of these trees and the lack of management schemes to set up rest-rotation harvesting system might have a damaging effect in the long run. Since individuals in the harvesting group do not have the freedom to operate outside the social group without the consent of its members, harvesting activities that jeopardize group-access to the fields are avoided. Despite self policing on the part of the harvesters, trespassing violations are known to occur from time to time. In addition, the number of harvesters is a fraction of what they used to be before the 1970s. Given this drastic drop in harvester numbers from 3,000 in the 1970s to approximately 193 in the 1998-1999 harvesting season, it is conceivable that over-harvesting was more of a problem then than it is at the present time.

## A.6 CONCLUSION

Frankincense extraction in Oman has undergone a major shift in the organization, structure and management systems that affect all of the frankincense industry. The evolution of frankincense extraction from an entirely Omani-controlled process to a hybrid system controlled by stakeholders consisting of Omani owners, Somali-Omani wholesalers/merchants, and Somali harvesters is still evolving but is stacked in favor of harvesters, transporters and wholesalers with a common Somali lineage.

Frankincense producing trees are under the control of Al-Kathiri, Al-Mahra and Al-Qara tribes of Oman's Dhofar region. Ownership will remain with the tribes for the foreseeable

future and the size of *menzela*t will continue to decline with each sequence of inheritance that results in increased fragmentation. Eventually, it appears that individual ownership parcels will become too small and economically unfeasible to rent or exploit under the current structure.

Even though there are legitimate grounds for government and public concern about the potential effects of over-harvesting in frankincense-producing habitats, Somali harvesters will use their frankincense extraction skills and their social capital to strengthen their networking with Somali-Omani kinsmen in order to maintain a foothold in Dhofar's *luban* production industry. As long as their skill and experience is needed and there are Omani nationals willing to hire them, and as long as frankincense remains a sought-after product, Somali harvesters will exploit their niche in the production and processing of frankincense in the field through rental or sharecropping arrangements.

Somali-Omani wholesalers/merchants are familiar with both the Somali and Omani cultures and customs and they maintain social capital links with Omani owners and Somali-harvesters. Moreover, their access to Somali *luban* products gives them an added advantage to continue playing a leading role in Oman's frankincense industry.
The store of knowledge of frankincense management and production that is currently held by the older generation of Omanis will likely disappear as the younger generation is drawn to other forms of employment. Given the lack of young Omanis willing to

participate in *luban* extraction, a significant portion of the art of managing the structure and organization of frankincense will die with the elders who possess this knowledge.

The diffusion of the Somali harvesting knowledge system is taking hold in Dhofar. As long as there are no direct Omani supervision and monitoring management systems in the field, Somali harvesters will use their human and social capital assets to acquire the necessary physical and financial capital required to gain unfettered access to the natural capital (frankincense). Obtaining and maintaining frankincense usufruct rights will enable Somali harvesters to play a leading role in frankincense extraction.

## A.7 REFERENCES

Al-Ghassani, A.S. 1980. *Dhofar ard al-luban [Dhofar the land of frankincense]*. Almatabi Al-almiyah, Ruwi, Sultanate of Oman.

Al-Hatrushi, S. M. 1989. Rangeland Degradation: The Case of the Southern Region in the Sultanate of Oman. U.M.I, Ann Arbor.

Al kathiri, A. M. 1996. *Qabat wa Marai Jibal Muhafadat Dhofar [The mountains of Dhofar's forest and rangelands]* . Dhofar National Printing Press, Oman.

Allen, C.H. Jr., and Rigsbee, W.L.II.2000. Oman Under Qaboos from Coup to Constitution 1970-1996. Frank Cass. London pp 140,150, 152.

Anderson, C. L., Locker, L., and Nugent, R. (2001). Microcredit, social capital and common pool resources. *World Development* 30(1): 95-105.

Baratta, M. T., H. J. D. Dorman, et al. 1998. "Antimicrobial and antioxidant properties of some commercial essential oils." *Flavour and Fragrance Journal* 13(4): 235-244.

Baser, K. H. C., B. Demirci, et al. 2003. "Essential oils of some Boswellia spp., myrrh and opopanax." *Flavour and Fragrance Journal*, 18(2): 153-156.

Bird, S. R. 2003. African aromatherapy: past, present and future applications. *International Journal of Aromatherapy* 13(4): 185-195.

Buckle, R. J. 2003. Aromatherapy in the U.S.A. *International Journal of Aromatherapy* 13(1): 42-46.

Carter, J. R. L. 1982. *Tribes in Oman*. Paninsular Publishing, London, U.K.

Case, R.J., Tucker, A. O., Maciarello, M. J., and Wheeler, K. A. 2003. Chemistry and ethnobotany of commercial incense, copal, copal blanco, copal oro, and copal negro of North America. *Economic Botany*. 57(2):189-202.

Clapp, N. 1998. The Road to Ubar: Finding the Atlantis of the Sands. Houghton Mifflin Company, New York.

Coleman, J. S. 1988. Social capital in the creation of human capital. *The American Journal of Sociology*. 94: 95-120.

Conelly, W. T. 1985. Copal and rattan collection in the Philippines. Economic Botany. 39(1):39-46.

Duan, R. 2002. *Anticancer effects of Boswellia acids, the compounds isolated from gum resin of Boswellia serrata, on human colon and liver cancer cells*. DIAS Report, Horticulture. 2002; (29): 26 32, Tjele Denmark: Danmarks Jordbrugs Forskning.

Ellis, F. 1998. Household strategies and rural household strategies. *The Journal of Development Studies*. 33(1): 1-38.

Etzel, R. 1996. "Special extract of Boswellia serrata (H 15) in the treatment of rheumatoid arthritis." *Phytomedicine* 3(1): 91-94.

Evershed, R.P., Bergen, P.F. van, Peakman, T.M., Leigh-Firbank, E.C., Horton, M.C., Edwards, D. Biddle, M., Kjlbye-Biddle, B., and Rowley-Conway, P.A. 1997. Archeological frankincense. *Nature.* 390(6661):667-668.

Farah, A. Y. 1988. *The milk of the Boswellia forests: frankincense production among the pastoral Somali*, UK: London School of Economics and Political Science University of London.

Farah, A. Y. 1994. *The milk of the Boswellia forests: frankincense production among the pastoral Somali.* Reprocentralen HCS, Uppsala.

G.R.M. 1982. *Range and Livestock Survey*. Final Report, GRM International Pty Ltd. Brisbane.

Groom, N. 1981. *Frankincense and Myrrh: a Study of the Arabian Incense Trade*. Longman, London pp 16.

Inder, G., P. Ashok, et al. 2001. "Effects of gum resin of Boswellia serrata in patients with chronic colitis." *Planta Medica* 67(5): 391-395.

Jansen, J. 1986. *Nomads in the Sultanate of Oman: Tradition and Development in Dhofar*. Westview Press, London.

Kasali, A. A., A. M. Adio, et al. 2002. "Antimicrobial activity of the essential oil of Boswellia serrata Roxb. (Fam. Burseraceae) bark." *Journal of Essential Oil Bearing Plants* **5**(3): 173-175.

Kay, S. 1988. *Enchanting Oman*. Motivate Publishing, Dubai, U.A.E.

Kockelman, P. 1999. The collection of copal among the Q`eqchi` Maya: shifting liaisons and lasting silence. In B.L. Isaac (ed), *Research in Economic Anthropology Vol. 20*, JAI Press Inc., Stamford, Ct.

Lacuna-Richman, C. 2004. Using suitable projects in adding value to nonwood forest products in the Philippines: the copal (Agatha philippinensis) trade in Palwan. *Economic Botany*. 58(3):476-485.

Lemenih, M., Abebe, T., and Olsson, M. 2003. Gum and resin resources from some Acacia, Boswellia and Commiphora species and their economic contribution in Liban, south-east Ethiopia. *Journal of Arid Environments*. 55(3): 456-482.

Maddocks-Jennings, W., and Wilkinson, J. M. 2004. Aromatherapy practice in nursing: literature review. *Journal of Advanced Nursing*. 48(1): 93-103.

Marshall, S. 2003. Frankincense: festive pharmacognosy. *The Pharmaceutical Journal*. 271:862-864.

Miles, S. B. 1872. On the neighbourhood of Bunder Marayah. *Journal of the Royal Geographical Society of London*. 42: 61-76.

Miller, A.G. and Morris, M. 1988. Plants of Dhofar: *The Southern Region of Oman Traditional, Economic and Medicinal Uses*. The Office of the Adviser for Conservation of the Environment, Diwan of Royal Court, Sultanate of Oman

Morris, M.J. 1986. *Pastoral management study-1986*. Technical Secretariat Planning Committee for Development and Environment in the Southern Region, Salalah, Sultanate of Oman.

Murthy, T. K. and Shiva, M P. 1977. Salai guggul from Boswellia serrata Roxb. - its exploitation and utilization. *Indian Forester*. 103(7):466-474.

Pretty, J., and Ward, H. 2001. Social capital and the environment. *World Development*. 29(2): 209-227.

Quinn, C. H., Huby, M., Kiwasila, H., Lovett, J. C. 2003. Local perceptions of risk to livelihood in semi arid Tanzania. *Journal of Environmental Management*. 68(2): 111-119.

Rahmato, D. 1991. *Famine and survival strategies*. Scandinavian Institute of African Studies, Uppsala.

Phillips, W. 1966. *Unknown Oman*. David McKay Company Inc., New York.

Pretty, J., and Ward, H. 2001. Social capital and the environment. World Development 29(2): 209-227.

Shao, Y., C. Ho, et al. 1998. "Inhibitory activity of Boswellia acids from Boswellia serrata against human leukemia HL-60 cells in culture." *Planta-Medica* 64(4): 328-331.

Simla, B., A. Koch, et al. 2001. "A verticillane-type diterpene from Boswellia carterii essential oil." *Flavour and Fragrance Journal* 16(5): 315-318.

Skeet, I 1992. Oman: Politics and Development. St. Martins Press. New York p13.

Stross, B. 2004. *MesoAmerican copal*. http://www.utexas.edu/courses/stross/papers/copal.htm

Svoboda, K. P., J. B. Hampson, et al. 2001. "Boswellia from Somalia, a source of high quality frankincense." *Medicinal Plant Conservation*. **7**: 16-19.

Thomas, B. 1932. *Arabia Felix: Across the "Empty Quarter" of Arabia*. Charles Scribner's Sons. New York.

Thomas, B. 1937. *The Arabs: The Life Story of a People Who Have Left Their Deep Impress on the World*. Doubleday Doran and Co., Garden City, New York.

Thulin, M., and Warfa, A. M. 1986. The Frankincense Trees (Boswellia spp. Burseraceae) of Northern Somalia and Southern Arabia. *Kiwi Bulletin* 42(3):445-500.

Tirfe, A., Haile, T., G/Silasse, S. and Kidane, A. 1987. Study of the consumption and distribution pattern of gum olibanum within the Addis Ababa region. Institute of Development Research (IDR), Addis Ababa University, Ethiopia

Wisdom, C. 1940. *The Chorti Indians of Guatemala*. Chicago: University of Chicago Press.

Woolcock, M. and Narayan, D. 2001. Social capital: implications for development theory, research, and policy. *The World Bank Research Observer*. 15(2): 225-249.

*http://www.fao.org/DOCREP/005/Y4640E/y4640e06.htm*

*http://www.amouage.com/englishweb/amouage/complexity_of_creation.htm*

# APPENDIX B. THE SUSTAINABILITY OF NON-TIMBER FOREST PRODUCTS IN ARID ENVIRONMENTS: FRANKINCENSE PRODUCTION AND MARKETING IN THE DHOFAR REGION OF OMAN

Farah, Mohamud H.

Office of Arid Land Studies

University of Arizona, Tucson, Arizona 85719

## B.1 ABSTRACT

Frankincense, a much revered non-timber forest product (NTFP) in Oman, is a gum-resin extracted from Boswellia species. Apart from its ceremonial and occasional medicinal uses, frankincense is an important economic commodity that Dhofaris refer to as luban (in Arabic) and sahaz (in Jabbali). Hojari, Nejdi, Shazri and Sha'bi signify the four general types of luban in Oman; they are also indicative of the zones (Hojar/Habjar, Nejd, Shazr and Sha'b) associated with Boswellia sacra habitats in Dhofar. The harvesting season in the Hojari/Nejdi zones in eastern Dhofar extends from the beginning of April to the end of September while the Shazri and Sha'bi zones in western Dhofar start in October and end in March. Although frankincense is a commercial product widely traded in local and international markets, the economic significance, production, processing and marketing of frankincense, and its contributions to sustaining livelihood in arid shrublands are neither well understood nor sufficiently researched. This study conducted in 1998-1999 documents the processes involved in getting this NTFP from the field to consumers in the local and international markets. Poor undocumented Somali migrant laborers constitute more than 95% of luban harvesters and depend on this NTFP

extraction for 100% of their income. Luban production in the Hojari/Nejdi zone from April to mid-June 1999 was estimated at 8,710 kg with a seasonal projection of 24,840kg-30,360kg in the study area. Approximately 83% of all documented frankincense imports between 1993 and 2000 originated from Somalia. During the same period, the United Arab Emirates (UAE) was the biggest importer of Omani-frankincense, accounting for 81.5% of Oman's total frankincense export. Most Omani produced frankincense is consumed locally. Although harvest pressure was much higher a generation ago (perhaps by a factor of 46), at the end of the last millennium, only a small number of harvesters, totaling 43, were extracting luban inside the 45,000 km² Jabal Samhan Nature Reserve (JSNR) compared to about 2000 before the 1970s. If current low harvester numbers, minimal human settlements, coupled with restricted grazing trends in JSNR continue, the extraction of this NTFP for its economic value appears to be sustainable.

## B.2 INTRODUCTION

Frankincense is a gum-resin produced from the Boswellia species. The production of frankincense is based on regulated successive tapping cycles (Farah 1994) that consist of incising the bark of the main stem of the tree once every 14 days (Al-Qassani 1980). The hardened gum-resin that exudes from the incisions (Bevilacqua et al 1997) is collected and marketed as frankincense. Although some species are presumed to exist only in Saudi Arabia and Iran, most documented species are endemic to Oman (*B.sacra*), Ethiopia (*B.neglecta, B.ogadensis*), Nigeria (*B.dalziellii*), Eritrea (*B.papyrifera*), Somalia (*B.sacra*, *B.fereреana*), Yemen (*B.sacra*, *B.dioscoridis* , *B.ameero*, *B.elongata*, *B.nana*,

*B.popviana*, *B.socotrana*), and India (*B.serata*). Frankincense is a much revered non-timber forest product (NTFP) that has played and continues to play a major role in Omani culture and tradition. In addition to its value in ceremonial and occasional medicinal uses, frankincense is an important economic commodity that Omanis refer to as luban (in Arabic) and sahaz (in Jabbali). Frankincense is harvested on government owned land; but the trees that produce this olio-resin are privately owned and, for the most part, governed by traditional laws and customs that are imbedded within an established tribal kinship structure. The shrub that produces frankincense (Boswellia sacra) is locally known as meqerot or luban, and is without doubt the most famous plant of Dhofar (Miller & Morris 1988). In Oman, this shrub occupies an arid belt between the desert and the wetter mountain ranges, with the exception of the coastal plains.

Although Oman is an Islamic country, frankincense-related rituals and practices predate Islam. In Dhofar, people fumigate their residential areas and offices with frankincense to keep evil spirits away, to freshen the air and to promote tranquility and good luck. Fumigating clothes and water containers to eliminate unpleasant smells has been a long standing ritual (Groom 1981) but the general practice of this custom has diminished and is now largely confined to the countryside. Chewing frankincense and swallowing the slightly bitter liquid extract is believed to help relieve stomach ailments and joint pains while the sweet smell of the chewing gum residue serves as a powerful mouth freshener.

Oman has a long history of NTFP extraction from the Boswellia shrublands in the governate of Dhofar. Although current NTFP extraction is limited to frankincense and tourism, Dhofaris have extracted frankincense, myrrh, gum, dyes, flowers and fodder from these arid shrublands on the fringes of the desert for many generations. Owners and harvesters of frankincense-producing trees (Boswellia sacra) are dependent on income generated from commercial frankincense to sustain their household livelihood systems. This economic dependence and commercialization creates frankincense overexploitation that could threaten the sustainability of this important NTFP. Even though NTFP are often associated with tropical woodlands and forests, this resource extraction practice is well established in Dhofar's arid shrublands. Although frankincense is a commercial product widely traded in local and international markets, the economic significance, production, processing and marketing of frankincense, and its contributions to sustaining livelihood in arid shrublands, is not well understood and is insufficiently researched.

This research will use the conventional NTFP acronym to address the economic aspect of frankincense extraction practices from arid shrubland/woodland environments in Dhofar, a province in the Sultanate of Oman. Although the forest reference might be misleading when the focus is clearly on arid shrublands, the term (NTFP) was chosen to emphasize the similarity of the extraction process and its value to household and regional economies with other forest and woodland resources

Most economic analysis of forest resource extraction studies have focused on tropical forests with an overwhelming importance given to timber benefits (Tewari 2000). NTFP play a more important role in local rural economies of developing countries than has generally been understood (Kant 1997), and the contribution of NTFP to the forestry sector (Tewari and Campell 1995), rural livelihood (Arnold and Pérez 2001; Narendran et al 2001), policy formulation (Larsen et al. 2000; Campbell et al. 2000;), and sustainability and conservation (Shankar et al. 1996; Mahapatra and Mitchell 1997; Gould et al. 1998; Shackleton 2001) in many countries is significant. NTFP are important components for the sustenance of numerous communities that live in and around forested areas. Households in these communities often derive a significant portion of their primary or secondary sources of income from NTFP sales. Gunatilake et al. (1993) found that NTFP contributed 16.2% to total household income in three Sri Lankan villages. Chege's (1994) study in Ghanian villages found incomes ranging from 49% to 87%; Narendran et al. (2001) put the annual per capita contribution of NTFP to rural households at 15%-50%; Gram's (2001) study of villages in the flood plains of the Peruvian Amazon found that extracted forest products made up 57% of the local economic value.

A Food and Agricultural Organization of the United Nations (FAO) report indicates that non-wood forest products (NWFP) are widely traded in the international markets with a total world trade value estimated at US$ 11 billion (FAO 1995) . Even though a large number of botanicals (with a range between 4,000 and 6,000) enter the international

markets, at least 150 NWFP, including 26 essential oils are of major significance in international trade. (FAO 1995).

Even though they were once ignored or perceived to have minor economic contribution or benefits, there has been renewed interest in the economic significance of NTFP in the last 20 years (Tewari 2000). Some of these perceptions were due to the fact that NTFP were historically viewed as byproducts of the national revenue generating timber products (Tewari and Campell 1995). Advancements in the recognition of linkages between economic development, livelihood issues and non-wood forest resources in the last decade have highlighted the significant economic contribution NTFP provide to sustain livelihoods, the local economy and international markets. Although numerous researchers attempted to measure the economic value of forest resources, economic valuation of NTFP is complex and difficult. However, it is necessary to calculate this value so as to be able to compare the economic importance of NTFP with the value of products from alternative land uses (Broekhoven 1996).

Some of the difficulties arise from the fact that forest resources might be utilized and marketed differently between communities and possibly between individuals within a community. Products that are traded in the market in a particular community might be bartered in another. Social, cultural and religious values of NTFP are often instrumental in sustaining livelihood and social wellbeing (Thadani 2001), but these are inherent values and their economic and commercial values are difficult, if not impossible, to

quantify (Broekhoven 1996). Thus, the focus of most NTFP research tends to be oriented towards commercial products whose market value can be ascertained.

Some researchers have valued the stock (Prance et al. 1987; Peters et al. 1989); others have valued the flow (Godoy and Feaw 1989; Schwartzman 1989, Kants 1997), while some valued both (Padock and de Jong 1989; Tewari 2000). A more accurate valuation method entails measuring the product on site (Godoy et al 1993), as it enters the village (Wilkie and Curran 1991), or at the farm or forest gate (Gunatilake et al 1993). The differences in the methodologies applied by researchers have also led to very significant differences in estimates of the values of NTFP (Godoy and Lubowski 1992; Godoy et al. 1993; Chopra 1993; Thadani 2001). Consequently, conclusions about the economic importance of forest extraction activities as compared to farming and other occupations seem to depend on the selected methodology (Gram 2001).

In order to gain insight into the important role NFTP plays in the economy of the people of Dhofar, this study utilized a direct measurement valuation approach whereby the biweekly harvest was tallied as it was assembled at road-head camps. Furthermore, a sample of each shipment was randomly weighed at the market to establish the equivalent weight of a sack of frankincense in kilograms.

In this study, the term NTFP is used to refer to a single tradable non-timber product (frankincense) extracted from arid shrublands in Dhofar. These shrublands are

predominantly in Hojar, Nejd and Shazr on the leeward sides of the Dhofar Mountains but some are known to occur in fragmented Sha'bi habitats along coastal-draining wadis. This paper will look at the economic significance of frankincense and the sustainability of this arid land product. In order to address these issues, this study seeks to:

6. Identify and delineate frankincense producing areas.
7. Evaluate the roles of primary and secondary stakeholders.
8. Assess the level of production and methods of production.
9. Document the processing and marketing of frankincense.
10. Investigate NTFP contribution to household livelihood.
11. Address the sustainability of this resource given the current extraction rate.

## B.3 STUDY AREA

This study was conducted in the province of Dhofar located in the Sultanate of Oman. Dhofar is the southern-most province in Oman bordering Yemen on the west, Saudi Arabia on the north and the Indian Ocean on the south. The province covers an area about 99210 square kilometers approximately between latitudes 16º north and 21º north, and longitudes 51º east and 56º east. Dhofar is the largest of eight provincial regions, represents about 32% of Oman's total area, and consists of nine administrative districts six of which are concentrated in the three mountain ranges along the southern coastal area of the province.

Even though there will be references to other luban producing areas or provincial districts, the primary focus of this study is on dry streambed channels (wadis)

predominantly in Wilayat Sadh (WSd), Wilayat Rakhyut (WRk), and Wilayat Salalah (WSl). The NTFP produced in these wadis will be referred to in accordance with local terminology, as Hojari/Nejdi, Shazri, and Sha'bi respectively. This naming convention adheres to a local classification scheme consistent with the primary type of frankincense harvested in the area. The research focused on the wadis, regardless of the ecological zones or the political administrative boundaries they might cross. Most, if not all, of Oman's frankincense is produced in WSd, WRk and WSl where all the current active fields are located.

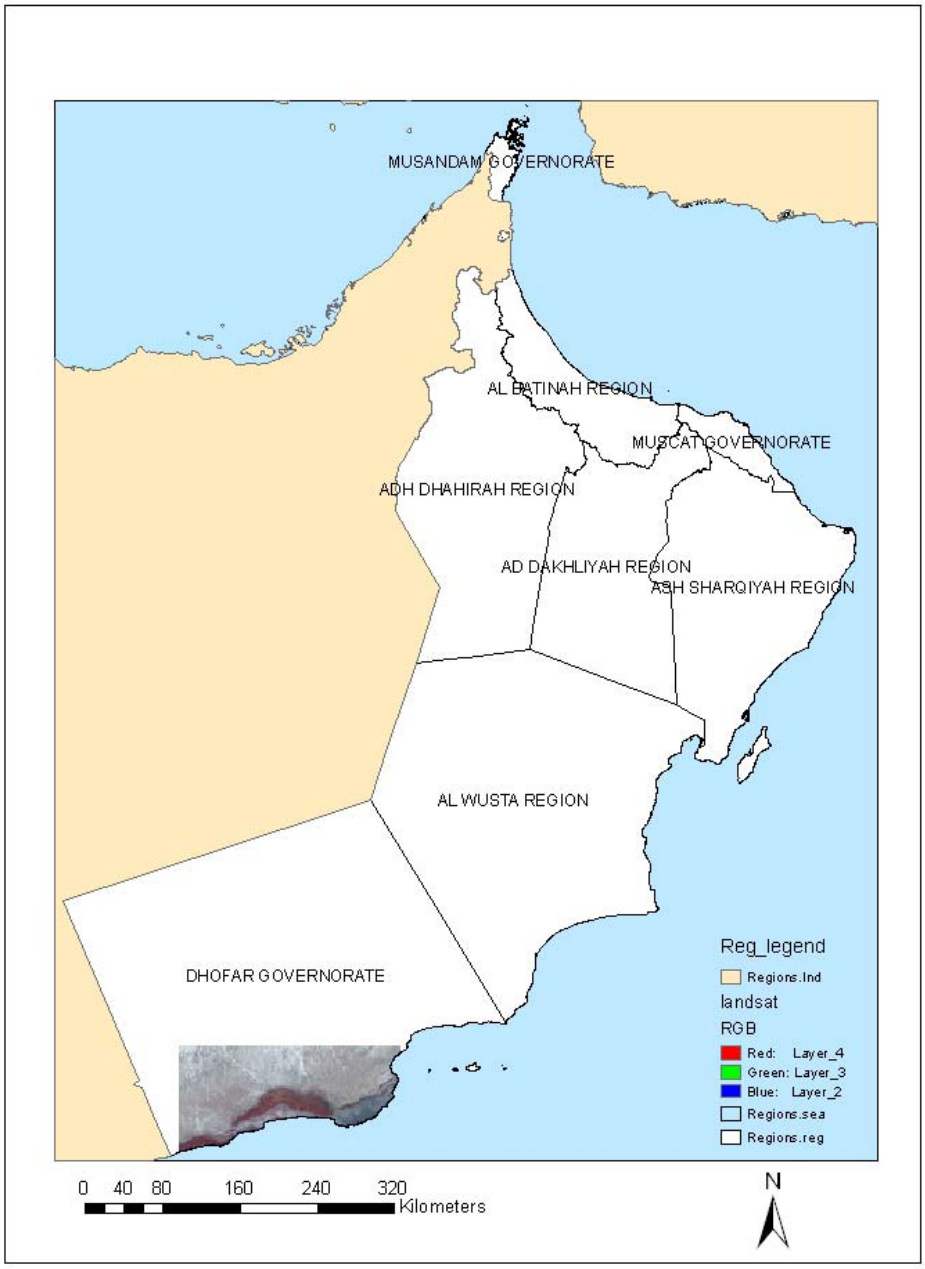


**Figure B1;** The eight provinces (wilayat) of the Sultanate of Oman with a false color composite satellite image showing the Dhofar mountain range and adjoining habitat areas.

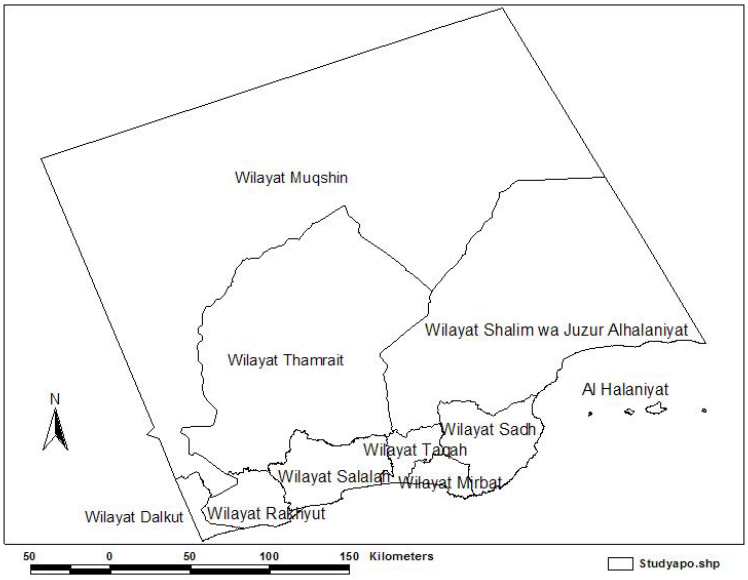


**Figure B2:** Governate of Dhofar showing the nine wilayat (provincial districts) and Halaniyat Island

There are several classification schemes for the ecological zones of Dhofar ranging from coarse to fine spatial categories. Jansen (1986) classified Dhofar into three broad ecological categories – coastal plain (*sahil*), Dhofar highlands (jabal), and desert zone (*badiyah*) - based on the topography of the region. Al-Hatrushi (1989) took a similar approach to Jansen but reclassified the desert zone into desert, gravel plain and sand desert (Empty Quarter). Traditional classification is often vegetation-based and tends to have finer categories that range from 7-10 ecological zones. A range and livestock study classified the region into 14 distinct categories based on the availability of range (GRM 1982 by the Ministry of Agriculture and Fisheries). Miller and Morris (1988) took the traditional categories and reconstituted them into seven vegetation-based classes.

Dhofar has rich vegetation diversity and species richness which is floristically more similar to those found in the island of Socotra (Yemen) and the drier regions of Northeast Africa than those found in northern Oman (Miller and Morris 1988). Most of this rich flora is restricted to a mountain range belt and adjoining zones about 40 km at its widest extent and approximately 240 km long extending from Hasik to Oman's border with Yemen. The mountains of Dhofar form a raised plateau reaching an altitude of 2,000 m in the south and dipping to the north beneath the sand dunes of Rub' al Khali (Guba and Glennie 1998). As the Dhofar mountain-range slopes north, the vegetation becomes sparse and aridity increases (Phillips 1966 p170), while the seaward-facing southern aspect is characterized by cliffs, slopes and wadis covered in thickets of drought–deciduous woodlands (Gallagher 1977). The dry leeward side of these mountains known to the locals as Nejd and pockets of fragmented habitats on the coastal plain (sahil) are the principal frankincense zones.

The Dhofar plains are comprised of aeolian sand and alluvial limestone gravel, and are traversed by a network of wadis that drain from the mountains (Ghazanfar 1998). The coastal plains consist of the Salalah Plain bounded by Jabal Qara, the Rakhyut Plain bounded by Jabal Qamar, and the Sadh Plains bounded by Jabal Samhan. Where it exists, the Rakhyut plain is a narrow strip less than 2 km wide. The Salalah Plain is predominantly flat semi-desert grassland except along the northern boundaries where it transitions into drought-deciduous woodlands. The bow shaped feature of Jabal Qara and its proximity to the coast creates mist and clouds that lead to higher humidity and rainfall

than in the Qamar and Samhan mountains. In addition to receiving significant rainfall, the Salalah plain receives considerable periodic runoff from the seaward draining wadis.

This study was carried out in Wadi Arah and Wadi Sanwik in the Hojari/Nejdi zone, Wadi Maqsail and Wadi Afol in the Shazri zone, and Wadi Adonib in the Sha'bi zone (Figure B3.1). Although two wadis were identified in the Hojari/Nejdi area, frankincense extraction observed in this study was carried out beyond the boundaries of those two watersheds.

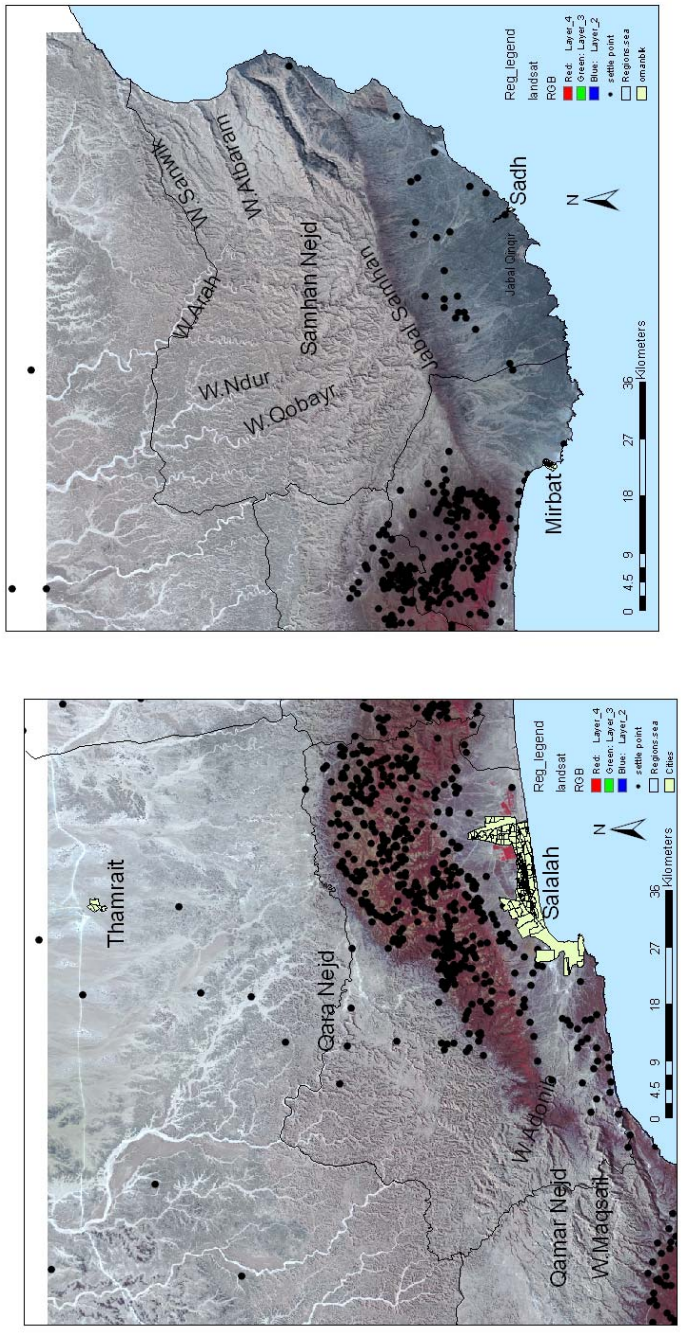


**Figure B3:** Landsat image of the *B.sacra* zones in *Qamar Nejd*, *Qara Nejd Samhan Nejd* and *Jarbeeb*.

Figure B 3: False color composite Landsat image of the *B.sacra* zones in *Qamar Nejd*, *Qara Nejd Samhan Nejd* and Jarbeeb. Black dots indicate human settlements, boundaries of major provincial districts, cities and luban producing wadis in the study area

## B.4 METHODOLOGY

The methodology utilized in this study consists of Rapid Rural Appraisal, formal interviews through the use of questionnaires, informal interviews with various stakeholders ranging from government agencies, tribal elders, wholesalers, retailers and harvesters. In addition, field measurements were carried out and biweekly harvested frankincense in sacks destined for the market were tallied by the truckload at road-head camps. Sacks of frankincense were randomly weighed at the destination (Salalah) to determine the equivalent weight of each sack in kilograms.

Frankincense import-export data were compiled from the "Foreign Trade Statistics for the Sultanate of Oman." Local government purchasing records in Salalah were obtained from the Public Agency for Marketing of Agricultural Products (PAMAP).

### B.4.1 RAPID RURAL APPRAISAL

This research utilizes rapid rural appraisal (RRA) techniques to elicit and extract local knowledge (Chambers 1994). The RRA approach used in this study was based on semi-structured interviews designed to identify local ecological zones of Dhofar, and frankincense producing habitats, and to capture differences among local stakeholders and markets. The appraisal identified five groups: (1) owners (2) harvesters/ tappers (3) wholesalers (4) government agencies and (5) retailers, who all play significant roles in

the production, sale and marketing of this important NTFP. In addition to understanding luban production, the appraisal revealed the existence of four important luban-producing habitats, four luban types and the existence of a major market in Salalah and a minor one in Musqat.

Local Omanis have ownership rights and control access to the Boswellia stands that produce the NTFP. Although local Omanis occasionally get involved in harvesting, they usually rent their fields to harvesters from outside the region. In addition to having ownership rights, a few owners are successful wholesalers in the luban industry.

Harvesters are almost universally poor migrant workers who rent fields to sustain their livelihood. These Somali migrants have no work authorization permits and frankincense extraction or livestock herding are the only options they have to gain meaningful employment. Harvesters predominantly control the production of frankincense in the fields.

Wholesalers occupy the next rung up the production ladder, and are the most powerful players in the frankincense industry. Some wholesalers have their own fields while others have well established strong ties with owners and harvesters. Wholesalers supply retailers, and government agencies such as PAMAP, and play a major role in the import/export segment of this NTFP.

PAMAP controls the processing of frankincense. This government agency sorts the luban into six different grades and serves as the gateway to quality control assurance. In addition, it supplies specialized local industries, sells packaged frankincense products at PAMAP retail store and exports some value-added products to overseas markets such as wholesalers, fragrance and perfume companies, essential oil producers, aromatherapy practitioners, and natural healing service providers.

Retailers range from small operations run by individuals, who sell frankincense in the market bazaars, to more broadly established businesses with many employees. Retailers perform limited value-added processing geared towards obtaining favorable prices for their luban in the local markets. Most processing operations at this level are primarily small-scale and involve sorting frankincense into a minimum of two grades or a maximum of four grades.

### B.4.2 FORMAL INTERVIEWS

A formal survey questionnaire was devised to capture various aspects of frankincense extraction. A total of 16 harvesters were interviewed between December 1998 and June of 1999. A total of 12 harvesters were interviewed during the April-September 1999 NTFP extraction season in the Hojari/Nejdi zone, but only 3 collectors from the Shazri/Sha'bi zone were interviewed during the October 1998-March 1999 season.

### B.4.3 INFORMAL INTERVIEWS

Informal interviews with elders, government agencies, wholesalers and retailers were instrumental in capturing luban production, processing, marketing and sales methods. Moreover, these interviews revealed the increased level of interdependence between the various stakeholders. The information gathered during these interviews was instrumental in mapping the ecological zones associated with frankincense. Informal interviews provided an insight into the structure of the frankincense trade from the harvester in the field to the customer on the street.

### B.4.4 FIELD MEASUREMENTS

Frankincense-sacks produced biweekly and brought to road-camp locations for shipment to markets in Salalah were tallied. Five sacks were randomly chosen from each truck and weighed to determine the equivalent weight of each sack in kilograms. These biweekly measurements were taken from April-June 1999.

### B.4.5 GOVERNMENT RECORDS

Government records of the agency responsible for acquiring frankincense from local wholesalers are obtained from the PAMAP branch in Salalah. These official records were limited to the locally produced luban sold to PAMAP from 1987 until the practice was officially curtailed at the end of the 1995 harvesting season. In an effort to support the local frankincense industry, the Sultanate of Oman authorized PAMAP to purchase all the frankincense local producers brought to the Agency for sale. Although the sale of

luban to non-government entities continued to persist during this period, the percentage of the crop sold to PAMAP or others is not known. The quantity is expressed in kilograms and the value per kilogram is expressed in Riyal Omani and U.S. dollars (Table B 1).

**Table B1:** PAMAP's Frankincense purchases from local producers from 1987-1995.
Source: Public Agency for Marketing of Agricultural Products

| Year | Quantity (Kg) | Total Value (R.O) | Value/kg (R.O) | Value/kg $(US) | Total value $(US) |
|---|---|---|---|---|---|
| 1987 | 27,652 | 55,304.0 | 2.0 | 5.3 | 146,555.60 |
| 1988 | 11,724 | 25,567.0 | 2.2 | 5.7 | 66,826.80 |
| 1989 | 36,124 | 72,713.0 | 2.0 | 5.3 | 191,457.20 |
| 1990 | 37,191 | 68,414.0 | 1.8 | 4.8 | 178,516.80 |
| 1991 | 336 | 565.0 | 1.7 | 4.4 | 1,478.40 |
| 1992 | 52,814 | 72,078.0 | 1.4 | 3.6 | 190,130.40 |
| 1993 | 13,541 | 18,080.0 | 1.3 | 3.5 | 47,393.50 |
| 1994 | 549 | 774.0 | 1.4 | 3.6 | 1,976.40 |
| 1995 | 15,341 | 28,761.0 | 1.9 | 4.9 | 75,170.90 |
| Total | 195,272 | 342,256.0 | | | 899,506.00 |

Frankincense import-export data were compiled from the annual government publication of "Foreign Trade Statistics for the Sultanate of Oman." Although frankincense now has a unique product designation, prior to 1993 it was grouped with other resins, latexes and oleoresins like myrrh under a group commodity designation. Therefore, frankincense import/export data prior to 1993 could not be compiled from the grouped data.

## B.5 RESULTS

The legendary system of transporting frankincense to Salalah, Mirbat and Sadh through the use of camels has been replaced with the use of donkeys and trucks. Donkeys are the major means of transportation used to haul the harvest from the luban-producing watersheds to road-head camps where the luban sacks are loaded onto a truck destined for the Salalah market. Each of the three groups studied owned 3-4 donkeys and every individual within a harvesting group was entitled to take his turn using these animals to

transport his NTFP share to a designated loading location. The road-head agent, who operated the only vehicle that hauled the frankincense into town, was the primary and only link between the harvesters and the destination market in Salalah. In addition, he served as the point-man in acquiring new harvesting locations. The extent of the harvesting territory, the number of owners and the rental arrangement was a well guarded secret among all harvester groups. Although the extent of illegal harvesting was very difficult to quantify, many locals claimed that harvesters tapped luban trees in areas they were not authorized to harvest. The absence of written rental agreements, clearly defined boundaries, and ownership deeds complicates verification of local claims and harvester counter claims about the methods and areas of extraction. In addition, Somali harvesters name some areas in a manner inconsistent with the local naming practices. For example, a section of Wadi Arah frequented by a protected leopard is known to Somalis as shabellay (the tiger place).

No owners were encountered at any of the observed harvested premises. Owner absence created a management vacuum which increased the possibility of migrant harvesters illegally exploiting unattended fields. The lack of recognizable and defined boundaries between ownership parcels made it difficult to determine where one field began and another ended, or the extent of tapping violation. Rented ownership parcels or boundaries could not be determined due to absentee landlords and harvesters' secrecy about rented fields and the respective owners of those parcels. Harvesters were unwilling to provide names of owners and when they did furnish that information it was often misleading and

unreliable. This was done in part to protect their livelihood and in part to conceal possible illegal tapping. Due to time and monetary constraints, this study did not conclusively ascertain the cost of renting Boswellia stands or fields with respect to the area the rental agreement covers. Hence, the focus on income generated from frankincense production.

All 16 interviewed harvesters collected luban to make money and send some of the proceeds to their families in Somalia. Everyone expressed interest in acquiring legal documents and 75% indicated they would give up harvesting upon receiving documentation that would authorize them to work anywhere. Income generated from the seasonal sale of harvested frankincense is the primary and only source of income for the migrant luban harvesters accounting for 100% of their income. A total of 276 sacks (approximately 8280 kg) was collected in three harvesting cycles from April 1st to the 9$^{th}$ of June. If harvester numbers and groups stay the same, and harvested *menzela* remain constant in Wadi Arah and Wadi Sanwyk, nine or eleven harvesting cycles per season will yield 828 sacks (24,840 kg) or 1012 sacks (30,360kg) respectively. When five sacks per load were randomly weighed, the measured average weight per sack (*jawan*) was 31.5 kg instead of the 30 kg weight designated in the field. The difference in weight between harvester measurements in the field and actual weights in Salalah is no accident. Harvesters often add extra luban in each sack or per weighted quantity to make up for possible luban weight decrease resulting from the product losing any lingering moisture content during the drying process. Assuming that the luban does not lose more weight, and all the resin is sold by the kilogram, the wholesaler stands to gain 414.0 kg from the

entire harvest between April and June as illustrated in Table B 2. When these figures are projected over nine or eleven cycles per season, the extras yield 1242 kg or 1518 kg respectively. At a wholesale value of approximately $3.0 per kilogram, the wholesaler stands to gain $3,726.0 - $4,554.0 from the extra weight.

**Table B2** Frankincense production tallies and estimates at the forest gate in 1999.

| Month | date | Wadi | Q (sacks) | L(kg/sack) | Ql (kg) | Qm (kg) |
|---|---|---|---|---|---|---|
| April | 25 | Shakhwoot | 30 | 30 | 900 | 946.7 |
| April | 27 | Arah | 32 | 30 | 960 | 1009.8 |
| April | 30 | Sanwik | 30 | 30 | 900 | 946.7 |
| | | | | | | |
| May | 15 | Shakhwoot | 30 | 30 | 900 | 946.7 |
| May | 20 | Arah | 31 | 30 | 930 | 978.2 |
| May | 22 | Sanwik | 32 | 30 | 960 | 1009.8 |
| | | | | | | |
| June | 2 | Shakhwoot | 30 | 30 | 900 | 946.7 |
| June | 5 | Arah | 30 | 30 | 900 | 946.7 |
| June | 9 | Sanwik | 31 | 30 | 930 | 978.2 |
| total | | | 276 | | 8280 | 8709.3 |

Quantities tallied in three harvesting cycles at forest gate in 1999.
Q (sacks) = number of nylon sacks per load
L = harvester measured quantity per sack in (kg)
QL = quantity per load (kg) based on harvester measurement
Qm = quantity per load (kg) based on direct measurement of randomly selected sacks
Source: field data

Owners have other sources of income and often use the rental proceeds from their frankincense field as supplementary income. The discovery and production of petroleum in Oman brought new wealth and employment opportunities to the country. The oil wealth stimulated economic development that induced most households that relied on local luban harvest to forgo the hard physical labor required to extract a living from frankincense. Local Omanis were unwilling and often detested working in the luban

fields. As a result, owners were left with the option of hiring foreign laborers, renting out the fields, or entering into a sharecropping arrangement. Hiring help and sharecropping requires constant site supervision and management, paying wages, acquiring work permits and providing healthcare for the workforce. Most owners avoid these responsibilities and opt for receiving rent instead of incurring expenses at the front end. A few owners expressed interest in contract labor from Somalia if and when the government reinstates such practice.

Perhaps surprisingly, there has been a noticeable improvement in the quality of frankincense in the last 20 years according to knowledgeable local luban-industry sources. Luban retailers in local bazaars, wholesalers and some owners conclude that resin quality has improved with the introduction of contracted harvesters from Somalia in the late 1970s. Most argue that in the past luban used to have more rocks to inflate the weight, had more impurities and often came in smaller quantities from individual sellers.

Although the 14-16 day harvesting cycle is observed in the field, the road-head agent's merchandise pickup does not always conform to this schedule. Mechanical problems, driver health and stamina, and unforeseen administrative obstacles at military and police checkpoints are some of the factors that affect the frequency with which luban is transported from the field to the market.

Concern about nature conservation, environmental protection and the sustainable use of *B.sacra* prompted the Government to curtail PAMAP's pre-1995 open purchase policy of frankincense. Even though this study was aware of some unofficial luban sales to PAMAP, the agency did not acknowledge the existence of concurrent documentation. Government buyout of locally produced frankincense was intended to help local producers but many natural resource managers, some government officials and private citizens felt it was encouraging the encroachment of transient Somali harvesters into Dhofar. The policy also emboldened shady wholesalers to engage in product mixing where locally produced frankincense was mixed with frankincense imported from Somalia and then sold to PAMAP as a local product. Although PAMAP continued to purchase luban in an unofficial capacity after 1995, the quantities bought were small and this study could not obtain agency frankincense data that would corroborate the existence of such records. It is possible that documenting the existence of those unofficial sales might violate policy or reveal unintended results with less desired consequences.

Some frankincense wholesalers and owners felt that PAMAP's continued unofficial purchase gave them the impression that the original open sale policy will be reinstated. Thus, frankincense production continued unabated for at least one year after the policy change.

Frankincense export increased from zero in 1995 to 16,600 kg in 1996 at the same time frankincense imports decreased from 1,112 kg to 759 kg (Table B3). The combined effect of a government crackdown on illegal Somali transient harvesters that started in 1997 and PAMAP's unofficial low level purchase of locally produced frankincense

resulted in the reduction of Somali harvesters. The increased importation of frankincense after 1997 can be attributed to the reduced number of harvesters which has led to decreased local production levels.

Somalia and U.A.E are Oman's largest frankincense trading partners. Somalia is the principal exporter of frankincense into Oman and U.A.E. is the largest importer of Omani frankincense (Table B3). Although further studies are required to account for the type of frankincense Oman exports and the amount of imported frankincense that Oman re-exports, Omani wholesalers export the bulk of imported Somali-frankincense into other countries.

**Table B3** Frankincense imports and exports

| year | T-Import | T-Export | Imp_SOM | Imp_UAE | Exp_UAE |
|---|---|---|---|---|---|
| 1993 | 0 | 6000 | 0 | 0 | 6000 |
| 1994 | 516 | 0 | 500 | 16 | 0 |
| 1995 | 1112 | 0 | 750 | 282 | 0 |
| 1996 | 759 | 16600 | 0 | 599 | 14500 |
| 1997 | 520 | 9958 | 520 | 0 | 6195 |
| 1998 | 11762 | 71 | 10960 | 758 | 0 |
| 1999 | 10650 | 1828 | 10560 | 90 | 1828 |
| 2000 | 5812 | 550 | 5620 | 192 | 0 |
| total | 31131 | 35007 | 28910 | 1937 | 28523 |

Table indicates total frankincense imports and exports (T-Imports, T-Exports) respectively and the portion imported from and/or exported to Somalia and UAE. Imp_SOM = frankincense import from Somalia; Imp_UAE = frankincense imports from UAE; Exp_UAE = frankincense export to UAE

Value added processing at various processing stages enhances luban grading and marketing. For instance, frankincense essential-oils data compiled from 16 dealers in Europe and North America show an average retail value of $12.10 per 5 milliliters (ml). A kilogram of frankincense yields 200 ml of oil in Oman's Amouge (fragrance industry)

processing plant. This, in turn, would fetch an estimated value of $484 in European and North American markets. Some frankincense grades available in the international markets have variations of the Hojari and Nejdi name association and are sold for as high as $204/kg to as low as $35/kg retail. A comparable Hojari luban, in Oman, is sold for $2.19/kg in the field, $3.51/kg wholesale, $7.89/kg retail and $46.05/kg in PAMAP stores (Table B5).

Some transient Somali harvesters use luban extraction practices that are detrimental to the health and survival of the *B.sacra* but most of these harmful extraction methods decrease with more harvester experience. More experienced harvesters have a wealth of information about seasonality, plant cycles, habitat locations and the effect of those factors on luban extraction. Transient harvesters are often interested in short term financial gains and are more likely to engage in harvesting practices that negatively affect *B.sacra*. When such individual's practices come to the attention of the harvesting group, the concerned party or parties are given the option to reform their ways or leave the group.

Owners rent their *B.sacra* holdings to harvesters with the understanding that tappers will practice sustainable luban extraction methods that minimize injury to *B.sacra* and enable harvesters to improve their livelihood from the economic benefits of frankincense extraction. Although direct supervision and management is minimal at best, most harvesters honor the arrangements they make with *B.sacra* owners. Extraction practices

such as trunk stabbing, deep or large incisions, closed circle bark removal around the trunk and indiscriminate tapping that owners deem injurious to luban-producing plants often result in the loss of group usufruct rights to harvest an area.

Operating within the owner-harvester contract framework, 43 harvesters were extracting luban inside Jabal Samhan Nature Reserve (JSNR), a protected zone of 45,000 km² (http://www.mrmewr.gov.om/naturjebel.htm ) containing approximately 60%-70% of the Hojari luban zone. Tribal ownership of NTFP within the reserve poses a management challenge that could threaten the current balance between economic interest and environmental concerns. Government agencies plans that institute *B.sacra* conservation management policies to limit the number of activities and people in the JSNR conflicts with the unfettered access and utilization tribal owners require to manage and exploit their resources without government intrusions.

## B.6 DISCUSSION

### B.6.1 PRODUCTION

Frankincense production takes place on government owned land administered by the Ministry of Municipality and Environment, the Ministry of Agriculture and the Wali of Dhofar representing His Majesty Sultan Qaboos. Although the land belongs to the government the trees that produce frankincense (*B.sacra*) are under the private ownership

of individuals belonging to Omani tribal kinship structures. The production, processing, marketing and sale of this NTFP are illustrated in Figure B 4.

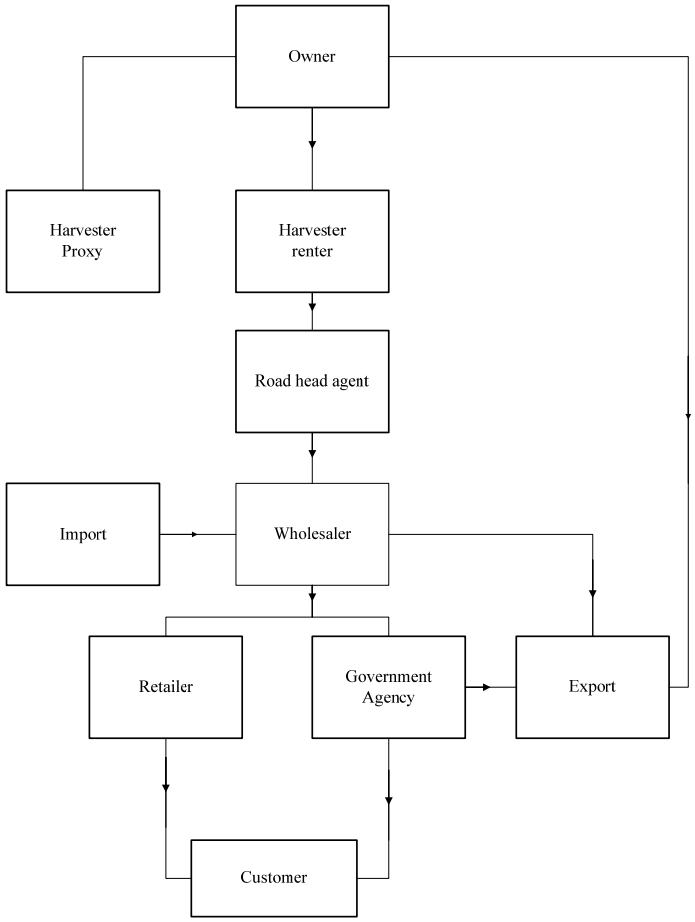


**Figure B4** Flow chart indicating the production and processing of frankincense from the fields of owners to individual customers in the local bazaars.

Owners are exclusively men because *B.sacra* is inherited and passed from generation to generation through the male-line. Although women are entitled to inheritance rights, instead they receive monetary compensation for their portion of the inheritance. This is

done to ensure *B.sacra* ownership, access and control remain within the tribe. Most often, owners rent their fields to harvesters on a seasonal basis. Occasionally, owners engage in the direct production of luban when they get access to dependable and trustworthy hired labor. At times, owners might enter into a sharecropping arrangement with harvesters whereby the owner provides food, shelter, transportation and a small allowance during the harvesting season. Upon the sale of the harvested NTFP, all the expenses are paid back to the owner. The remainder is split two ways, half going to the owner and the other half to the harvesters.

Harvesters hold usufruct rights that grant them complete harvesting access rights during the rental season. After they have established a good working relationship, most resin collectors make rental arrangement directly with the owners. Others use Omani nationals of Somali origin who share a kinship relationship as proxy rental agents to get access into the production of frankincense. An Omani-Somali rents the intended parcels from predominantly Omani-Arab owners then turns them over to a Somali harvester. Most often this is done with no additional cost to the Somali harvester but with the explicit understanding that the harvested frankincense is sold to the proxy renter/wholesaler.

Field production is carried out almost exclusively by illegal migrant workers from Somalia who eke a living from the bi-seasonal collection of this resin from the dry hot and arid shrublands on the fringes of the hyper-arid deserts of Dhofar. Without legal documents or work authorization papers, these migrants find work as herdsmen for the

local tribes or they engage in the harvesting of frankincense. Both occupations are very labor intensive and it is common for some of these workers to move back and forth between herding and harvesting. Although it requires more physical labor and longer work-hours, frankincense extraction is the preferred form of employment among the undocumented migrants for several reasons. First the Boswellia fields are in isolated rugged mountain terrain that minimizes contact with government authorities. Second, most fields have limited water and forage and are less frequented by nomads. These conditions help the harvesters maintain a low profile minimizing human contact. Finally, harvesting offers NTFP collectors a gainful form of employment with a significant level of individual independence and freedom to maintain their livelihood and send remittances to their families in Somalia.

Each individual has exclusive ownership and control over his production and labor within a work-party except on those occasions when he is called upon to fulfill his obligation to the group. Some of these obligations are not limited to but include cooking for the group, harvesting for a sick group-member and participating in charitable donations. Group loyalty and cohesion is an insurance policy against unforeseen circumstances such as illness or injury that might limit the individual harvester's ability to tend his fields. Under such difficult circumstances, the group takes on the responsibility of donating time to collecting the sick individual's share until his condition improves.

Even though harvesters exercise considerable self-management and policing, lack of legal documentation pose potential health risks to the harvesters and the local community. Furthermore, the illegal nature of their activity makes them susceptible to abuse such as delayed payments for their products, overcharges for supplies and tagging additional fees on parcel rental. Moreover, as harvesters move in or out of a group in search of better employment, group dynamics change and might witness an unforeseen shift in harvester skills and experience that could be detrimental to the existing equilibrium within the group.

#### B.6.1.1 SEASONS AND LABOR ORGANIZATION

The harvesting season in the Hojari/Nejdi zones in eastern Dhofar extends from the beginning of April to the end of September while the Shazri and Sha'bi harvesting season in western Dhofar begins in October and ends in March. A tapping is made about every two weeks in a cyclical harvest, which allows 9-11 harvests per season (Svoboda et al 2001).

The major unit of resin production often consists of a joint work party of adult men (Farah 1994). The number of harvesters in each work party is variable but most often this ranges from 11-15 individuals. The work party is a mixture ranging from semi-skilled inductees to seasoned professionals who are skilled in the art of resin production and processing. Harvester groups organize themselves along tribal and kinships lines governed by a code of conduct that is common among frankincense harvesters in

Somalia. Group members are often from the same tribe or sub-tribe and are more often related to each other than the next group The codes cover a multitude of issues such as group dynamics, individual conduct within the group, access to resources, conflict resolution, individual ownership and group cooperation. Kinship affiliation within a group is instrumental in strengthening group cohesion, loyalty and dynamics. In addition, the annual harvesting rotation system gives *B.sacra* stands some respite from tapping, during the fallow season contributing to vegetation healing and recovery from incisions inflicted during the NTFP extraction season and contributes to a sustainable harvest.

### B.6.1.2 Collection Methods

Frankincense collection is a daily activity extending from dawn to dusk with occasional breaks for lunch and tea. Resin extraction techniques entail tapping the trunk at regular two week intervals (Al-Qassani 1980). The resin resides in the living inner bark of the trunk and tapping involves making incisions into the bark and collecting the exudates (http://www.fao.org/docrep/V9236E/V9236e07.htm ). The number of incisions varies and often depends on tree size, harvester experience, and the cultural practice of the communities engaged in the collection of frankincense. Some of the differences associated with cultural practices include allowing limited but targeted incisions on the trunk instead of allowing numerous incisions, or making incisions on a bud and associating it with productivity or prohibiting it because such practice hinders plant vitality. Larger trees receive more incisions and are believed to produce more resin. Big

trees also have more and bigger multiple stems and branches that allow more incisions than small trees.

The size, shape, location, and depth of incisions on the trunks and branches depend on the harvester. Experienced tappers make shallow cuts while less experienced collectors make deeper incisions that are detrimental to the longevity of the harvested trees. Deeper incisions don't heal well and makes the tree vulnerable to secondary diseases. The size of an incision varies from about 2x2 inches to 3x5 inches placed at random anywhere above knee height. An ideal cut is one that is made on a bud location above knee level and within the reach of a standing average height harvester. Most cuts have an irregular shape and extend a few millimeters into the bark.

The resin that exudes from these incisions is allowed to drain freely and dry on the trunk into tear-shaped nuggets, although a portion of exudates is wasted because it drops to the ground before it forms the semi-solid nuggets on the trunk. In order to minimize resin loss a slightly deeper cut is made at the lower lip of the incision. The deeper lip tends to trap the excess exudate long enough for it to turn solid. Once every two weeks, the incisions are revisited, the dry resin is colleted and the incision is scraped by taking off the healing membrane that forms over the two week old incision. In addition, old incisions are slightly enlarged around the edges and occasionally new ones are made. A different set of trees is earmarked for frankincense harvesting every day on a two week rotation. When the last set of trees is incised, the first set of incised trees is ready for

harvesting and scarification the following day. This two week rotation process is maintained for the duration of the six months harvesting season. The daily harvest is taken back to the caves where frankincense is allowed to dry and subsequently cleaned, sorted and packaged.

Caves serve as storage for the collected frankincense and shelter for the harvesters from the scorching summer heat, occasional monsoon storms, and the freezing winter and fall night temperatures. Cave temperatures are fairly constant (80-90 degrees F) and are 20-30 degrees cooler or warmer than temperatures outside the cave during the summer and winter months respectively. Frankincense is an oil-based resin that is vulnerable to heat and moisture. Heat melts the olio-resin and deforms or ruins the tear-drop shape required of marketable frankincense. Melted olio-resin can easily bind with soil particles, debris and other impurities that diminish resin quality. Water dissolves a significant portion of the olio-resin and the remaining solid becomes water logged and unsuitable for market. Thus, cave dwellings in these deeply incised barren ravines in the *B.sacra* habitat zones are ideal for the storage of frankincense. The dry and constant cave temperature helps the harvested resin to dry while protecting it from the natural elements that could potentially damage the quality, marketability and value of frankincense. Furthermore, field preprocessing of extracted olio-resin is conducted in the caves.

Once every two weeks, weighed harvested portions are packed in nylon sacks and transported by donkeys to makeshift road-head loading points. These road-head areas

serve as temporary meeting places where each group receives their bi-weekly food, emergency water supplies and other essentials such as sneakers, medication and news updates from home. The harvested resin is loaded onto a truck destined for Salalah and arrangements for the next pickup and drop off locations are made at these temporary camp sites. After the shipment is made, the camp is abandoned and each individual or group of individuals moves to temporary cave camps deep in the Boswellia shrublands.

The small number of harvesters spread over a wide area in the Hojari/Nejdi zone creates conditions that reduce pressure on *B.sacra* resources. The low harvester per area ratio enables tappers to access large high-yielding trees on wadi bottoms and easily accessible slopes. This is also significant because it fosters the production of more high quality NTFP. Work-party cohesion also facilitates a high degree of self-policing and less reliance on destructive NTFP extraction methods. The six months harvesting cycle provides *B.sacra* some respite from tapping for six months.

The low harvester/area ratio, work party cohesion, self-policing, stand fallow rotation and the production of quality NTFP contributes to increased gum-resin value and the sustainable use of *B.sacra* shrublands. Other stakeholders such as wholesalers, retailers and PAMAP play a major role that contributes to setting up additional value-enhancing quality control measures at various processing stages.

B.6.2 PROCESSING

There are four levels of processing required in getting a quality product to the market. Field and retailer processing are minor in scope but nonetheless add some value to frankincense. On the other hand, wholesalers and government agency processing are large scale and involve significant value added procedures.

Field processing activities involve simple procedures that serve as the first gateway to frankincense quality control. Harvested frankincense is spread on designated areas on the cave floor where it is allowed to dry. The dried resin goes through basic and limited cleaning, sorting, and packaging that meet market standards. These standards require good quality dry frankincense that is free from impurities such as moisture, rocks, soil, and other debris that reduce product quality and inflate its weight. In general, each two week harvest destined for the market is reconstituted into a harvester determined blend and poured into nylon sacks with 30-33 kg capacity. The top portion of each sack is almost always filled with the most desirable frankincense tears that appeal to most potential buyers as they open the sack. The raw product at this processing stage fetched $2.19/kg at the market in 1998-1999.

Based on wholesaler request, occasionally a high grade luban (*fusoos*) of specific tear shapes and color harvested in the Hojar or Nejd zone are put together in one or two sacks. Fusoos Hojari/Nejdi consists of foggy-white large to medium size tear shaped nuggets with a slight blue undertone. This requires a group effort since it will take considerably longer than 2 two-week cycles for an individual to fulfill such a request. A group of

individuals and sometimes all individuals in the group contribute a portion of their high grade luban to meet the wholesaler request. When traded in the market, this high grade product fetches a high price that is double or triple what they would normally get for a regular sack. Harvesters got paid $5.7/kg for these pre-sorted nuggets while the same product sold for $8.3/kg at the wholesale level in 1999. Furthermore, the harvester assumes the cost of transporting the product to the market. The proceeds from the sale of this high value product are then divided among the contributors. The processing time involved and level of management required to keep track of contributors and the portion of their proceeds limits the regular packaging of such value-added product independent of the wholesaler.

Retailers primarily buy raw unprocessed frankincense from wholesalers and occasionally from harvesters. Most separate the raw mix into lighter-colored Hogari, Nejdi (Hogari-mix) and powder (chips and powder residue), while some have two additional low grades known as Shazri and Sha'bi. The later two are dark brown and dark, respectively, and are the least desired grades.

Apart from selling the raw product, for an additional fee of 5RO/sack ($13.2), the wholesaler provides a service for the retailers by sorting each sack into big nuggets, little nuggets and powder. For the more lucrative exclusive markets they assemble frankincense nuggets hand picked according to specific shapes, colors and sizes. This product known as Fusoos is sold by the kilogram and fetched (1999) an average of

6RO/kg ($15.8/kg).The unprocessed Hojari/Nejdi sack contains roughly 30kg and sold for 40RO or about $3.51/kg. A similar named Hojari cost $7.9 and $46.1 per kilogram at retailers and PAMAP respectively (Table B5).

PAMAP is the local government agency responsible for the purchasing and processing of frankincense. Although the open and supported purchase of luban has ended, a limited unofficial acquisition of frankincense from local wholesalers continues. PAMAP sorts the luban into the following six grades: (1) Hojari (2) Nejdi (3) Shazri (4) Na'eem (5) Powder and (6) raw mix. PAMAP supplies some of the local retailers, sells selected products in their agency store in Musqat and exports some to various overseas markets. They are the sole supplier of high grade frankincense to the specialized exclusive frankincense based local perfumery known as Amouge.

The value of frankincense is enhanced with each subsequent processing step but the lack of certification limits harvester access to potential new markets. Certification provides a useful framework in which to address a variety of issues relating to NFTP sustainability because it requires grounding in management, as well as in broader environmental, social and marketing issues (Shanley and Laird 2002). PAMAP is in a perfect position to formalize some reputable standards that would enable local harvesters to reap the benefits of putting a certification system in place.

### B.6.3 VALUE ADDED PROCESSING

Processing adds considerable value to the raw product (Tewari and Campell 1995). Therefore, the large-scale stakeholders in the frankincense industry have the financial means, technological know-how and control to reap most of the benefits of value-added processing.

In addition to developing a frankincense grading system, PAMAP also produces a number of market-oriented packaged products. Traditional eyeliner, known as Kuhul, is made from a residue collected after burning frankincense in olive oil. Another innovation destined for the tourist and export market involves the prepackaging of a small incense burner, some incense and a small credit card size brochure about frankincense and Oman. In addition, the PAMAP outlet store sells an assortment of pre-packaged sorted and graded frankincense at their Musqat outlet. The lowest PAMAP grades (powder, raw) are not sold but often used for the production of kuhul. A small box of kuhul sold for 3RO ($7.9) in 1999..

Amouge uses a steam distillation system to extract oil from Hojari frankincense supplied by PAMAP. According to Amouge's classification scheme the supplied raw material is categorized as silver-frankincense and PAMAP is the exclusive supplier. PAMAP acquires preprocessed silver frankincense from wholesalers who market the product as fusoos and fusoos awal. Amouge uses all the frankincense oil it produces. This oil is highly priced and is predominantly sold by the gram or milliliter in international markets (Table B3). A 5ml bottle of this oil is valued at about $12 in North American and

European markets. Although there are alcohol-based and chemical solvent-based oil extraction methods that produce superior oil quality and increased yield, Amuoge has not invested in these technologies. The additional investment required to acquire these processing technologies is too costly to meet the desired objectives of generating profits for the company.

**Table B4:** a sample of frankincense essential oil prices ($/5ml) available on the web (2004).

| Company | Frank-oil | Frank_oil ($/5ml) |
|---|---|---|
| | | |
| Alexader essentials | £6.85/5ml | 11.96 |
| Aroma Land | 49.92/oz | 8.8 |
| Aroma therapy | 7/5ml | 7 |
| E-scent-ials | 21.25/oz | 3.75 |
| Essential7 | 17.24/oz | 3.04 |
| Goholistic | 5.99 pound/5ml | 10.46 |
| Health quest international | 65/15ml | 21.67 |
| Lifetree Aromatix | 25/6ml | 20.83 |
| Nature's gift | 12/5ml | 12 |
| NexTag | 11/4ml | 13.75 |
| Scents of earth | 15/10ml | 7.5 |
| Soothing essentials | 14/5ml | 14 |
| Standing horse | 14/5ml | 14 |
| Soulhealer | 13.95/5ml | 13.95 |
| Alohaholistic | 73/15ml | 24.33 |
| One planet | | 6.63 |
| | Sum | 193.67 |
| | Avg | 12.10438 |

Some wholesalers carry out value-added processing steps that create two top grade products that fetch high prices in specialized markets. Under normal circumstances these high priced grades are sold as fusoos, but occasionally they are reprocessed into fusoos-awal (1$^{st}$ grade nuggets) and fusoos (2$^{nd}$ grade nuggets). The difference between the two

grades is minimal and less conspicuous to the average trader, but the most distinguishing characteristic is the shape, size and general structure of the nuggets. Fusoos-awal have slightly larger, more oval shaped nuggets than fusoos.

Value adding processes expand the range of products developed from luban and the opportunity to bring new high valued products into the market. Although this is a useful component in accessing new markets and increasing the demand for this important gum-resin, it has the potential to create an influx of new harvesters seeking to make a living in luban production, thus increasing the pressure on available resources. However, with proper management and planning, the economic utilization of this NTFP can be sustained while safeguarding the environment.

### B.6.4 IMPORT AND EXPORT

Long standing trade and family ties between Omani citizens of Somali heritage (Omani-Somalis) in Dhofar and their kin in Somalia have been instrumental in enabling the former to enjoy near exclusive control over the import of frankincense from Somalia's Bari region. Although a significant portion of these imports are transshipped to other countries via Oman, the government of Oman's export data do not indicate the portion exported to international markets. The low levels of Omani frankincense export and the projected frankincense production levels of this study indicate that the bulk of Omani frankincense is consumed locally.

Wholesalers and PAMAP control the import and export of frankincense. Omani wholesalers of Somali origin are major players in the frankincense economy and dominate the importation of frankincense from Somali. Approximately 83% (28910 kg) of all documented frankincense imports between 1993 and 2000 originated from Somalia with a total value of 20,710 RO ($54,500). During the same period, the United Arab Emirates (UAE) was the biggest frankincense importer from Oman, accounting for 81.5% (28,523 kg) of Oman's luban export trade valued at 81,418 RO ($214,257).

PAMAP is the primary agency responsible for maintaining the delivery of authentic frankincense products to its local and international customers. A trust-based system between the harvester, wholesaler and PAMAP ensures that an authentic Omani product is delivered to PAMAP. Although this long standing trust-based relationship strengthens resin quality control measures, a reliable product testing mechanism at the forest gate certifying the point of origin would be more beneficial to the NTFP industry. Even though wholesalers perform their own quality control tests to differentiate and separate various brands of frankincense based on smell, color and shape, all wholesalers and producers do not adhere to this practice. Some wholesalers and producers engage in luban blending across grades and across brands, often passing off a low grade resin as a higher priced product. The percentages of the constituents in the blend often depend on the target market, experience of the buyer(s) and the prevailing market price. Luban brand-mixing (i.e. Somali and Omani types) is more frequent in products destined for international markets but less common in products consumed locally.

Although PAMAP is the sole agency that has authority to provide government sanctioned certificate of authenticity for its frankincense products, the procedure needs to be expanded to cover wholesalers and producers. The current arbitrary testing system based on the word of the seller alone needs to be replaced with a more reliable and standardized certification procedure such as adhering to sustainable harvesting methods and authenticating the time and place of production. Obtaining certification may present important benefits to NTFP producers and the industry alike (Laird and Guillén 2002). In the absence of government subsidies, however, the added cost of the certification process might outweigh the benefits small-scale migratory producers derive from the harvest.

The import of frankincense into Oman increases the available supply in local markets, weakens the value local harvesters can charge for their product and increases the livelihood risk of the harvesters. In order to minimize potential risks to their livelihood, harvesters increase their production level by spending longer hours in the field or illegally harvesting additional frankincense groves outside the rented area. Low market value also discourages potential harvesters from seeking employment in the luban-industry and in some instances harvesters switch to livestock herding and reduce the number of rental fields they acquire to minimize the cost of renting. Fewer harvested fields coupled with lower harvester numbers often lead to decreased production that minimizes potential risk to *B.sacra*. Moreover, imports indirectly contribute to the sustainable use of this NTFP in Oman because it induces harvesters to adopt alternative

livelihood strategies other than luban harvesting. When the unintended consequences of this strategy take frankincense groves out of production, *B.sacra* groves become less prone to harvesting related risks.

### B.6.5 GRADING FRANKINCENSE

Harvesters utilize grading to categorize their gum-resin based mainly on the area it was harvested. Grading is part of an intricate process that enables harvesters and other industry players to obtain favorable pricing for their NTFP. Although this processing system plays an important role in increasing product value and marketability, it also serves as a quality control measure against luban adulteration.

As already noted, Omani frankincense is produced in one of four areas: Hojar, Nejd, Shazr and Sha'b. Hojari luban extracted from Hojar is the most desired followed by Nejdi then Shazri with Sha'bi being the least preferred product. Categorizing frankincense into various grades often involves an arbitrary process using a naming convention associated with a specific zone of production. The shaded luban grades in Table B5 are listed from high to low and are the accepted grading categories in Oman. However, similar grade name utilization across processing entities such as harvesters, wholesalers, retailers and PAMAP is not indicative of equivalent product quality.

**Table B5:** Frankincense grades and respective value per kilogram at five processing outfits. Value based on 1999 field-data.

| Grades | Harvester | Wholesaler | Retailer | PAMAP | Amouge |
|---|---|---|---|---|---|
| Value | ($/kg) | ($/kg) | ($/kg) | ($/kg) | |
| raw | 2.19 | 3.07 | 5.26 | X | |
| pre-processed | 5.7 | 8.3 | | | |
| fusoos | | 15.79 | | | |
| hojari | | 3.51 | 7.89 | 46.05 | |
| nejdi | | 3.51 | 6.58 | 13.15 | |
| shazri | | 3.07 | 3.95 | 5.26 | |
| shabi | | | | | |
| naim | | | | 3.16 | |
| powder | | | | X | |
| Silver frankincense | | | | | X |

Harvesters, in general, group their harvest into raw and preprocessed grades. The former is mixture consisting of all possible grades, but the later is equivalent to fusoos also known as fusoos-hojari or fusoos-nejdi which is the best luban grade in Oman. Although the preprocessed product might originate as Hojari, Nejdi, or Shazri, it is almost always marketed as fusoos-hojari if the luban nuggets have the Hojari look. Hojar or Habjar is a specific *B.sacra* habitat that is known to produce the best frankincense in Oman . Thus associating ones harvest with that area enhances its market value.

Wholesalers and retailers also classify their resin into Hojari, Nejdi, Shazri, Sha'abi. However, wholesalers have an additional category of higher grade frankincense known as fusoos which is occasionally subdivided into higher-grade (fusoos) and highest-grade (fusoos-awal) categories. Sha'bi is seldom harvested at the present time and is neither

popular nor widely available in the market. For the most part, brown and dark luban nuggets from all harvesting zones are combined and sold as Shazri or Sha'bi.

PAMAP maintains a grading system consisting of the following six classes: Hojari, Nejdi, Shazri, Naim, Powder and Raw. While harvester, wholesaler and retailer describe Raw grade as indicative of unprocessed frankincense, PAMAP's Raw represents a mixture of the least desirable luban after processing. The two lowest grades powder and raw, respectively, are not sold but used for in-house processing such as the manufacture of kuhul.

Although the dark or brown color tones are associated with the Shazri and Sha'bi resin, even the high priced Hojari exudates turn black when harvested in the cold winter season. Resin color also changes as the season progresses with the end harvest producing an inferior darker tone colors. Even though the effect is temporary, rain during the harvest season also causes the luban trees to produce black and deep brown resins.

Grading is a significant value adding process but the lacks of standardization and authentication processes complicates comparing this NTFP across processing units such as harvesters, wholesalers, retailers and government agencies. Although the naming convention associated with luban grading is retained, there is considerable luban blending across the zones of production during the processing stages. Value enhancements as a

result of improved grading and certification has the potential to make luban more profitable and sustainable.

## B.7 CONCLUSION

Frankincense/luban is a NTFP that plays an important role in the economy and culture of Dhofar. Luban production and processing are sustainable because the numbers of harvesters are very low to have a detrimental impact. In addition, the owner's threat to suspend group harvesting rights, who engage in harmful gum-resin extraction methods, is an effective management tool that fosters self- monitoring among harvesters. Since harvesters depend on frankincense to maintain their livelihood, work parties exercise considerable self-policing that encourages sustainable low impact harvesting methods in order to protect group usufruct rights.

There are large tracts of protected reserves (JSNR) that contain about 60% of the two most important luban habitats (Hojari/Nejdi) but these areas lack active management plans. JSNR was set up by Sultan Qaboos by Royal Decree 48/97 (in 1997) and could prove to be instrumental in the sustainable conservation and management of *B.sacra* and other natural resources in the reserve.

Documenting migrant workers and providing them work authorization papers will legalize the harvesting process, and stabilize the NTFP workforce, thus reducing abuse by and against harvesters. Similarly, standardized resin classification and certification at the wadi of origin or forest gate will enable local harvesters to authenticate and enhance the grading, marketability and profitability of their frankincense. If current low harvester numbers, and minimal human settlements, coupled with restricted grazing trends in JSNR

are maintained, the extraction of this NTFP for its economic value appears to be sustainable

Luban production is sustainable within its current configuration. However some of the things that might make it more socially just (i.e., legalizing Somali harvesters) and potentially more profitable to all involved (i.e. better grading/documenting origin/overseas markets) could both threaten the sustainability because it would (a) make it more profitable, and hence (b) increase pressure by encouraging more (legal) Somali tappers.

## B.8 REFERENCES

Al-Hatrushi, S. M. 1989. Rangeland Degradation: The Case of the Southern Region in the Sultanate of Oman. U.M.I, Ann Arbor.

Al-Qassani, A. S. 1980. *Dhofar ard al-luban* [Dhofar the land of frankincense]. Almatabi Al-Almiyah, Ruwi, Sultanate of Oman.

Arnold, M. J. E., and Pérez, R. M. 2001. Can non-timber forest products match tropical forest conservation and development objectives? *Ecological Economics* 39:437-447.

Bevilacqua, Maria., Bevilacqua, Matteo., Serra, E., Vianello, A., Garrou, E., Sparangna, B., Barale, U., and Zaccagna, C.A. 1997. Natural resin association such as incense and Propolis in zootechnology. *Agriculture Ecosystem and Environment*. 62:247-252.

Broekhoven, G. 1996. *Non Timber Forest Products: Ecological and Economic Aspects of Exploitation in Colombia, Ecuador and Bolivia*. IUCN, Gland, Switzerland, pp 11.

Campell, B., Frost, P., Goebel, A., Stuunda-Gunda, W., Mukamuri, B., and Veeman, M. 2000. A conceptual model of woodland use and change in Zimbabwe. *International Tree Crop Journal* 10(4):347-366.

Chambers, R. 1994. The origin and practice of participatory rural appraisal. World Development 22(7):953-969

Chege, N. 1994. Africa's non timber forest economy. World Watch, pp.19-23.

Chopra, K. 1993. The value of non-timber forest products: an estimation of tropical deciduous forests in India. *Economic Botany* 47(3), 251-257.

FAO 1995. *Trade Restrictions Affecting International Trade in Non-wood Forest Products: non-wood forest product 8*.

Farah, A.Y. 1994. The Milk of Boswellia Forests: Frankincense Production among Pastoral Somali. Reprocentralen HCS, Uppsala

Gallagher, M. 1977. The Oman flora and fauna survey, 1977 (Dhofar). *Journal of Oman Studies*, 3:1 9-13.

Ghazanfar, S. 1998. Vegetation of the plains. In S. A. Ghazanfar and M, Fisher (eds.), *Vegetation of the Arabian Peninsula*, Klumer Academic Publishers, Netherlands, 175-190.

Godoy, R., and Feaw, T.C. 1989. The profitability of smallholder rattan cultivation in Borneo. *Human Ecology* 7:397-420.

Godoy, R., and Lubowski, R. 1992. Guidelines for the economic valuation of non-timber forest products. *Current Anthropology* 47(3):423-433.

Godoy, R., Lubowski, R. and Markandya, A. 1993. A method for the economic valuation of non-timber tropical forest products. *Economic Botany* 47(3), 220-233.

Gould, K., Howard, A.F., and Rodriguéz, G. 1998. Sustainable production of non-timber forest products: Natural dye extraction from El Cruce Dos Aguadas, Petén, Guatemala. Forest Ecology and Management 111:69-82.

Gram, S. 2001. Economic valuation of special forest products: an assessment of methodological shortcomings. *Ecological Economics*. 36:109-117.

G.R.M. 1982. *Range and Livestock Survey*. Final Report, GRM International Pty Ltd. Brisbane.

Groom, N. 1981. *Frankincense and Myrrh: a Study of the Arabian Incense Trade*. Longman, London pp 16.

Guba, I. and Glennie, K. 1998. Geology and geomorphology. In S. A. Ghazanfar and M, Fisher (eds.), *Vegetation of the Arabian Peninsula*, Klumer Academic Publishers, Netherlands, 175-190.

Gunatilake, H.M, Senaratne, D.M.A.H., and Abeygunawardena, P. 1993. Role of non-timber forest products in the economy of peripheral communities of Knuckles National Wilderness Area of Sri Lanka: a farming system approach. *Economic Botany*. 47(3):275-281.

Jansen, J. 1986. *Nomads in the Sultanate of Oman: Tradition and Development in Dhofar*. Westview Press, London.

Kant, S. 1997. Integration of biodiversity conservation in tropical forest and economic development of local communities. *Journal Of Sustainable Forestry*. 4(1-2):33-61.

Laird, S. and Guillén, A. 2002. Marketing issues. In P. Shanley, A. Pierce, S. Laird, and A. Guillén (eds), Tapping the Green Market: Certification and Management of Non Timber Forest Products, Earthscan Publication Ltd, London, 322-336.

Larsen, H.O., Olsen, C.S., and Boon, T.E. 2000. The non-timber forest policy process in Nepal: actors, objectives and power. *Forest Policy and Economics*. ??( ), 267-281.

Mahapatra, A., and Mitchell, C.P. 1997. Sustainable development of non-timber forest products: implication of forest management in India. *Forest Ecology and Management*. 94:15-29.

Miller, A.G. and Morris, M. 1988. Plants of Dhofar: *The Southern Region of Oman Traditional, Economic and Medicinal Uses*. The Office of the Adviser for Conservation of the Environment, Diwan of Royal Court, Sultanate of Oman

Narendran, K., Murthy, I.K.,Suresh, H.S., Dattaraja, H.S., Ravindranath, N.H., and Sukumar, R. 2001. Non-timber forest product extraction, utilization and valuation: a case study from the Nilgiri Biosphere Reserve, southern India. *Economic Botany*. 55(4):528-538.

Padock, C., and de Jong, W.D. 1989. Production and profit in agroforestry: an example from the Peruvian Amazon. In J.G. Browder (ed), *Fragile Lands of Latin America: Strategies for Sustainable Development*. Westview Press, Boulder, pp. 102-113.

Peters, C. M., Gentry, A. H., and Mendelsohn, R.O. 1989. Valuation of an Amazonian rainforest. *Nature* 339(6627): 655-656.

Phillips, W. 1966. Unknown Oman. David McKay Company Inc., New York.

Prance, G., Balee, W., Boom, B. M., and Carneiro, R. L. 1987. Quantitative ethnobotany and the case for conservation in Amazonia. *Conservation Biology* 11(4): 47-68.

Schwartzman, S. 1989. Extractive reserves in the Amazon. In J.G. Browders (ed), *Fragile Lands of Latin America: Strategies for Sustainable Development*. Westview Press, Boulder, pp. 150-163.

Shackleton, C.M. 2001. Re-examining local and market-oriented use of wild species for the conservation of biodiversity. *Environmental Conservation*. 28(3):270-278.

Shanley, P. and Laird, S.A. 2002. The process of drafting and revising guidelines for NFTP certification. In P. Shanley, A. Pierce, S. Laird, and A. Guillén (eds), *Tapping the green market: certification and management of non timber forest products*, Earthscan Publication Ltd, London 20-27.

Skankar, U, Murali, K.S., Shaanker, R.U., Ganeshaiah, K.N., and Bawa K.S. 1996. Extraction of non-timber forest products in the forests of Biligiri Rangan Hills, India. 3. Productivity, extraction and prospects of sustainable harvest of Amla, *Phyllanthus emblica* (Euphorbiaceae). *Economic Botany* 50:270-279.

Svoboda, K.P., Hampson, J.B., and Hall, L. 2001. Boswellia from Somalia, a source of high quality frankincense. *Medicinal Plant Conservation* 7:16-19.

Tewari, D., and Campbell, J.Y. 1995. Developing and sustaining non-timber forest products: some policy issues and concerns with special reference to India. *Journal of Sustainable Forestry* 3(1): 53-79.

Tewari, D. 1999. Income and employment generation opportunities and potential of non-timber forest products (NTFP): A case study of Gujarat, India. *Journal of Sustainable Forestry* 8(2): 55-76.

Tewari, D. 2000. Valuation of non-timber forest products (NTFP): Models, problems and issues. *Journal of Sustainable Forestry* 11(4):47-69.

Thadani, R. 2001. International non-timber forest product issues. In M. R. Emery and R.J. McLain (eds.), *Non-Timber Forest Products: Medicinal Herbs, Fungi, Edible Fruits and Nuts, and Other Natural Products from the Forest*. Food Products Press, Binghamton, NY, pp 5-23.

Wilkie, D.S. and Curran, B. 1991. Why do Mbuti hunters use nets? Ungulate hunting efficiency of archers and net-hunters in the Ituri rain forest. *American Anthropologist*. 93(3):680-689.

http://www.fao.org/forestry/foris/webview/forestry2/index.jsp?siteId=1141&langId=1

http://www.mrmewr.gov.om/naturjebel.htm

# APPENDIX C. THE EFFECT OF LAND USE ACTIVITIES ON ARIDLAND RESOURCES: ASSESSING THE IMPACT OF HARVESTING, GRAZING AND LAND CONVERSION ON BOSWELLIA SACRA REGENERATION AND CONSERVATION.

Farah, Mohamud H.

Office of Arid Land Studies

University of Arizona, Tucson, Arizona 85719

## C.1 ABSTRACT

This study examines the distribution of Boswellia sacra in its area of endemism in the Sultanate of Oman. The distribution describes the occurrence of *B.sacra* within ecological zones based on a local classification scheme in the province of Dhofar. This study postulates that land use activities such as land conversion, frankincense harvesting and livestock browsing are the major factors affecting *B.sacra* regeneration. The interaction between land use impacts and the biological systems can lead to the instability, fragmentation or extinction of local populations. *B.sacra* is primarily a single or multiple stem shrub restricted to wadis in arid environments on the northern rain-shadow zones of the Dhofar Mountains. Although *B.sacra* may be less than 2m tall at the upper elevation limits of its habitat, in each zone of occurrence, it can reach a height of up to 8m in favorable sites. The elevation range of *B.sacra* varies depending on location but it can be found at 60m above sea level in Wadi Adonib (Jarbeeb) and 1,770m above sea level in Wadi Kharish (a branch of Wadi Qobyr in Jabal Samhan).

Propagation trials of *B.sacra* were undertaken to assist in the reestablishment of *B.sacra* in its natural habitats and reclaiming fragmented habitat. Even though germination rates were very low, seeds soaked overnight before planting had better germination rates than seeds that were scarified. Untreated seeds had the lowest rates of germination. Seeds maintained at 25C had the lowest germination rate of any temperature treatment. Trees taller than 3.5m with extensive root systems are less susceptible to mortality from grazing effects if the bark of major stems and branches remains intact. Trees shorter than camel height (< 3m) tend to be more vulnerable to mortality from browsing. Conversely, larger trees are more vulnerable to the detrimental effects of harvesting because of their ability to produce sustained quantities of resin; smaller trees are less productive and thus less vulnerable to mortality from harvesting. Gravel mining operations are threatening isolated *B.sacra* stands near gravel strip mining activities in Wadi Adonib and Wadi Dowkah. Radiocarbon dating results did not correlate well with tree height. Seven samples (36.8%) were dated as post-atomic bomb era (53 yrs or younger) and the remaining 12 samples (63.2%) ranged from 68-457 years old. These findings confirm *B.sacra* regeneration.

Regardless of the ecological zone, frankincense trees on easily accessible flat or gently sloping terrain are susceptible to stress and mortality from harvesting, browsing and mining while trees on cliffs and steep slopes are least vulnerable to the effects of these land-use activities.

## C.2 INTRODUCTION

Boswellia sacra is a resinous plant endemic to specific habitat zones in northern Somalia, southern Yemen and southern Oman. The xerophytic genus Boswellia has its principal center of endemism in northeastern Africa, southern Arabia and Socotra (Engler 1915, Mies et al 2000). *B.sacra*, locally known as *meqerot* and luban, produces frankincense and is without doubt the most famous plant in the province of Dhofar. However, increased animal and human activities in the *B.sacra* habitats contribute to land use changes that heighten the vulnerability of this plant and the vegetation assemblage in which it occurs. The continuous production and exploitation of frankincense habitat for various uses, such as increased surface gravel mining operations in streambeds and high livestock numbers, will require the formulation of land-use management and revegetation strategies that reduce vegetation vulnerability and contribute to the regeneration and conservation of *B.sacra* in southern Dhofar.

The mountainous regions of Jabal Qamar, Jabal Qara and Jabal Samhan, along the southern coast of Oman, have the highest rainfall in Dhofar and thus contain the richest fauna and flora in the province. Consequently, most human settlements and livestock grazing are concentrated in and around these three mountains thus intensifying the pressure on their fragile environments. Although these mountains form a single range, they vary in height, and they differ in orientation and proximity relative to the coast. These differences create a number of microclimates and ecological zones that condition the type of vegetation that they contain. In turn, these patterns have shaped settlement patterns and the routes of nomadic migration systems, but current stocking rates and land

use practices appear now to exceed what the land can support without degrading the resource base.

Jabal Samhan is drier and less vegetated than either Jabal Qamar or Jabal Qara because its coastal escarpment faces southeast and moisture-laden winds from the southwest tend to move parallel to its face and thus yield little precipitation (Miller and Morris 1988). Because of this condition, indigenous ecological classification schema place Jabal Samhan in a unique ecological zone category (Al-Shahri 1994). In contrast, Jabal Qamar and Jabal Qara face south and force the moisture-laden southwestern monsoon winds to rise and yield precipitation. While Jabal Qamar occupies a narrow belt and rises precipitously from the coast in a straight line along the shore, Jabal Qara is wider, has higher rainfall and forms an arc around the coastal plains of Salalah (Jarbeeb). As a result, Jabal Qara has a wider range of vegetation distribution, denser human settlement and more livestock concentration than Jabal Qamar and Jabal Samhan.

Dhofar has a rich vegetation diversity and species richness which are floristically more similar to what is found on the island of Socotra (Yemen) and the drier regions of Northeast Africa than those regions found in northern Oman (Miller and Morris 1988). Most of this rich flora is restricted to the mountain range belt and adjoining zones that are approximately 40km at their widest extent and about 240km long from Hasik in the east to the Oman/Yemen border on the west. The mountains of Dhofar form a raised plateau reaching an elevation of 2,000m in the south and dipping to the north beneath the sand

dunes of Rub' al Khali (Guba and Glennie 1998). As the Dhofar mountain-range slopes north, the aridity increases and vegetation becomes sparse (Phillips 1966). The seaward facing southern aspect is characterized by cliffs, slopes and wadis covered in thickets of drought–deciduous woodlands (Gallagher 1977). Climatic, human and animal induced land-use and land-cover changes are exerting more pressure on the environment and threaten the rich vegetation diversity in Dhofar.

The Sultanate of Oman instituted initiatives to set up nature reserves to protect the environment and natural resources. The majority of these initiatives were instituted in the late 1980's and culminated with the establishment of the Directorate General of Nature Reserve (DGNR) in 1991. DGNR is responsible for nature conservation inside and outside the reserves (Fisher et al. 1998). Jabal Samhan Nature Reserve, established in 1997 with Royal Decree no.48/97, covers 4500 km² and contains most of the *B.sacra* habitats in the Samhan Nejd (Fisher et al. 1998). It is one of the most important conservation reserves in Oman.

Boswellia sacra studies in the Sultanate of Oman are few. Most studies address the traditional, historical and cultural uses of frankincense (Groom 1981; Philips 1966; Thomas 1937; Al-Shahri 1994). Although *B.sacra's* habitat-range in northern Somalia extends from 700m-1,230m (Thulin and Warfa 1987), little is known about the elevation limits of this shrub in Dhofar. Even though most studies in Oman agree that *B.sacra* is not known to occur in the moist windward slopes of the Dhofar Mountains, Phillips

(1966) claimed to have found *B.sacra* on the seaward facing slopes of Jabal Qara. While this assertion might have given credence to earlier mistaken assumptions about *B.sacra* association with high rainfall areas, *B.sacra* is endemic to specific arid habitats in Dhofar (Miller and Morris 1988; Al-Ghassani 1980; Thomas 1931; Groom 1981; Farah 1994).

Carter (1846) provided the first classification of Boswellia in Southern Arabia as *Boswellia serrata*. Flueckiger (1867) properly reclassified Carter's sample as *B.sacra*. Birdwood's (1869) follow up study shed more light on the classification of Boswellia. Thomas (1931) gave the first detailed description of the plant, as well as describing the people who use it and the arid nature of *B.sacra* habitat. Thulin and Warfa's (1987) seminal taxonomic study focused on the indigenous and scientific classifications of Arabian and Somali Boswellia and determined that the Arabian frankincense trees belonged to *B.sacra* while the Somali species consisted of *B.sacra* and *Boswellia frerena*. Miller and Morris (1988) reached similar conclusions after an extensive study of the plants of Dhofar. Although there is general consensus that Oman's Boswellia belong to *B.sacra* species, some remote habitats have not been studied nor definitively classified.

B. sacra propagation has potential for future domestication, commercialization and habitat rehabilitation strategies in Dhofar. Unfortunately, *B.sacra* propagation trials in Oman are limited to ad hoc forestry germination trials in Salalah. However, there has been *B.sacra*, *Boswellia papyrifera* and *B.serrata* propagation trials in other countries. Khan (1972) propagated *B.papyrifera* from branch cuttings in Ethiopia. Barbier's three-

pronged approach included running propagation trials from seedlings, cutting and tissue culture (Barbier 1984). Hoffman (1986) propagated three *B.sacra* cuttings imported from Oman in the Brooklyn Botanical Garden with great success. Tilahun (2001) carried out *B.papyrifera* seed germination studies both in the field and in a laboratory in Western Tigray (Ethiopia).

There are major similarities between the various traditional harvesting and collection methods of frankincense practiced in Somalia (Farah 1994); Oman (Al-Ghassani 1980); Southern Arabia (Groom 1980; Phillips 1966; Thomas 1931); Ethiopia (Tilahun 2001; Mulugeta, et al. 2003) and India (Sarin et al. 1982). The emergence of seed harvesting for commercial purposes in conjunction with tapping has the potential to influence population dynamics and *B.sacra* regeneration. In addition to the benefits derived from frankincense, extraction practices associated with this Non Timber Forest Product (NTFP) can have undesirable economic consequences for sustaining livelihoods, and detrimental ecologic consequences for the environment if it is not managed properly. Within these ecosystems, harvesters depend on frankincense extraction and nomads depend on livestock husbandry for their livelihoods. Similarly, gravel industry owners and workers rely on gravel mining, in stream channels near or in *B.sacra* habitats, for their economic wellbeing. Therefore, it is important to study the effects of these competing land-use activities on *B.sacra*.

There are various studies on the effects of livestock grazing in Dhofar (Chatty 1996; Al-Kathiri 1996; Seif El Din 1990; El Samani 1990; Jensen 1986; GRM 1982), but there are no studies targeted on the effect of livestock browsing and frankincense (luban) harvesting on *B.sacra*. Similarly, the effects of gravel mining activities near *B.sacra* fields have not been addressed, not much is known about *B.sacra* stand age structures and there are no studies on the state of *B.sacra* regeneration and conservation in Oman.

*B.sacra* habitat degradation associated with land-use change is a major concern in the Sultanate of Oman. Given this concern and the limited research on the topic, this research project has sought to:

5. Document the current distribution of *B.sacra* in Dhofar.
6. Investigate land-use activities affecting *B.sacra*
7. Assess the impact of human and animal activities on the regeneration of *B.sacra*.
8. Address the prospects for the propagation and conservation of *B.sacra*.

## C.3 STUDY AREA

This study was conducted in the province of Dhofar in the Sultanate of Oman. Dhofar is the southern-most province in Oman bordering Yemen on the west, Saudi Arabia on the north and the Indian Ocean on the south. The province covers an area about 99,210 square kilometers between approximately latitudes 16º north to 21º north, and longitudes 51º east to 56º east. Dhofar is the largest of the eight provinces of Oman. It represents

about 32 percent of Oman's total area and consists of nine administrative districts, six of which are concentrated in the three mountain ranges along the southern coastal area of the province (See Map1).

The primary focus of this study is on *B.sacra* habitats in the province of Dhofar. In Dhofar, *B.sacra's* area of endemism is located in ecological zones on the arid leeward side of Qamar, Qara and Samhan mountains known locally as Nejd. *B.sacra* is also endemic to pockets of fragmented habitats in the Jarbeeb (coastal plains), and in isolated sections of seaward facing slopes south of the Kharish and Harkak mountain passes in Jabal Samhan. Although these mountain passes are the ancient frankincense caravan routes to the coastal ports of Mirbat and Sadh, they are still in use and serve as the primary access routes for human and animal migration. *B.sacra* habitats are predominantly found in arid areas beyond the reach of monsoon rains (Miller and Morris 1988) and are often limited to wadi channels that drain the higher, moister mountains.

### C.3.1 ECOLOGICAL ZONES:

There are several classification schemes for the ecological zones of Dhofar that range from coarse (landscape) to fine (site). Jansen (1986) classified Dhofar into three broad ecological zones – coastal plain (*sahil*), highlands (*jabal*), and desert (*badiyah*)- based largely on topography. Al-Hatrushi (1989) took an approach similar to Jansen but reclassified the desert zone into desert (*sahra*), gravel plain and sand desert (*rimal*-also called the Empty Quarter or Rub-al-khali in Arabic). Traditional classifications are often

vegetation-based and tend to have finer categories ranging from 7-14 ecological zones. For example, a 1982 study commissioned by the Ministry of Agriculture and Fisheries classified the region into 14 distinct regions based on the availability of animal forage (GRM 1982); while, Miller and Morris (1988) took traditional categories and reconstituted them into 7 vegetation physiognomic-based classes. This research project adopted Miller and Morris's approach and used a local ecological zone classification that categorizes Dhofar into (1) *jarbeeb*-coastal plains (2) *jabal*-woodland and grassland zone (3) *qatan*-shrubland/grassland plateau (4) *nejd*-arid shrubland (5) *sahra*-desert (6) *rimal*-sand dunes/Empty Quarter and (7) *sololat*/Jabal Samhan (Sharqiya)-which consists of zones similar to 1,2,3 and 4 (Al-Shahri 1994) when considering the ecological distribution of *B.sacra* and the state of this vegetation in Dhofar.

**Table C1:** Ecological zone classification of Dhofar by four researchers

| Class | Al-Shahri | Miller/Morris | Jensen | Al-Hatrushi |
|---|---|---|---|---|
| 1 | *Jarbeeb* | Coastal Plain (4 sub-classes) | Coastal plain (*sahil*) | Coastal plain |
| 2 | *Jabal* | Foothills | Highlands (*jabal*) | Dhofar highlands |
| 3 | *Qatan* | Escarpment (2 sub-classes) | Desert (*badiyah*) | Desert Pavement |
| 4 | *Nejd* | Dry plateau | | Gravel Plain |
| 5 | *Sahra* | North-facing cliffs | | Sand desert |
| 6 | *Rimal* | Desert | | |
| 7 | *Sololat*/ Jabal Samhan | Jabal Samhan | | |

Source: complied from classification schemes by Al-Shahri 1994, Miller and Morris 1988, Jensen 1986, and Al-Hatrushi 1989.

The primary focus of this study is on *B.sacra* habitats in stream channels (wadis) located in Jarbeeb, Nejd and Sharqiya ecological zones. In order to highlight the spatial association between each mountain (Jabal) and its respective *B.sacra* habitat, this study reclassified the Nejd ecological zone into Qamar Nejd and Qara Nejd. Similarly, Sharqiya was categorized into Samhan Nejd and Seaward zones (Figure C3). The Seaward facing area consists of the Sadh/Mirbat coastal plain, Jabal Qinqir and the southern aspect of Jabal Samhan. Samhan Nejd encompasses the north and east draining wadis north of Jabal Samhan. The main wadis of interest in Samhan Nejd were Qobyr, Ndur, Arah, and Sanwik even though sections of other wadis such as Takbiat, Kaifar, and Dahnat were visited. Qara Nejd, situated north of Jabal Qara, consists of wadi Dowkah

and Wadi Iyun. In the case of Iyun, scattered trees of *B.sacra* along the road between Iyun spring and Qairoon Hiraiti were considered for sampling and evaluation. The Qamar Nejd study area consists of Afol and Maqsail wadis, north of Jabal Qamar, that drain into the sea. The Jarbeeb study area consists of Wadi Adonib, Wadi Raysut and their tributaries in the coastal plain west of Salalah.

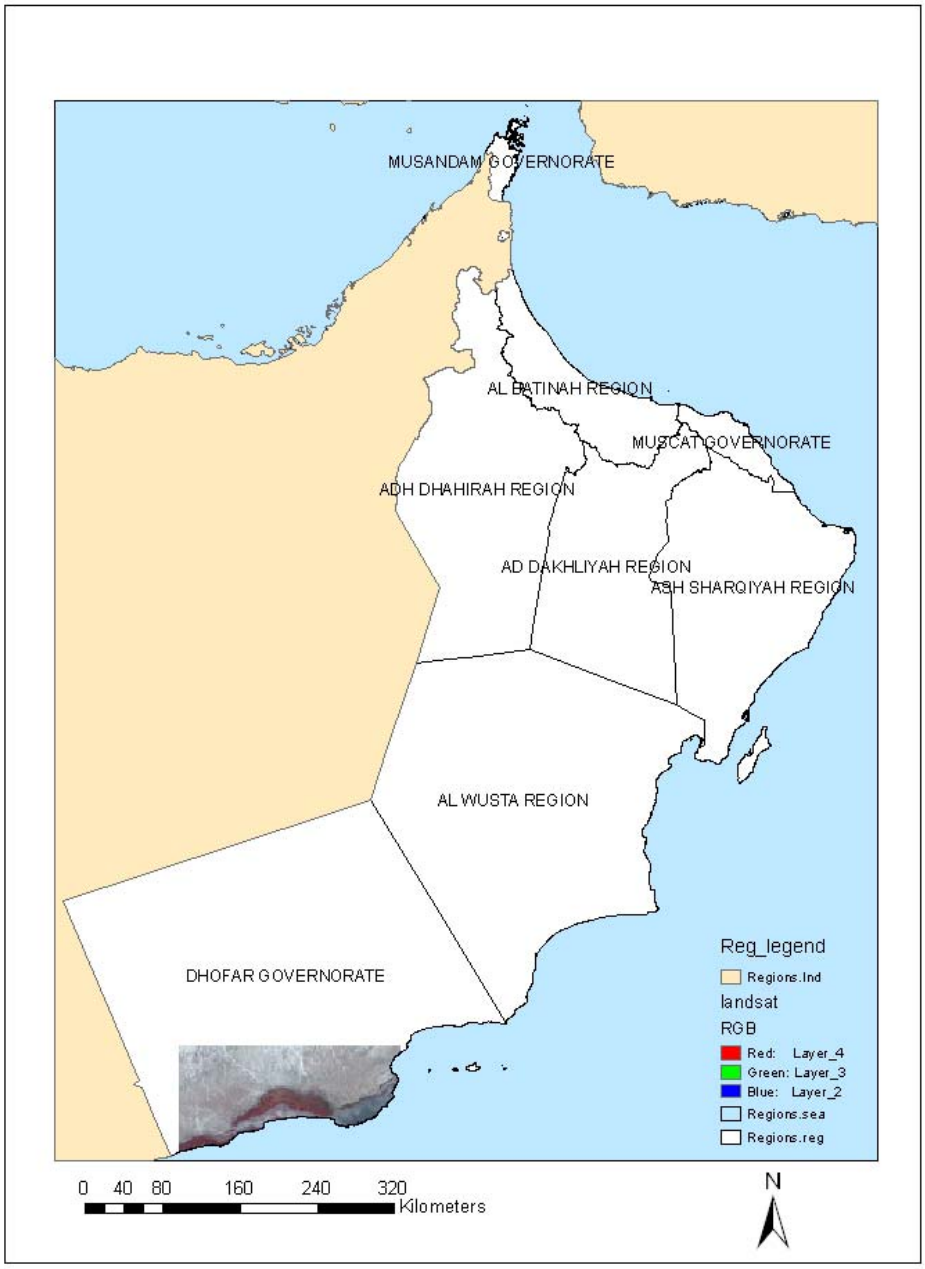


**Figure C1:** The eight provinces (*wilayat*) of the Sultanate of Oman. The false color composite satellite image inset shows the Dhofar mountain range and adjoining habitat areas considered in this study.

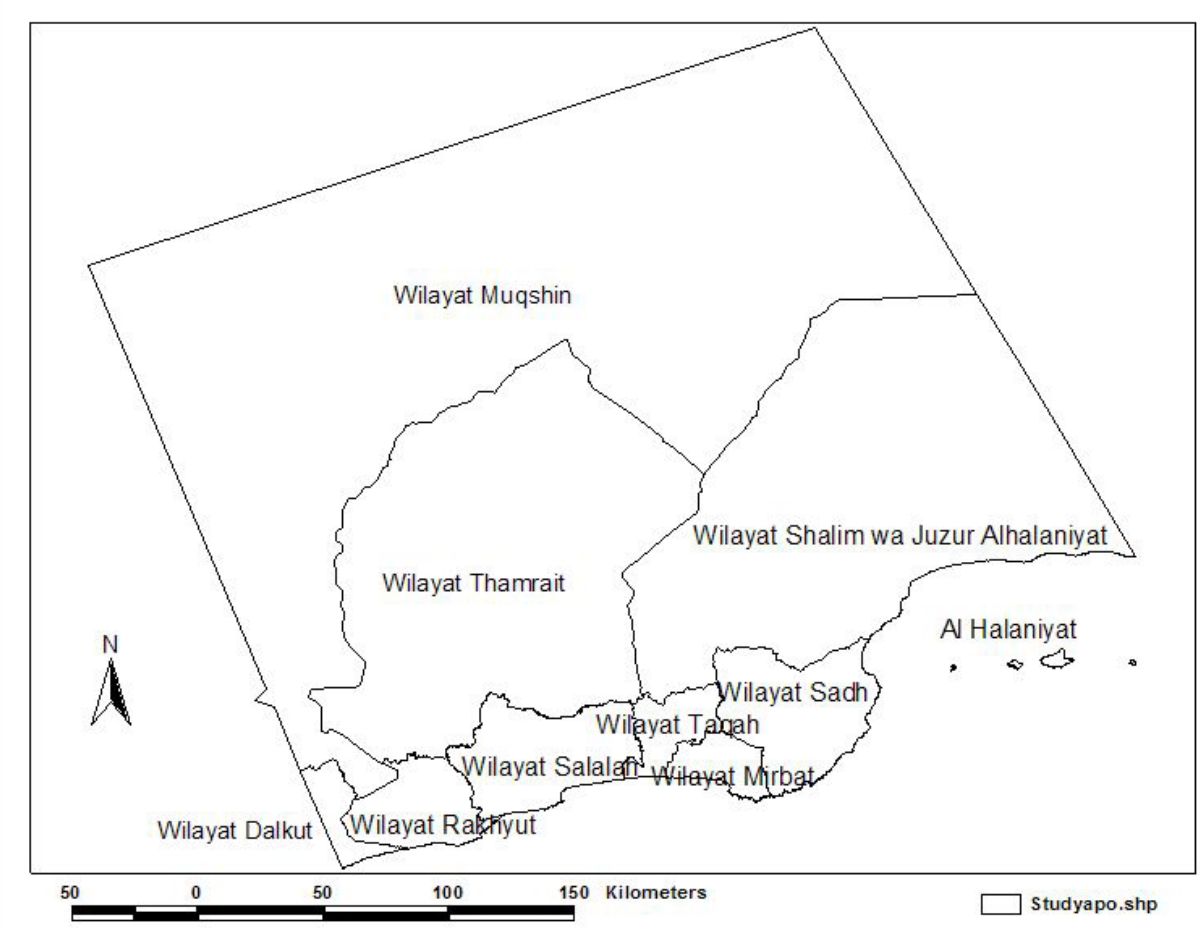


**Figure C2:** Governate of Dhofar showing the nine wilayat (provincial districts) and Halaniyat Island.

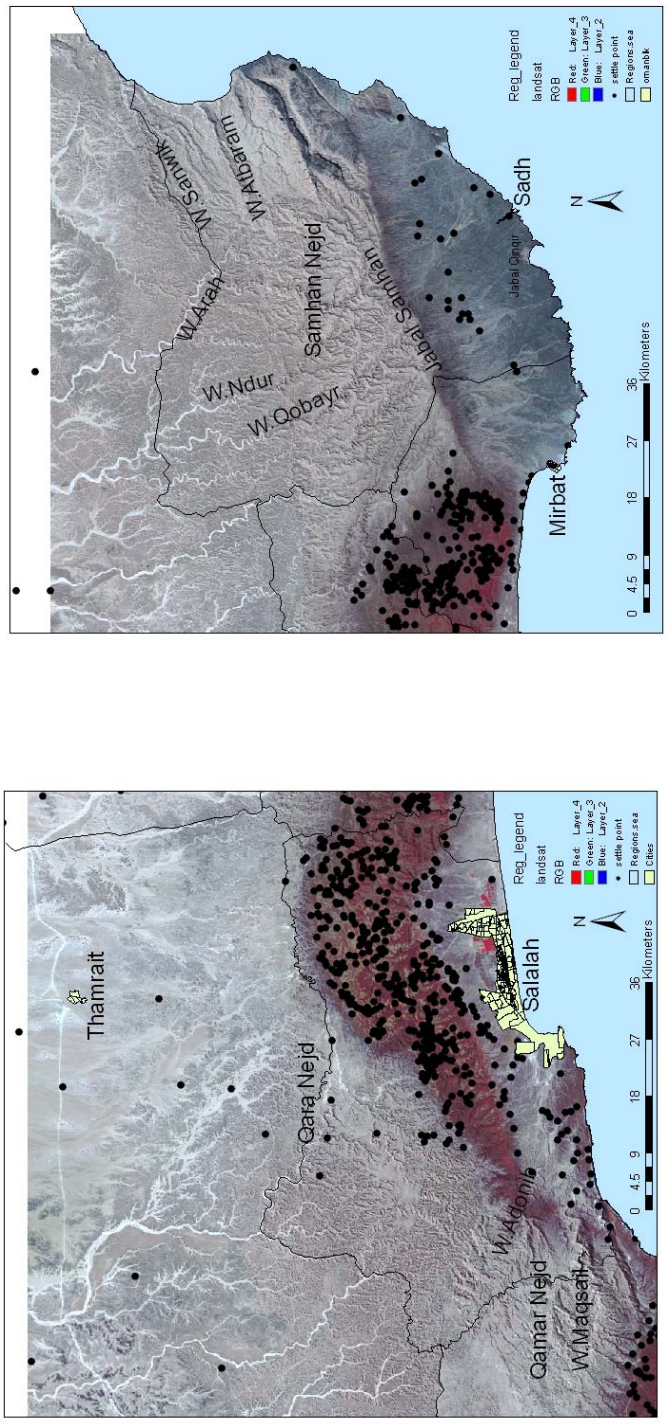


Figure C 3: False color composite Landsat image of the *B.sacra* zones in *Qamar Nejd*, *Qara Nejd Samhan Nejd* and Jarbeeb. Black dots indicate human settlements, boundaries of major provincial districts, cities and luban producing wadis in the study area

**Figure C3:** Landsat image of the *B.sacra* zones in *Qamar Nejd*, *Qara Nejd Samhan Nejd* and *Jarbeeb*.

## C.4 METHODOLOGY

Two sets of methods were used. To capture and understand management practices, surveys of major stakeholders were conducted. These consisted of formal interviews using questionnaires, and unstructured informal interviews with various stakeholders, ranging from government agents, tribal elders and harvesters. To characterize the effects of management and land use practices, complementary studies were conducted that included laboratory experiments and field sampling of plants. Laboratory and field sampling aspects (Table C2) of this study included seed collection, seed germination, incision sampling, *B.sacra* grazing data, and the collection of *B.sacra* stem cross sections and stem cores.

Table C2: Tabular representation of the sampled wadis and the type of sampling carried out. X indicates sampling. S-Section = stem cross section. S-Core = stem core extraction. Wadi-Loc = location or name of sampled Wadi.

| Wadi-Loc | Grazing | Incision | Seed | S-Section | S-Core |
|---|---|---|---|---|---|
| Adonib | X | | | | X |
| Afol | X | | X | X | X |
| Arah | X | X | | X | X |
| Dowkah | X | X | X | | X |
| Iyun | | | | | X |
| Maqsail | X | X | | | X |
| Ndur | X | | | | |
| Qobyr | | | X | | |
| Raysut | | | | X | |
| Sadh | | | | | X |
| Shakhwot | | | | | X |
| Sharqiya | | | | | X |
| Takbiat | | | | | X |

### C.4.1 FORMAL INTERVIEWS

A survey questionnaire was devised to capture various aspects of frankincense extraction like production, transportation, processing and management; while formal interviews elicited information regarding harvester perception of *B.sacra* health and the duration of fallow between harvesting cycles. A total of 16 harvesters were interviewed between December 1998 and June of 1999. A total of 12 harvesters were interviewed during the April-September 1999 luban extraction season in the Hojari/Nejdi zone, but only 3 collectors from the Shazri/Sha'bi zone were interviewed during the October 1998-March 1999 season.

### C.4.2 INFORMAL INTERVIEWS

Informal interviews with elders, government agencies, wholesalers and retailers were instrumental in capturing luban production, processing, marketing and sale methods. Moreover, these interviews revealed the increased level of interdependence among the various stakeholders. The information gathered during these interviews was instrumental in mapping the ecological zones associated with frankincense. Informal interviews provided insight into the structure of frankincense production and tapping methods, and grazing/browsing and settlement patterns. In addition, the interviews revealed human and animal migration patterns, frankincense caravan routes and nomadic mobility.

C.4.3 GERMINATION:

Seed collection and germination experiments were carried out to investigate how seed from different wadis and ecological zone respond to various propagation treatments and temperature regimes. The main objectives behind these trials were two fold: (1) to assess if zonal differences affect seed germination and (2) to establish baseline data that might be useful for the domestication, revegetation and conservation of *B.sacra*.

Seeds were taken from dried fruits in Wadi Dowkah, Wadi Afol, and Wadi Qobyr. The dried fruits from each wadi were cleaned to extract the seeds. Seed that were chipped or cracked, or which showed weevil holes were discarded. The remaining seeds were stored in glass jars and used to conduct germination trials in Sultan Qaboos University.

Seeds from each wadi were divided into three groups to test the optimum germination treatment. One batch was soaked in water for 24 hours, a second was scarified using sand paper, and the third was not treated and used as control. Seeds from each treatment were germinated under three temperatures 25ºC, 30ºC and 35ºC. The germination medium consisted of one part potting soil and one part perlite mix. They were watered once a day. The same process was repeated for similar sets of seeds that were watered once every two days.

C.4.4 HARVESTING INCISIONS:

Wadi Arah, Wadi Maqsail and Wadi Dowkah were sampled to determine the number of incisions harvesters administered on trees of different heights during the frankincense

extraction season. A total of 50 *B.sacra* trees were sampled in each wadi. The number of incisions observed on the trunks and branches of each sampled *B.sacra* tree were tallied. Sampled trees were grouped into five predetermined classes based on tree height. The five classes were also aggregated into, short and tall, harvester-based tree height categories and compared with questionnaire data about incisions.

### C.4.5 GRAZING:

Grazing transects were taken at 3 locations in each wadi. Each transect was 100m long. Frankincense trees were sampled for grazing, and the intensity of grazing was recorded at 5m intervals. Grazing intensities were based on four predetermined categories indicating the severity of grazing based on foliage, terminal buds and bark removal. These categories consisted of no grazing, low grazing, medium grazing and high grazing based on sight inspection  The four classes represented no grazing to minimal grazing of foliage only, foliage and some terminal buds removal, high foliage and high terminal bud removal, bark removal from stems and branches, respectively.

### C.4.6 CROSS SECTION AND CORES:

*B.sacra* stem cross sections and cores were obtained to determine the age of frankincense trees to determine if a relationship could be established between age and height. This test Tree ring data were also to be used to assess the possibility of climate reconstruction in the Boswellia habitats. A total of 5 *B.sacra* stem cross-sections and 18 stem cores were collected for analysis from 5/5/99-5/22/99 of which 4 samples were contaminated and

discarded. The number of contaminated samples from Dowkah, Maqsail and Sadh were 2, 1, 1 respectively.

### C.4.7 CARBON DATING:

Radiocarbon dating was carried out to test the age of trees with different heights to validate the height / age relationship established through tree ring analysis. Radiocarbon content of dried frankincense tree rings obtained from living trees were measured in the AMS laboratory of the University of Arizona. Thin slices of the samples from the inner and outer rings received the following pretreatment to remove any non-native carbon:

1. Soak in 3N HCL overnight to remove inorganic carbon.
2. Rinse to neutral pH with type-1 water.
3. Soak in 2% NaOH overnight to remove mobile carbon (i.e.: humic or fulvic acids).
4. Rinse to neutral pH with type-1 water
5. Soak in 3N HCL to neutralize any remaining NaOH.
6. Rinse to neutral pH with type-1 water.

$CO_2$ was extracted using standard AMS combustion procedures. The gas was passed through several clean-up traps, measured and reduced to graphite. Each sample was measured four separate times on a General Ionex 2.3 MV Cochroft-Walton Accelerator, yielding a precision of approximately 0.5% (Lange et al.2001).

## C.5 RESULTS

### C.5.1 STAND CONDITION

B. Sacra florets and seed production and the presence of seedlings were judged to be indicators of relative stand condition. Arah had the best production of florets and seed. Maqsail had moderate seed production and Dowkah's seed production was often limited to those tree parts that were above the heights that camels could browse. No seedlings were observed in any of the study sites due, in part, to the project's termination before the onset of the monsoon rainy season. Although a few saplings were found in Afol and Maqsail wadis, the highest number of saplings and mixed Boswellia stands were observed in Sharqiya. Regardless of ecological zone, saplings were often limited to steep inaccessible slopes and areas less frequented by grazing livestock.

Tree height decreased with elevation along a cross-section across a wadi. Taller trees were found at the base of the wadis and decreased in height along the side slopes. Hardly any trees at the highest elevation along the slopes were harvested. These trees were often small in stature with slender stems; they were widely dispersed and were understood to produce small quantities of resin. Terrain difficulty increases harvester vulnerability to tapping and collection-related injuries. Consequently, harvesters avoid risky terrain that also requires the expenditure of considerable energy and effort during tapping and collection.

Unsupervised harvesters engage in unlawful seed collection and detrimental rest rotation practices. Although Ministerial Notice no. 25/96 bans the export of *B.sacra* seeds (Fisher et al. 1998), some harvesters admitted to collecting *B.sacra* fruits to extract seeds for sale and export while administering incisions on individual trees. In addition, Harvesters

observe a rest rotation cycle of approximately 6 months even though they estimate it takes about 12-16 months for the incised bark to heal.

### C.5.2 GRAZING AND TOPOGRAPHY

Steady increases in animal and human populations have accelerated the degradation of land and forage. Although intense grazing pressure prevails in most of Dhofar, *B.sacra* vegetation north of Jabal Samhan and on the southern slopes of Samhan are least affected by grazing (Figure C4). There were significant relationships between grazing and wadis as well as grazing intensity and wadis. The north and east draining wadis of Sharqiya had taller *B.sacra* trees and more diversified *B.sacra* stands over a wider area than any frankincense-producing zone.

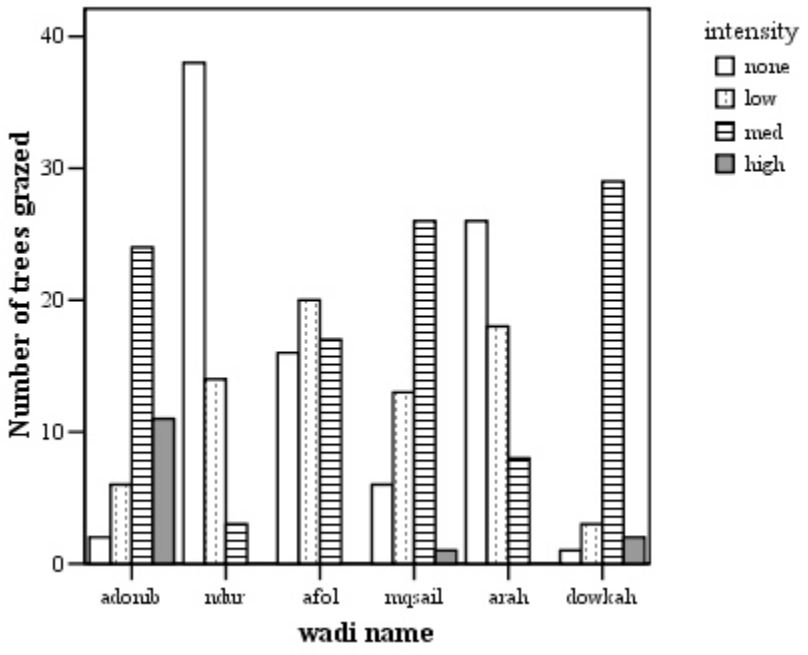


**Figure C4:** *B.sacra* grazing intensity clustered by wadis in the Sharqiya (Ndur and Arah), Qamar Nejd (Afol and Maqsail), Jarbeeb (Adonib) and Qara Nejd (Dowkah).

The oil boom in the Middle East increased economic opportunities in the formal sector (Spicer 1999) and enabled nomads to acquire pickup trucks as the preferred mode of transportation at the expense of traditional camels. Oil wealth improved socioeconomic conditions of nomadic livelihoods (Rowe 1999; Jansen 1986) but also contributed to the sedentarization of nomadic communities (Chatty 1996). Migration routes that normally took from days to weeks and months on camelback (Johnson 1969) are now crossed and utilized quickly using motor vehicles. Adopting a sedentary life style and embracing the truck as the preferred mode of transportation has enhanced pastoral mobility and increased land utilization options available to nomads (Chatty 1996; Jansen 1986).

Given this rapid mobility, traditional pasturing grounds do not have time to recover between periods of grazing. In addition, using trucks not only increases the cost of running a nomadic operation, it intensifies the rate of grazing utilization, and accelerates the rate of land degradation. Trucking supplemental feed and water to permanent or semi-permanent livestock camps (Chatty 1996), especially camel camps, reduces the area livestock might graze, and prolongs camel grazing near the camps. On the other hand, this new development minimizes the isolation of the nomads from urban and agricultural centers (Rowe 1999; Spicer 1999), which increases the nomad's ability to buy and provide emergency animal feed for his livestock, and accelerates the movement of livestock to and from the market. Although some camels and livestock in general are moved to markets and between grazing destinations by foot, using trucks for all aspects of nomadic activity is increasingly the norm.

Frankincense trees, especially in Wadi Adonib and Dowkah, and somewhat in Maqsail, were adversely affected by overgrazing. Although camels and goats are the primary browsers of frankincense trees in Dhofar, camel grazing at times involves debarking frankincense trees (Figure 20). The presence of teeth marks or irregular tears around the soft bark of some *B.sacra* stems and branches in Wadi Adonib and Wadi Dowkah were indicative of camel browsing. Camels chew on the terminal buds of *B.sacra* and thus cause the branch tips to flare, dry up and die. This activity was observed in drainages along the road between Iyun and Qairoon Haraiti. Debarking the soft trunk tissue by camels is more common in areas with gentle slopes, especially those on the Salalah

Jarbeeb and Wadi Dowkah; while the Boswellia vegetation that displays the least evidence of grazing is found on isolated steep slopes or in small government protected enclosures.

Landscape topography and the proximity of wadis to human settlements, gravel mining activities and grazing camels are the major contributing factors to land degradation in *B.sacra* habitats. Boswellia vegetation in Wadi Dowkah is part of a *B.sacra* woodland limited to about a 11 km stretch south of Roya and north of the Jabal Qara foothills. The trees restricted to this wide, flat and gently sloping wadi were threatened by overgrazing but also by a surface mining operation where the streambed is bulldozed to extract sand and gravel for commercial use. Given the scarcity of smaller (younger) trees, these human activities appear to have detrimental effects on the ability of *B.sacra* to regenerate. In addition, there are no regulatory policies in place to manage or protect these resources in the face of the pressure of human land use pressure that accelerates land degradation and vegetation mortality.

There was no evidence of high intensity grazing in Arah, Ndur and Afol. Available water resources in the Arah/Ndur zone were limited and human settlements were very sparse (see Figure 3 and Figure 4). In addition, the steep slopes and deeply eroded Sharqiya wadis that drain to the north and east produce little forage, thereby reducing grazing opportunities and limiting nomadic settlement and use of the area. Consequently, overgrazing of frankincense trees in Wadi Adonib, Wadi Dowkah, Wadi Maqsail and

other accessible areas are attributed to the grazing of camels and, to a lesser degree, goats.

### C.5.3 INCISIONS

The numbers of frankincense harvesters in western Dhofar (Qamar Nejd) and in eastern Dhofar (Samhan Nejd) during the 1998-99 harvesting season were approximately 150 and 43, respectively. Qamar Nejd has a higher number of harvesters for several reasons. First, Jabal Qamar is one of the corridors that illegal Somali migrant harvesters use to gain entry into Oman. Second, there is easy access to the city of Salalah where migrants can connect to a network of local Somali residents and Somali-Omani citizens. Third, harvesters come to Salalah to sell their luban harvest in the various open markets without a middleman. Finally, if their livelihood or personal safety and security is threatened, harvesters can slip across the border to the safety of Yemen. Increases in the number of harvesters often translate into more incisions on individual trees, more tapped trees, or both.

The number of incisions from tapping increased with tree height. When sampled trees were aggregated into harvester-determined categories (short and tall trees), trees shorter than 2 meters had an average of 4 incisions per tree and trees taller than 2m had up to 32 incisions per tree (except in Wadi Dowkah). The high number of incisions on tall trees will increase plant vulnerability to stress and mortality (Ogbazghi 2001). Although Phillips (1966), Groom (1981) and Thomas (1932) addressed plant mortality from over harvesting, this study did not find tapping related *B.sacra* mortality. When sample data

were analyzed according to measured height ranges and harvester based height classes, the results showed similar trends (Figure 5 and Figure 6). However, harvesters generally overestimated the number of incisions in both categories of trees.

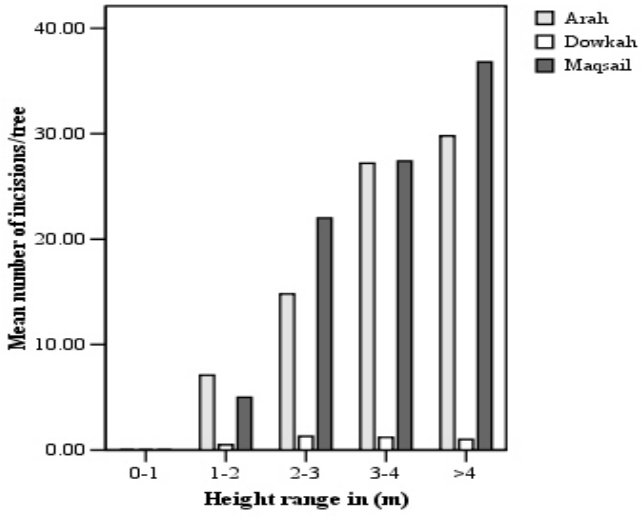


**Figure C5:** Mean number of incisions per tree in Arah, Dowkah and Maqsail clustered by five height range classes. Number of incisions increased with tree height. Dowkah is not harvested.

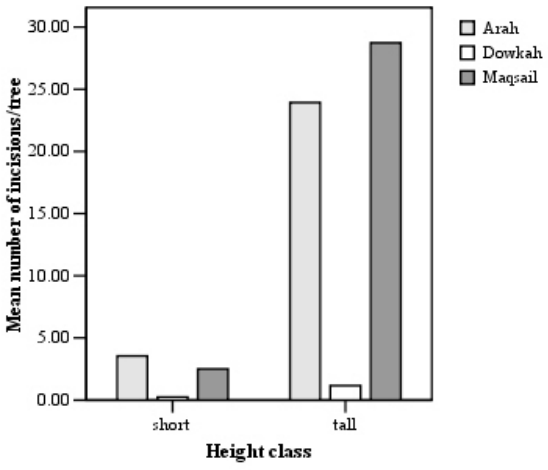


**Figure C6:** Mean number of incisions per tree in Arah, Dowkah and Maqsail clustered into two harvester determined height classes. Trees taller than 2m had high number of incisions except inactive Dowkah fields.

## C.5.4 GERMINATION TRIALS

There were no significant differences between the seeds watered once a day and the seeds watered once every two days. Seeds collected from W.Qobyr, in Jabal Samhan, performed better in germination than the seeds from W.Dowkah and W.Afol where grazing apparently has reduced the both the availability and viability of seed. Due to low grazing pressure, visual observation of *B.sacra* in the upper reaches of W.Qobyr appeared more vibrant because even trees slightly taller than 1 meter had foliage, intact terminal buds, and bark and seeds that would often be susceptible to herbivory in Dowkah and Adonib were more abundant in this area. Moreover, during the seed cleaning process, most of the seeds from Dowkah and Afol were dark brown and discarded due to weevil infestation. In contrast, seeds collected in Jabal Samhan were light brown and had less weevil infestation.

Seeds germinated in the 25ºC chamber had the lowest germination rate. This suggests that the comparatively "cool" 25ºC is not the optimum temperature to grow frankincense seeds. Best germination rates were achieved with frankincense seeds that had been soaked and germinated in 30ºC-35ºC temperatures.

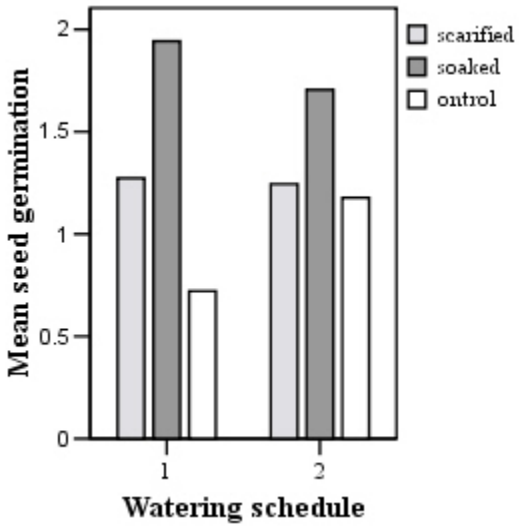


**Figure C7:** Seed germination clustered by watering schedule

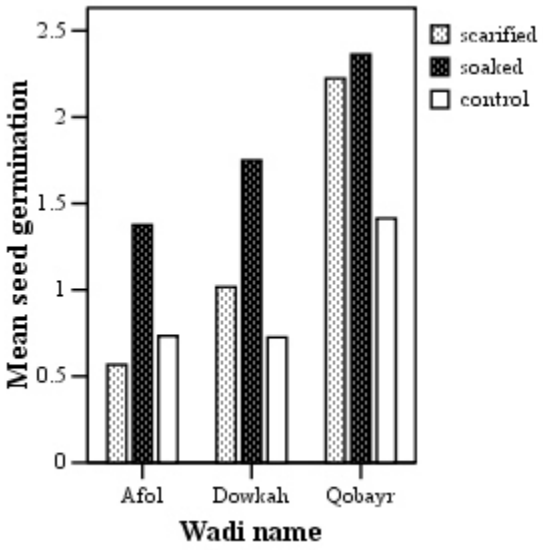


**Figure C8:** Seed germination clustered by wadi

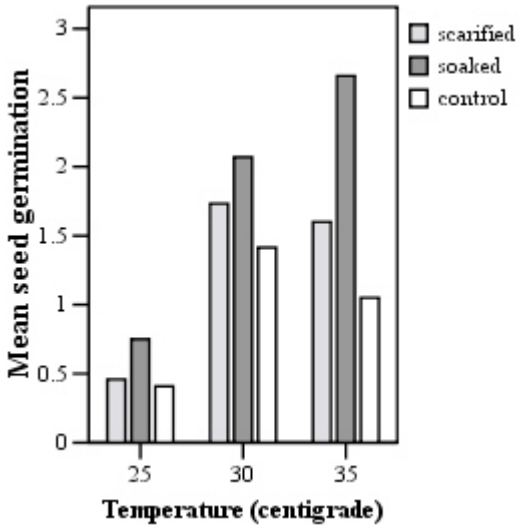


**Figure C9:** Seed germination clustered by temperature

## C.5.5 RADIOCARBON DATING

Radiocarbon dating of 14 stem cores and 5 stem cross-sections showed that tree height was poorly correlated with tree age (see appendix). Some small trees were found to be three times older than trees more than twice their height. Seven of the dated samples (36.8%) were dated as post-atomic bomb era (58 years before present) and the remaining 12 samples (63.2%) ranged from 68-457 years old. These findings confirm the presence of *B.sacra* regeneration.

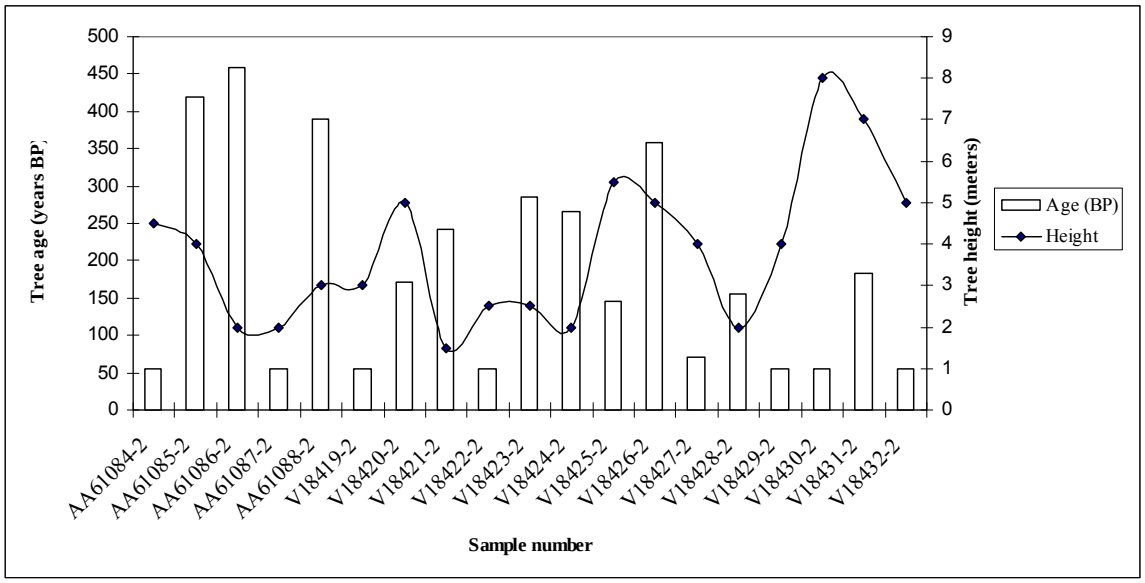


**Figure C10:** Age and height of carbon dated *B.sacra* samples. Numbers (AA#) indicates stem cross sections and (V#) indicates cores. Radiocarbon dated samples are expressed in years before present (BP) and sampled trees heights are expressed in meters

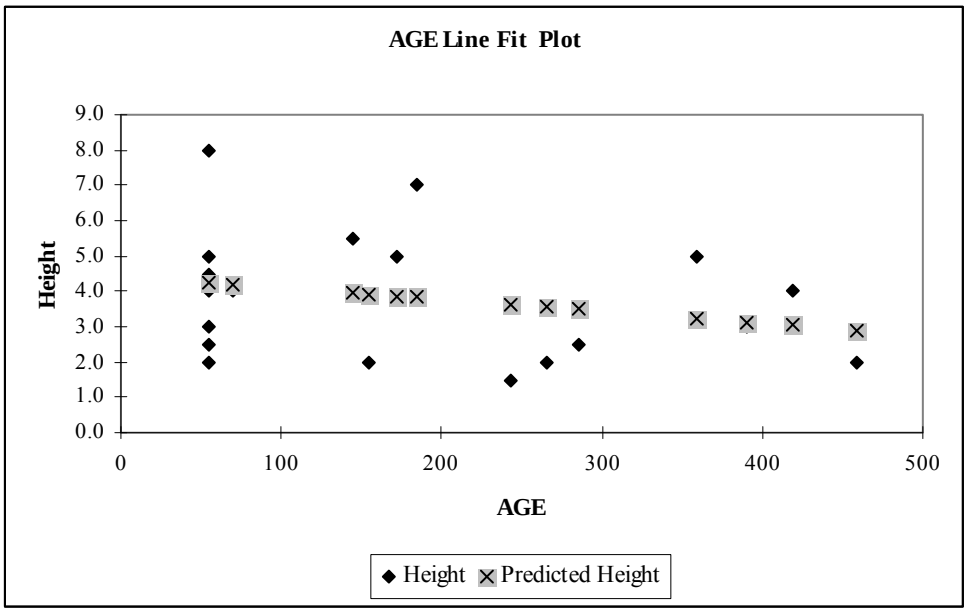


**Figure C11:** *B.sacra* height versus age regression. Graph illustrates there is no correlation between tree height and tree age of the collected samples.

## C.6 DISTRIBUTION OF *B.SACRA*

The distribution addressed in this study documents the general areas of *B.sacra* occurrence and their more specific habitats of endemism. In addition to the distribution of luban trees on the physical landscape, this study examines elevation as it relates to *B.sacra*. Boswellia is predominantly restricted to stream channels; therefore, all distribution discussions are based on luban trees in these water course (wadis).

This study focused primarily on Sanwik, Qobyr, Arah, Ndur, Dowkah, Adonib, Maqsail and Iyun wadis. Other places such as the Sadh plains, Wadi Iyun, Sharqiya south facing slopes, and Wadi Takbiat were visited and sampled for the extraction of stem-cores. The upper reaches of Wadi Dahnat were visited, while wadis like Raysut, Qobyr and Iyun were sampled for obtaining stem cross section, seed collection and stem core extraction

respectively. Other references to Atbaram, Raykhut, Dahboon, and Salafun wadis were obtained from structured interviews and participant observation.

### C.6.1 DOWKAH

Wadi Dowkah at the base of the north slope of J.Qamar and south of the Salalah-Musqat highway supports *B.sacra* vegetation on gently sloping and wide gravelly channels. Vegetation in Wadi Dowkah was in relatively flat terrain at the base of a rocky dry stream channel. *B.sacra* in this wadi was extremely vulnerable to grazing and other human disturbances. The upper elevation limits of the vegetation, south of the gravel processing operation and west of the Salalah-Thumriat highway, consisted of small stunted trees ranging from 1m to 2m high. However, the *B.sacra* situated downstream were predominantly large multiple-stemmed trees that reached a height up to 7m. Although the area did not appear to be frequented by frankincense harvesters, it was heavily grazed. The continuous browsing by camel and goat herds, the easily accessible terrain, the lack of alternative sources of forage combined with gravel mining operations upstream threaten the long term survival of *B.sacra* in this wadi.

Sand and gravel mining, where sand and gravel is removed from around individual trees, leaves individual plants standing on small individual, isolated pedestals (see Figure C13). Excavating the streambed severs the lateral roots of the plant, and removes much of the soil mass from which the root system draws water and nutrients. Furthermore, soil and root removal also deprives the plants of their physical support structure and the

reconfigured surface makes them especially vulnerable to water erosion, particularly during extreme rainfall events. Inevitably, these pedestals will disappear as will the plants they support.

**Figure C12:** *B.sacra* tree downstream from a gravel operation in Wadi Dowkah.

**Figure C13:** Gravel mining in Wadi Dowkah. Erosion processes from this upstream operation will eventually have detrimental effects on downstream vegetation such as those in figure C12 above.

There were no active harvesting operations in Wadi Dowkah. The few incisions observed had no resemblance to the systematic tapping that takes place in actively harvested areas with mature Boswellia growth such as those in W.Arah. Observed incisions were most likely the result of random resin extraction acts by campers, individuals curious about frankincense extraction and tour guides who often demonstrate the art of harvesting frankincense for their customers. Moreover, there were no visible teeth marks around the incisions to indicate camel grazing as the source of the observed incisions. Incisions administered with instruments results in uniform cuts with sharply defined edges, whereas incisions caused by grazing have irregular shapes, teeth marks and longitudinal bark tear. Tapping marks from harvesting have relatively uniform shapes and, depending on the size of the plant, the number of marks made can range from 6-30 incisions per tree during one harvest season.

Although the size of these trees makes them prime candidates for harvesting, their location next to a restricted military zone severely restricts access. The proximity of these woodlands to the military zone is a major factor in discouraging luban-collectors (primarily undocumented Somali harvesters) from venturing into areas such as Dowkah where, if apprehended, they might be subjected to detention and deportation.

## C.6.2 SOLOLAT – JABAL SAMHAN

The bulk of the frankincense trees in Dhofar are found in Jabal Samhan's (Sharqiya Nejd) leeward side. The most vibrant vegetation, the biggest trees and the best quality luban are found in Sharqiya wadis (Qobyr, Ndur, Arah, Sanwik, Atbaram, Dahnoot and Rakhyut). Sharqiya is the only habitat containing small patches of contiguous young seedlings and rich stands of varied height classes, all of which suggests conditions that were better than other sites (Figure C14). The fact that young saplings were not grazed suggests low grazing intensity in the area. Despite comparatively better conditions and adequate seed production levels, seed germination and seedling regeneration were minimal at best. The low regeneration rate is due to insufficient rainfall and soil moisture conditions, coupled with the exposure of barren rocky soils to dry hot summers, and dry and windy cold winters. Furthermore, land use pressures, such as grazing and harvesting, reduce *B.sacra's* ability to regenerate. The potential of Sharqiya's north and northeast-draining wadis as a grazing destination is reduced by barren limestone ravines, steep terrain, and limited water and forage supply and water discourages livestock grazing and human settlements.

**Figure C14:** Wadi Arah mixed age *B.sacra* stands. Limited forage

The upper-most limits of *B.sacra* occurrence were observed at an elevation of 1,770 meters on the dry northern slopes of the headwaters of Wadi Kharish (a branch of Wadi Qobyr), The vegetation at these upper limits was stunted and *B.sacra* was often the only shrub to be found as it graded into the higher rocky grassland plateau. This narrow strip of grassland area ends at the south-facing cliffs. In contrast, the upper limits of frankincense trees on the desert fringes of Wadi Arah were observed at an elevation of 517 m above sea level.

Forage and water availability in the luban-producing wadis were very poor and in many areas *B.sacra* was the only available forage and browse species. Consequently, human settlements and animal husbandry associated with these settlements were largely restricted to areas with access to permanent or seasonal water sources. Thus, trees in these areas were more vulnerable to the effects of unregulated harvesting than grazing. Wadi Arah, Wadi Sanwik and their respective tributaries leading to the edge of the plateau grasslands were under a harvesting regime that begins in March/April and ends in September/October.

### C.6.3 SEAWARD SLOPES:

Boswellia in the Sharqiya zone were commonly limited to the dry north and east draining wadis, but the seaward aspect under the cliffs supports scattered Boswellia trees within thick drought-deciduous acacia woodlands. Their appearance here is somewhat puzzling. Luban trees on the more humid south slope can be found at elevations as high as 1,400 and as low as 300 m. When most trees on the dry, rainshadow side have dropped all or a

significant portion of their fruits and leaves, trees on the seaward slopes had abundant fruits, flowers and leaves. This would appear to be due to the effect of the humid and cooler conditions found in these woodlands habitats.

**Figure C15:** *B.sacra* growing on cliffs and crevasses on the southern slopes of Jabal Samhan.

Most Boswellia on the rainy side of Jabal Samhan were limited to narrow threads along the south draining channels originating from the Kharish and Harkak passes. A few trees were also found growing amongst acacia woodland stands. These mountain passes offer the only migratory routes linking the Sadh-Mirbat coastal plains to the luban zone on the northern side of Sharqiya. The frankincense trees found here were not grazed. These trees were small in stature, often less than 2m high, with less developed stem and branch structures than the larger and more vibrant Boswellia trees found at the base of the southern slopes. Despite their small stature, radiocarbon dating of two core samples, collected at 1,225 m and 1,250 m respectively, showed one of the samples to be approximately 205±38 years old.

The scattered Boswellia on the southern slopes are less vulnerable to grazing because this area supports a variety of more palatable grasses and browse species. Furthermore, in these places, *B.sacra* grows in crevasses on cliffs and rock outcrops or steep slopes that are difficult to access. The very limited distribution of patches of Boswellia plants, often 50-100 meters apart, plus the small stature of the shrub, combined with the difficulty of the terrain, renders the trees on the southern slopes unviable for luban extraction and consequently less vulnerable to the detrimental effects of harvesting and grazing. Although the origin of these scattered shrubs are not known, seasonal livestock migration, camel caravans from the Hojar frankincense fields before the early 1980's, and other animal and wind transport of seeds might have contributed to the presence of *B.sacra* on the southern slopes. The occurrence of young saplings suggests more recent vegetation establishment. However, less is known about the processes that facilitated their establishment. There is no simple answer, but a combination of environmental, human and animal-induced factors are responsible for vegetation recruitment and establishment on the southern aspect of Jabal Samhan. It is also possible that *B.sacra* had been part of a permanent vegetation stand on the more moist habitats on the southern slopes of Jabal Samhan.

Frankincense camel caravan routes to Sadh and Mirbat ports came through Kharish and Harkak passes, livestock grazing on the plateau also used these passes during their seasonal migration from the plateau to the coastal plains and visa versa. Wind and birds transporting seeds over the seaward-facing cliffs and human and animal movements through the two passes might be responsible for seed transport, deposition and

subsequent germination on the southern slopes. Furthermore, most trees grow on steep slopes and rock outcrops that are not easily accessible, but some are found intermixed with thickets of acacia woodlands. Fewer luban trees have been spotted growing on ledges and crevasses on tall vertical escarpments skirting the seaward-facing slopes of the Dhofar mountains.

### C.6.4 SADH-MIRBAT PLAINS:

The Sadh/Mirbat plain supports fragmented *B.sacra* habitats in the Jabal Qinqiri area and in the coastal wadis around Sadh and east of Mirbat. These trees are easily accessible and are smaller in stature than their counterparts on the northern slopes of Samhan. They can be found in rocky areas as well as sandy soils in the coastal wadis and along the road side near Sadh. Although these shrubs can reach a height of up to 3 meters, they are commonly about 2 meters high. Grazing is intensive and there is very little available forage for the goat and camel herds that utilize these plains. In addition, the area supports many sedentary nomadic settlements that maintain herds of varying sizes throughout the year. The size of the herd often depends on forage availability which fluctuates depending on the season, the number of family and hired labor that can be obtained, and family income. Families with more discretionary income hire foreign herders and provide animal feed in permanent or semi-permanent settlements.

Supplementary feed increases animal survival and lowers animal out-migration but is not a substitute for livestock foraging on communal lands. During the dry season, when forage is limited, supplementary feed enhances livestock conditions and reduces animal

out-migration. Therefore, prolonged livestock presence in the area as a result of lower out-migration increases the intensity of utilization on existing forage resources.

In addition to permanent settlements of now non-transient nomads, the coastal plains of Sharqiya are part of a larger nomadic transhumant migration system along an elevation gradient extending from the Nejd lowlands to the Jarbeeb (coastal plains) north and south of Jabal Samhan highlands, respectively.

The comparatively high density of human settlements and increased animal population and concentration in the Sharqiya plains have created grazing pressures that are detrimental to the health of vegetation in general and to Boswellia survival in particular. This trend does not lend itself to securing a future protection plan for the scattered and fragmented *B.sacra* in these plains. Incisions resulting from luban harvesting were not observed in the Sharqiya plains, but even if harvested, this area is known for producing low-quality frankincense known as Sha'bi. Low quality luban is not considered economically viable, consequently harvesters focus their attention elsewhere. Moreover, because the area is easily accessible to the Omani authorities, undocumented immigrant harvesters are discouraged from working this zone. The absence of harvesting will reduce the harmful effects of tapping on plant reproduction cycles that affect regeneration and survival, but additional intervention measures are required for the conservation of isolated and fragmented *B.sacra* stands. If livestock numbers are not reduced and grazing is not managed, land degradation will lead to further fragmentation that will threaten the survival of *B.sacra* in these lowlands.

### C.6.5 ADONIB

Wadi Adonib and its tributaries support fragmented Boswellia stands. As in other wadis, the larger trees are found at the bottom of the wadi and smaller trees are relegated to the gently sloping and steep slopes on the sides of the wadis. *B.sacra* in Adonib is heavily browsed and is not under any harvesting regime. Many dead and dying trees were observed on gently sloping tributaries at wadi bottoms and Adonib is home to some of the most intensively browsed frankincense trees in the Dhofar.

Boswellia trees in Adonib's small government enclosure are protected from the browsing of camels. The enclosure is very small and is located about 100 m upstream from a gravel mining operation. Downstream sand and gravel excavation established a new wadi base level more than 2 m lower than the surface of the enclosure. As soil moisture levels adjust to the newly lowered streambed, the amount of available water for trees in the enclosure will diminish. In addition, stream flow from high rainfall events will bring about headward erosion that will cut back towards the enclosure. Consequently, these off-site factors will increase vegetation risk and mortality even within the protected area.

Luban extraction in Adonib is not pursued for three major reasons. First, the area is known to produce Sha'bi resin which, as noted, is the lowest quality and least profitable frankincense. Second, as in Sadh-Mirbat, the undocumented Somali harvesters feel that the area is neither mountainous nor isolated enough to shelter them from encountering the authorities or the local population. Finally, the presence of *firqat* (militia) and the military

camps in the general area, especially near the western bank of W. Adonib, discourages the harvesters from venturing into these areas.

### C.6.6 MAQSAIL AND AFOL

Wadi Afol is a small channel wedged between the wet southern slope of J.Qamar and Wadi Maqsail. Afol is narrower, smaller and has more diverse vegetation than the drier more extensive Maqsail watershed system. As in other wadis, the bigger trees that often reach a height of 6 meters are along the lowest points of the stream channels, while smaller trees of 2m to 3m are found on wadi slopes. The size and height of frankincense trees decrease with elevation along a lateral transect from the base of the main channel. Both wadis were harvested and observed grazing intensities were slightly higher in Maqsail than Afol. Dual exposure to concurrent browsing and luban harvesting will increase *B.sacra* vulnerability in this western Nedji zone. Luban trees in Afol and parts of Maqsail get some respite from grazing due to the availability of alternative forage plants, such as acacia. Grazing coupled with harvesting might also be one of the factors adversely affecting the quality of gum-resin produced in these wadis.

## C.7 DISCUSSION

### C.7.1 *B.SACRA* REGENERATION AND HUMAN-ANIMAL INTERACTION

Important prerequisites for regeneration of many forest stands include an adequate supply of viable seeds and environmental conditions conducive to seed germination and seedling establishment (Kozlowski et al 1991). Under ideal conditions, seedlings develop into

saplings which grow into mature trees that produce seed for the next generation in a continuous cycle. *B.sacra* habitats are less than ideal because they are located in arid environments that are subject to variable climate conditions that influence and affect plant regeneration. The extreme variability in interannual precipitation has significant impacts through alternating drought and flood events. Those are not considered here in detail. Instead, this study focuses on the interaction between the impacts of human-animal induced activities and the regeneration cycle. As illustrated in the conceptual model (Figure C16), the interaction between impacts and biological systems lead to outcomes that result in *B.sacra* population stability, fragmentation or extinction.

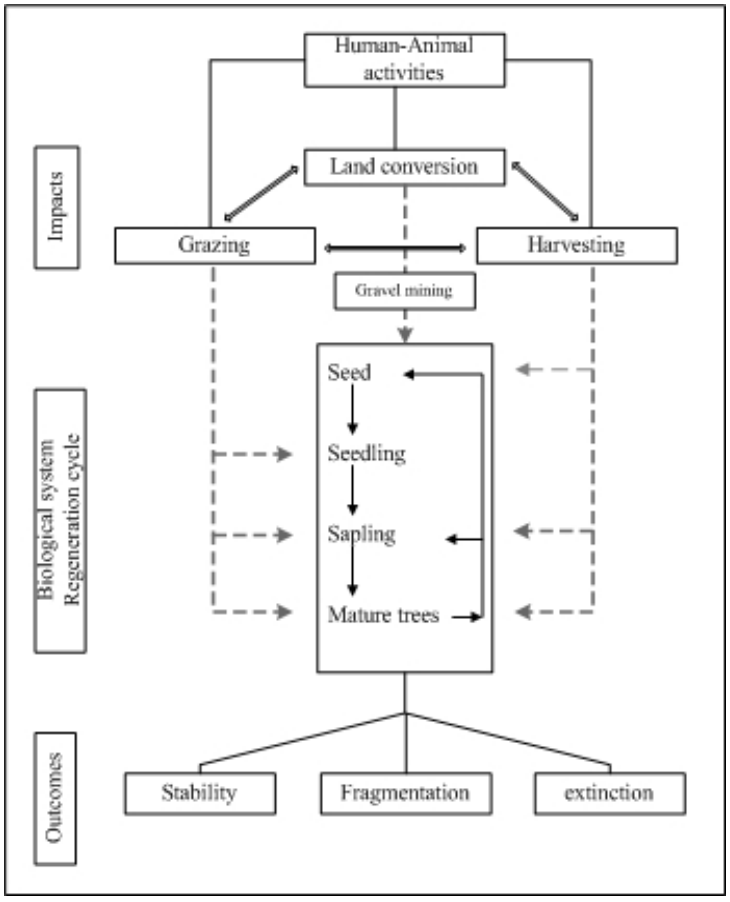


**Figure C16:** Regeneration model for human and animal induced activities showing the respective effects of grazing, gravel mining and harvesting on the regeneration cycle of Boswellia sacra and the potential outcomes of that interaction.

Increased human settlement and associated activities have altered traditional land utilization systems. The increasingly diversified and often overlapping agricultural, pastoral, urbanization and recreational activities are changing landscape use in Dhofar especially in and around Jabal Qamar, Jabal Qara and Jabal Samhan. These changes influence vegetation health in general and the maintenance of viable frankincense habitats and stable *B.sacra* stands in particular. However, it is important to recognize

again that the impacts illustrated in the model (Figure C16) are overlaid on extreme climate variability.

#### C.7.1.1 LAND CONVERSION

Increased human settlements in traditional communal rangelands brought about land-use/cover changes that are exerting more pressure on some of the ecological resources of Dhofar's arid environment. The rapid deterioration of rangelands in general and forest resources in particular has been traced to two related developments: (1) the sedentarization of nomadic tribal populations, and (2) the importation of foreign workers who are largely outside and unfamiliar with local modes of management (Seif El Din 1990). As the pressure on arid lands and its resources exceeds the land's carrying capacity, natural systems start to break down leading to land degradation. The extent and severity of land degradation is poorly documented and there is considerable controversy over the rate and extent of land degradation actually occurring in drylands (Narjisse 1999). Chatty (1996) argues that pastoralists are good custodians of the environment and any increase in their population is compensated by outmigration and sedentarization. Even though nomads care about their environment, land degradation in Dhofar is an increasing trend and will require the implementation of active management strategies. Al-Kathiri (1996) documents the gradual disappearance of native trees and shrubs from some areas on the foothills of Jabal Qara, and he emphasizes the negative pressures that the influx of increasing people and livestock are having on the Jarbeeb and Jabal rangelands. Other studies on rangeland management (FAO 1990), rangeland degradation (al Hatrushi

1986), livestock census (GRM 1982), and nomadic mobility (Jansen,1986) illustrate the changing dynamics of human-animal interaction with the environment in Dhofar. The evidence of land degradation in Boswellia habitats is consistent with similar degradation taking place in rangeland and woodland areas in Dhofar.

Land allocation for urbanization, agriculture and industrial use in the Jabal and Jarbeeb has taken prime rangelands out of communal use. As more pastoralist choose to own land for agropastoral or urban settlements, the traditional nomadic migration patterns are disrupted. These new settlement patterns in turn put new constraints on the system. Even under moderate levels of disturbance (Padmini et al 2001), these land-use changes directly or indirectly contribute to land degradation that affects *B.sacra* regeneration and survival. First, almost all land-use changes reduce pastoralist access to the full range of forage options across the landscape. Second, the concentration of more livestock on the remaining rangelands intensifies livestock competition for available forage resources. Third, as forage resources are exhausted, livestock are forced into increasingly marginal lands and to forage on less palatable species such as *B.sacra*. In addition, the prevalence of invasive species in many rangelands in Dhofar (Al Kathiri 1996) is a byproduct of overstocking and overgrazing and contributes to land degradation trends that will be difficult to correct.

### C.7.1.2 GRAVEL MINING

Gravel mining is a form of land-use change that has a direct effect on the natural regeneration of *B.sacra* in specific locations. For example, a surface mining operation where the streambed was bulldozed to extract sand and gravel for commercial use threatens one of the last remnants of *B.sacra* woodland in Wadi Dowkah.

In order to meet the city's construction needs gravel mining operations west of Salalah will continue for the foreseeable future. Urban interest groups have access to money, power and influence and the economic returns from gravel and other construction related mining activities far outweigh any interest to save *B.sacra* in the Jarbeeb. Even though there has been significant advances in mined land rehabilitation (Schuman and Redente 2002), reclaiming some of these mined *B.sacra* habitats will be costly and difficult to achieve. However, the propagation and domestication of *B.sacara* in less vulnerable alternative sites can offer valuable conservation alternatives.

**Figure C17: Surface Mining Operation** (Left) Soil removal around frankincense trees. (Right) Upstream gravel mining in streambed.

### C.7.1.3 HARVESTING

Extraction of fluids that are critical to basic plant function, such as latexes and resins, exerts stresses throughout the life cycle (Broekhoven 1996). Frankincense tapping, a method of administering incisions on the trunks and branches of luban trees to induce gum-resin exudation, has been in practice for millennia. Although luban extraction methods remained relatively modest and sustainable over time, recent harvesting techniques introduced by Somali luban collectors can have potentially adverse effects on vegetation health and regeneration. For example, prolonged luban extraction practices that coincide with the plant reproduction period decrease seed production and viability (Ogbazghi 2001). When this practice is coupled with tapping through the summer rainy season, the plant's ability to heal before the onset of the next harvesting season is compromised. These changes increase vulnerability and disrupt the ability of the tapped trees to produce abundant and viable seeds for regeneration. Harvesting exudates requires evaluation of tapping procedures, extent of tapping injury, recovery rates, understanding the physiological impacts of tapping and assessment of harvester skills and techniques (Pierce and Shanley 2002).

Luban harvesting is carried out from March through September or October in the Hojari/Nejdi luban producing zone in eastern Dhofar (Figure C19), and October through February or March in the Shazri and Sha'bi luban producing zone in western Dhofar(Figure C18). Harvesting in the two zones starts after the onset of the major rainy

season in the respective zones (Figure C20). Luban trees start to bloom around mid March to early April which coincides with the beginning of the harvesting season in Sharqiya and spring rain in the desert region (Thumrait) (See timeline figure 20 and 21). Given that all harvesters are renters, their primary motive is more about economic gain and less about vegetation management and environmental concerns. Therefore, harvesters do not adhere to a strict observation of *B.sacra* rest rotation and less injurious tapping practices. Although Farah (1994), Groom (1981), Al-Ghassani (1980) and local stakeholders confirmed the long standing practice of renting out *B.sacra* fields, the practice was not widespread in the past, when renting and sharecropping were confined to the owner's kin or tribal group.

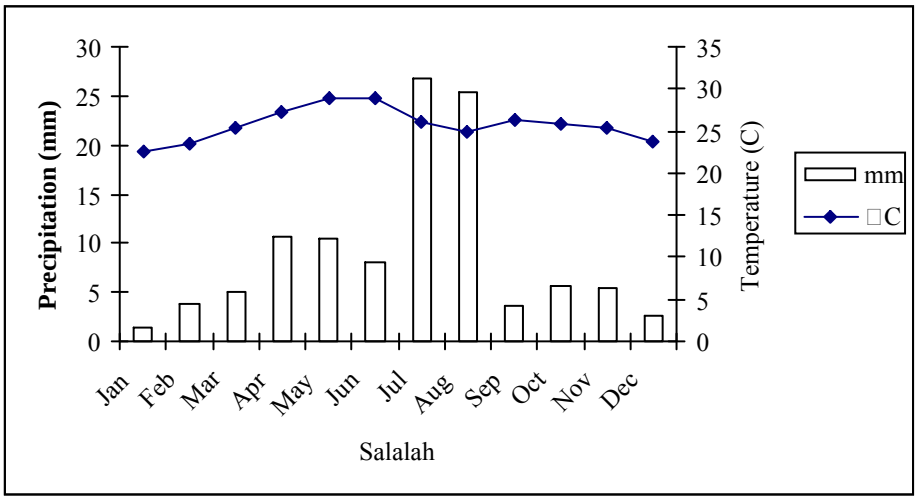


**Figure C18:** Monthly average precipitation in millimeters and monthly average temperature in degrees Centigrade in Salalah located in the coastal plain (Jarbeeb) south of Jabal Qara.
Source: World Climate (www.worldclimate.com).

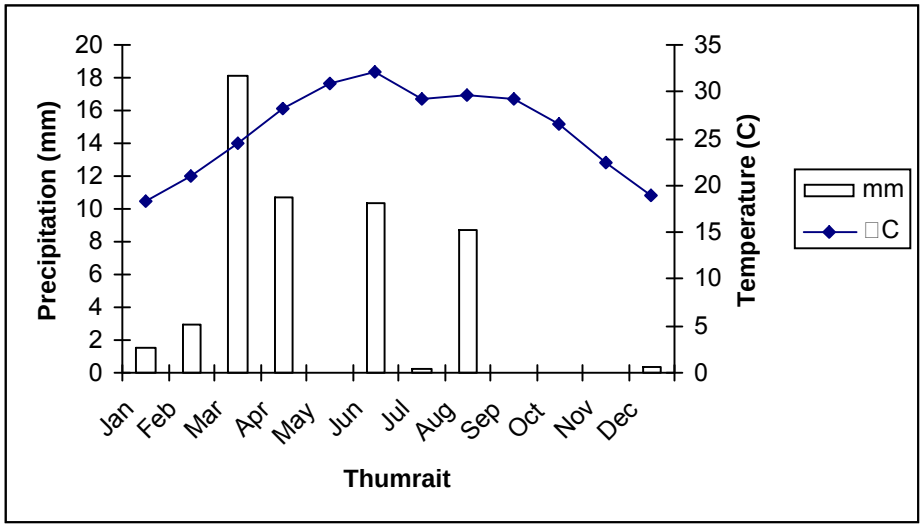


**Figure C19:** Monthly average precipitation in millimeters and monthly average temperature in degrees Centigrade in Thamrait. This station lies in the desert region north of Jabal Qara about 80 km north of Salalah. Source: World Climate (www.worldclimate.com).

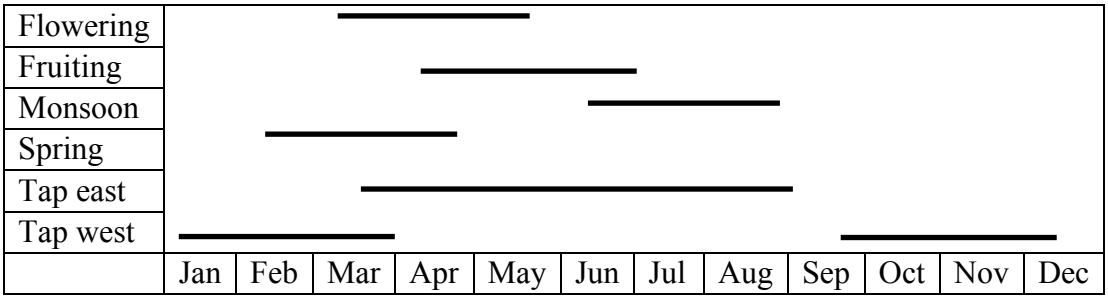


**Figure C20:** Harvesting timeline in relation to *B.sacra* flowering, fruiting, and rainy seasons. Tap-east indicates tapping in the Samhan Nejd (Sharqiya) zone in eastern Dhofar and Tap-west indicated tapping in Qamar Nejd zone in western Dhofar

As Groom (1981), Phillips (1966) and Thomas (1932) have confirmed, overexploitation of *B.sacra* by traditional Omani harvesters has been a long-standing issue in Dhofar. Although these individuals reported various degrees of *B.sacra* mortality as a result of tapping practices or tapping in conjunction with lack of monsoon rain, this study did not find tapping related plant mortality. Al-Ghassani (1980) put the number of luban

harvesters before the 1970's at 3000, during the course of this study harvester number were estimated at approximately 150 in Qamar Nejd and observed at 43 in Samhan Nejd. The present low number of harvesters might explain why tree mortality as a result of over-harvesting is less common today than in the past. Moreover, significant portions of the old luban producing areas or parcels remain inactive at the present time.

Undisturbed trees produced more seeds than those that were tapped or were in grazed areas. Differences in impacts on seed production between grazing and tapping could not be determined and even less is known about the effects of tapping on *B.sacra*'s physiological and phenological processes. It might be that plant energy allocated for the production of flowers and fruits becomes disrupted and apportioned between meeting reproduction needs, and mending injuries from tapping and stress from herbivores. As studies in Non Timber Forest Products such as rubber trees (*Hevea brasiliensis*) have shown, tapping affects plant productivity (Krishnakumar 1999) while a reduction in tapping frequency can reduce bark dryness and increase yield (Eschbach et al. 1986)

Frankincense yield is very low when luban trees are tapped during flowering and fruiting. However, luban yield is at its maximum during the dry hot summer months (Miller and Morris 1988; Groom 1981; Al-Ghassani 1980; Farah 1994; Thomas 1931) when the fruits dry and often drop and the plants lose most of their leaves. Even though harvesters unanimously confirmed the low yield during flowering, they attributed the drop to cold winter weather and lack of rain. Although the monsoon rains and winter rains play a

significant role in the plant's ability to produce resin, this does not explain yield differences between early and late harvest. If rain was the main factor, the early spring harvest should produce more resin than the late spring harvest. On the contrary, Boswellia trees produced more resin in late spring than early spring. Monitoring harvest levels in designated sites over time will be necessary to assess the impact of seasonal rainfall on resin yield.

Although seed harvesting practices have been curtailed, harvesters admitted to collecting frankincense fruits to extract seeds while administering incisions on individual trees. After the fruits had been sun-dried, the seeds were sacked for sale in Salalah.. Fruit collection from forests for medicinal uses (Ram-Prasad et al.2002) can affect regeneration. When seed harvesting for sale is coupled with intensive tapping practices, *B.sacra*'s regeneration potential is diminished.

Just as tapping reduces seed production, the collection of a small or a significant portion of the remaining seeds for sale causes further reduction in the number of seeds available for germination in *B.sacra* habitats. Unsustainable fruit harvesting practices can result in low fruit production (Ram-Prasad et al.2002) and the unsustainable collection of seeds and fruits adversely affects regeneration (Murali et al.1996).

The length of luban tree rest rotation between harvesting seasons affects vegetation healing and recovery time. . The current harvesting cycle of tapping for six months and resting for six months does not give the trees enough time to heal, particularly in an arid

region that is characterized by extreme interannual variations in precipitation. However, this rest and rotation schedule would work well if the same trees, wadi or section of wadi is harvested every other season. This would give the harvested trees 18 months of rest before the next visit.

Plants subjected to successive tapping over extended periods tend to experience stresses (Kumar and Bhandari 1994) that interfere with plant reproduction cycles and luban yield. In extreme cases, stresses from tapping injuries reduce resin production (Bhatt, Nair, and Ram 1989), weaken plant defenses and render the plant vulnerable to secondary infections that induce plant mortality. When plants do not have enough time to heal and recover from tapping injuries between seasons, vegetation stress and vulnerability interfere with *B.sacra*'s physiological processes and contribute to a reduction in the plant's natural regeneration processes (Ogbazaghi 2001). If excessive tapping practices are allowed to continue in their present form, the cumulative effect of harvesting intensity will have negative consequences for the natural regeneration and survival of *B.sacra*.

#### C.7.1.4 GRAZING

Nomadic lifestyles are on the decline in many parts of the world. The social and ecological destruction of 1970's Sahel droughts (Frank & Chasin 1992); the declining state of the traditional nomad (Dyson-Hudson 1985); the decline of Afar pastoralism (Gamaledin 1993); the state of the Fulani pastoralist in central Mali (Bruijn & Dijk 1993); the pastoral economy and the environment (Humphrey & Sneath 1996); and

pastoralism in East Africa (Markakis 1993) are some of the studies that address the dilemmas facing traditional nomadic societies.

The range and the extent of land utilization by the free-roaming nomads are constrained by political boundaries that restrict cross border movements (Meir and Tsoar 1996), development policies that favor agriculture over nomadism (El Sammani 1990), and land tenure issues that have disrupted traditional indigenous land use rights (Hjort 1976). The rate of pastoral migration and the intensity of resource utilization have accelerated to unsustainable levels that are detrimental to Dhofar's arid land environments. Increases in livestock population and semi-sedentary nomadic settlements are contributing to additional pressures on communal grazing lands.

Animals impinge on the life cycle of vascular plants at many stages: pollination, seed production (predispersal, dispersal, and postdispersal stages), seedlings growth and maturation (Aizen and Feinsinger 1994). Livestock grazing is the main factor affecting *B.sacra* regeneration and survival in lower elevation areas in Dhofar. In general, trees on flat lands or gentle slopes are most vulnerable to grazing. Although camels and goats are the primary browsers of frankincense trees in Dhofar, camel grazing at times involves debarking frankincense trees (Figure C22).

**Figure C21:** Land degradation as a result of overgrazing and off-road truck driving. Camels browsing on the bark of *B.sacra* in the Jarbeeb.

**Figure C22:** Camel browsing involves debarking *B.sacra* stems and branches. This form of debarking enables other hosts like termites to attack the plant. *B.sacra* rarely survive this extreme form of herbivory.

Mwalyosi's (1990) observation in Tanzania's Lake Manyara National Park is indicative of plant mortality as a result of elephants debarking of mature *Acacia tortilis* trees. Camel browsing of Boswellia trees is extensive in lowland areas. As the availability of more desirable and palatable forage declines camels resort to browsing on Boswellia trees. Camels browse on the flowers, leafs, seedlings, saplings and the bark of *B.sacra* (see Figure C21 and Figure C22).

The browsing of flowers reduces the seed source available for potential plant regeneration. Moreover, other herbivores such as weevils bore into some of the fruits developed from flowers that were beyond the reach of camel grazing-height, thereby further reducing the number of seeds that could develop into a viable seed source (Figure.24). Although assessing the level of seed predation for an individual plant is not always straightforward (Ollerton and Lack 1996), grazing during flowering and seed set reduces potential seed set (Milton 1992), predispersal predation significantly decreases seed germination (Schelin et al. 2004) and overgrazing reduces regeneration (Western and Maitumo,2004; Kumar and Bhandari1992).

**Figure C23:** High intensity grazing below camel reach and ungrazed foliage, flowers and seed above the browse line in Wadi Dowkah.

In heavily grazed areas, *B.sacra* trees shorter than the camel's reach are often denuded of seeds and leaves (figure C23) and the terminal buds on the soft tips of branches are often grazed to a stub or a flare. Shorter trees are also browsed by goats.

This extreme grazing activity at best stunts plant growth and at worst results in plant death. Even though overgrazing contributes to land degradation, socio-economic developments in Oman increased rangeland utilization options available to a growing segment of the nomadic population. The adoption of the truck in the day to day activities of the nomadic lifestyle transformed the traditional nomadic way of life. The truck gives the nomad ease of access to water, animal feed to supplement grazing needs and access to more distant rangeland resources and urban markets. Trucks ferry tents, mobile shelter structures as well as people and livestock to desired location at a moment's notice. Even though a significant portion of pastoralists are not economically well off to have a truck

at their disposal, the proliferation of automobile use has revolutionized pastoral mobility and accelerated rangeland utilization and degradation.

This mobility and new modes of transportation also extend to luban harvesting thereby eliminating the need for camel caravans and replacing the old routes with off road driving routes through a network of stream channels. The construction of water wells in many remote areas was part of Oman's development plan to improve rural livelihood and increase water availability for pastoralists and their livestock. Progress made in developing water resources for livestock, transformed constructed water wells into tribal centers that enable nomads to gain access to healthcare, education and other government services (Chatty 1996). Although the sedentary lifestyle improved nomadic livelihood, increased number of settlements and high animal concentration around developed wells intensified grazing pressure on available forage. Rangeland degradation contracted from the periphery to the center where the water source was located (Jeltsch 1997). Thus, areas close to the water source are severely degraded and often denuded of vegetation (Larsson 2003). Camel camps with permanent or trucked water sources are examples of overgrazing activity directly affecting luban-trees in the Jarbeeb and other easily accessible areas.

#### C.7.1.5 RADIOCARBON DATING:

Understanding the general age structure of tree stands will have management implications for the sustainable harvesting methods and age of optimum luban

production. The diversity of age groups in the sampled vegetation illustrated that there has been some *B.sacra* regeneration, particularly, in the last 53 years. Tree dating results will have implications for frankincense production and yield estimates. In the near term, owners and resource managers might find it necessary to limit or curtail grazing and other landuse activities in certain *B.sacra* woodlands in order to meet desired management objectives such as sustained luban production. In the longer term, tree dating will also help us understand *B.sacra* reproduction issues like flowering, seed production and dispersal and the way trees with different ages respond to stress. These factors are vital for the regeneration, management and conservation of *B.sacra*.

#### C.7.1.6 LANDSCAPE FRAGMENTATION:

Isolated and fragmented *B.sacra* habitats in the plains of Salalah and Sadh/Mirbat are threatened by grazing, urbanization, gravel mining and agriculture. Populations persist for longer periods in interconnected landscapes (Merriam 1984) but land use activities in the Dhofar are threatening habitat connectivity. Dhofar's fragmented *B.sacra* enclaves are over utilized and are not connected to other larger *B.sacra* habitats that are vital for maintaining a stable population. Over-exploitation of Jarbeeb resources can lead to excessive fragmentation and reduction of population sizes to a point that threatens population viability and species survival (Rajora and Mosseler 2001). Deficient seed dispersal due to habitat fragmentation seriously impacts the reproductive cycle (Cordeiro, and Howe 2003), and biodiversity (Zuidema et.al. 1996) and contributes to reduced regeneration and that threatens long-term conservation.

*B.sacra* in the Samhan Nejd are considerably more stable than those in other ecological zones. In addition to its location, most of the *B.sacra* fields north of Jabal Samhan fall inside JSNR. Although the reserve designation remains largely symbolic without an enforcement body, planned active management strategies relating to *B.sacra* will ensure the implementation of regeneration and conservation strategies that balance economic interests with environmental and ecological concerns.

## C.8 CONCLUSION

*B.sacra* is under threat on several fronts but there is some progress and promising developments on other fronts that will be vital in the long-term regeneration, management and conservation of this arid land resource. The Royal decree responsible for the establishment of 4500 km² Jabal Samhan Natural Reserve (JSNR) will at least maintain the woodlands in their current composition if the decree is complimented with an active management strategy.

Successful nursery propagation of *B.sacra* will play a significant role in the rehabilitation of fragmented *B.sacra* habitats and in the continuation of *B.sacra* regeneration. This study's propagation trials demonstrated the promise and possibility of more active management of *B.sacra*. Radiocarbon dating illustrated the opportunity to describe the age structure of *B.sacra* stands instead of relying on untested harvester claims. In addition, dating will play an important role in understanding and determining frankincense production levels that might be sustainable.

The distribution of *B.sacra* in Oman is generally restricted to dry environments on the rainshadow side of Jabal Qamar, Jabal Qara and Jabal Samhan. However, this study found scattered *B.sacra* trees growing amongst the drought deciduous acacia woodlands on the humid southern aspect facing the Indian Ocean. The trees on the seaward facing slopes are small in stature and too sparse to be viable for luban extraction.

*B.sacra* is found along an elevation gradient from 60 meters above sea level in the Jarbeeb to 1770 meters above sea level in Jabal Samhan. The vegetation's primary area of occurrence is within wadis. Bigger trees that often reach a height of 6 meters or more are found in the bottom of stream channels while smaller trees of 2 m to 3 m are found on wadi slopes. Although radiocarbon dating is an approximation, it showed that the age of sampled trees had no correlation with tree height thus disproving the belief among harvesters and locals that taller trees with larger girth are the oldest.

*B.sacra* growing in gently sloping easily accessible terrain such as those in Adonib, Dowkah, Iyun and other areas in the Jarbeeb are the most vulnerable to bark-stripping and overgrazing. These grazing activities contribute to vegetation stress and vulnerability and inhibit the ability of *B.sacra* to regenerate. In extreme cases, this form of grazing often results in the mortality of the plant.

Although *B.sacra* trees get some respite from grazing during the rainy season (*Khareef*), this relief is only temporary because the high animal population density tends to quickly exhaust available forage. As palatable forage or browse is exhausted (Al Kathiri 1996), camels in *B.sacra* habitats resort to browsing on less desired alternatives such as *B.sacra*. Locals indicate that increases in livestock population and human settlements are depleting grazing resources faster and disrupting the traditional rest rotation and migration patterns of the past.

Government incentives, remittances from family members working in urban centers, and improved personal incomes are enabling more nomadic families to provide supplementary animal feed and water in permanent or semi permanent location. Unfortunately, this practice effectively limits the range that livestock will travel to graze during the dry season or any other time when forage availability is reduced. Increasing the length of time livestock remain on any one site intensifies resource utilization and contributes to the general overgrazing trend in Dhofar.

The JSNR lacks active management strategies that can serve to enforce and/or implement the conservation legislation decreed by Sultan Qaboos. Several different land use and land right activities are often exercised on the same plot of land. These overlapping rights by tribal groups, rights of government agencies and ministries and the rights of the Royal branch require a careful synergy of the competing interests of the various stakeholders. The sensitive nature of these issues in JSNR makes managing the general area and *B.sacra* stands very challenging.

Increases in the number and density of human settlement and associated activities have altered traditional land utilization systems. The increasingly diversified and often overlapping agricultural, pastoral, urban, environmental and industrial activities are changing landscape use in Dhofar especially in and around the southern mountain ranges. These changes influence vegetation health, in general, and the maintenance of viable frankincense habitats and stable *B.sacra* stands in particular.

Land conversion, frankincense harvesting and livestock grazing are the three major impacts affecting *B.sacra* regeneration. The interaction among these impacts and the biological system result in outcomes such as vegetation instability, fragmentation or extinction.

Land allocation for urbanization, agriculture and industrial use in the Jabal and Jarbeeb removed prime rangelands from communal use and management. These land-use changes directly or indirectly contribute to land degradation that affects *B.sacra* regeneration and survival.

Plants subjected to successive tapping over extended periods tend to experience stresses that interfere with plant reproduction cycles and luban yield. In extreme cases, stresses from tapping injuries reduce luban production, weaken inherent plant defenses and thus render the plant vulnerable to secondary infections that induce plant mortality. Trees that are less than 2 meters in height are harvested less frequently than trees that are more than 2 meters high. Consequently tall trees are more susceptible to injuries from tapping. The higher resin production of the big trees and ease of access to them by the harvester makes those trees more vulnerable to stress and mortality from repeat harvesting. Furthermore, it appears that a “sustainable” harvest regime is dependent on a limited harvest pressure (i.e., not totally open-access), and a workforce of harvesters that have some level of skill.

Thus, if harvester numbers and their level of expertise remain at the current level the long-term detrimental effects of resin extraction could be minimized.

Absentee landlords in active tapping areas increase the likelihood that harvesters will engage in practices that are detrimental to the well being of *B.sacra* survival, regeneration and conservation. Even though harvesters exercise considerable self policing, on-site owner or owner-proxy supervision and management is vital: remote management does not work well. Owner absence encourages harvesters to use less stringent and shorter rest rotation periods between seasonal harvest cycles. Lack of sufficient rest rotation between harvesting cycles does not allow *B.sacra* to heal from tapping injuries and contributes to overall plant stress and vulnerability to pests and disease. In addition, the persistent practice of seed collection for sale that coincides with the *B.sacra* plant reproduction cycle and sustained tapping, reduce the availability of seed, and the overall regeneration potential of *B.sacra*.

Gravel mining operation effects are far more devastating than any other land-use activity and land degradation in the distressed area extends to soil removal, soil moisture conditions and nutrient availability. This activity leads to plant mortality because it directly affects the soil through erosion and earth removal, it deprives the plant of nutrients and water, and increases plant stress that reduce or curtails seed production. Reducing or eliminating the available seed bank disrupts the biological cycle and contributes to diminished plant regeneration potential from seed to mature plant and back to seed.

Resource management and land use trends that have emerged over the past several decades threaten not only the sustainable use of *B.sacra*, but its very existence. Continuation of current utilization trends Boswellia habitats, with minimal and variable rainfall will lead to the fragmentation and eventual extinction of a valuable arid land resource like frankincense in more vulnerable area such as the Jarbeeb, Wadi Dowkah and Wadi Adonib.

Large *B.sacra* trees are less susceptible to mortality resulting from grazing unless debarking is involved. Larger trees have an extensive root system and significant parts of the trees are beyond the reach – both above and below ground – of livestock browsing. In the absence of debarking and activities that transform the landscape (e.g., gravel mining), stands of big *B.sacra* trees might not regenerate but could persist as stable plant communities.

## C.9 REFERENCES

Aditya-Purohit, Maikhuri, R.K., Rao, K.S., Nautiyal, S. 2001. Impact of bark removal on survival of Taxus baccata L. (Himalayan yew) in Nanda Devi Biosphere Reserve, Garhwal Himalaya, India. *Current-Science* 81(5): 586-590.

Aizen, M.A., and Feinsinger, P. 2001. Forest fragmentation, pollination and plant reproduction in a Chaco dry forest, Argentina. *Ecology* 75(2):330-351.

Al-Hatrushi, S. M. 1989. *Rangeland Degradation: The Case of the Southern Region in the Sultanate of Oman*. U.M.I, Ann Arbor.

Al-kathiri, A. M. 1996. *Qabat wa Marai Jibal Muhafadat Dhofar[Forests and Rangelands of the Mountains of Dhofar]*. Dhofar National Printing Press, Oman.

Al-Ghassani, A.S. 1980. *Dhofar ard al-luban [Dhofar the land of frankincense]*. Almatabi Al-almiyah, Ruwi, Sultanate of Oman.

Al-Shahri, A. A. 1994. *Kaifa Ibtadayna Wa-kayfa Irtaqayna Bilhadara Alinsaniya Min Shabh Aljazira Al Arabiya: Dhufar Kitabatuha wa Nuqushuha Al Qadima*. Al Ghurair Printing and Publishing House Co. L.L.C., Dubai, U.A.E.

Barbier, C. 1984. *The Frankincense tree in Somalia: proposition for Propagation and* Management. Laboratoire de Botanique. Montpellier, France: Institute Botanique 1-27.

Bevilacqua, Maria., Bevilacqua, Matteo., Serra, E., Vianello, A., Garrou, E., Sparangna, B., Barale, U., and Zaccagna, C.A. 1997. Natural resin association such as incense

and Propolis in zootechnology. *Agriculture Ecosystem and Environment*. 62:247-252.

Bhatt, J. R., Nair, M. N. B., and Ram, H .Y. M. 1989. Enhancement of oleo gum resin production in *Commiphora wightii* by improved tapping technique. *Current Science*. 58(7): 349-357.

Birdwood, G. 1870. On the genus Boswellia, with descriptions and figures of three new species. *Transactions of the Linnean Society of London*. 27: 111-148.

Broekhoven, G. 1996. *Non Timber Forest Products: Ecological and Economic Aspects of Exploitation in Colombia, Ecuador and Bolivia*. IUCN, Gland, Switzerland, pp 11.

Bruijn, M., & Dijk, H. 1993. State formation and the decline of pastoralism: the Fulani in Central Mali. In Markakis, J. (ed), *Conflict and Decline of Pastoralism in the Horn of Africa*. Institute of Social Studies, Hampshire, UK.

Campbell, B., Frost, P., Goebel, A., Stuunda-Gunda, W., Mukamuri, B., and Veeman, M. 2000. A conceptual model of woodland use and change in Zimbabwe. *International Tree Crop Journal* 10(4):347-366.

Carter, H.J. 1846 A Description of the Frankincense Tree of Arabia with Remarks on the Misplacement of the Libanophorous Region in Ptolemy's Geography. *Journal of the Bombay Branch of the Royal Asiatic Society*, 2: 380-390.

Chambers, R. 1994. The origin and practice of participatory rural appraisal. *World Development* 22(7):953-969

Chatty, D. 1996. *Mobile Pastoralists: Development Planning and Social Change in Oman*. Colombia University Press, New York.

Cordeiro, N. J. and Howe, H. F. 2003. Forest fragmentation severs mutualism between seed dispersers and an endemic African tree**.** *Proceedings of the National Academy of Sciences of the United States of America*.100(24): 14052-15056. Washington, USA: National Academy of Sciences.

Dyson-Hudson, N., and McCabe,J. T. 1985, *South Turkana Nomadism: Coping With an Unpredictably Varying Environment*. Ethnography Series FL17-001. HRAFlex Books, New Haven.

El Samani, M.O. 1990. *Establishment of rangeland management programme in the Southern Region of Oman*. FAO report. OMA/87/013.

Engler, A. 1915. Die Pflanzenwelt Afrikas insbesondere siener tropischen Gabiete III. Bd., I. Heft. In A. Engler and O. Drude (eds.), *Die Vegetation der Erde*, Verlag W. Engelmann, Liepzig, 779-797.

Eschbach, J. M., Tupy, J., and Lacrotte, R. 1986. Photosynthate allocation and productivity of latex vessels in Hevea brasiliensis. *Biologia Plantarum*. 28(5): 321-328

FAO 1995. *Trade Restrictions Affecting International Trade in Non-wood Forest Products: non-wood forest product 8*. http://www.fao.org/forestry/foris/webview/forestry2/index.jsp?siteId=1141&langId=1

Farah, A.Y. 1994. *The Milk of Boswellia Forests: Frankincense Production among Pastoral Somali*. Reprocentralen HCS, Uppsala

Fisher, M., Ghazanfar, S.A., Chaudary, S.A., Seddon, P., Robertson, E.F., Omar, S., Abbas, J.A., and Boer, B. 1998. Diversity and conservation. In S. A. Ghazanfar and M, Fisher (eds.), *Vegetation of the Arabian Peninsula*, Klumer Academic Publishers, Netherlands, pp 265-302.

Franke, R.W., & Chasin, B.H. 1992, *Seeds of Famine: Ecological Destruction and the Development Dilemma in the West African Sahel*. Rowman and Allanheld, Lanham, MD.

Gallagher, M. 1977 The Oman flora and fauna survey, 1977 (Dhofar). *Journal of Oman Studies*, 3:1 9-13.

Gamaledin, M. 1993,The decline of Afar pastoralism. In Markakis, J. (ed), *Conflict and Decline of Pastoralism in the Horn of Africa*. Institute of Social Studies, Hampshire, UK.

Ghazanfar, S. 1998 Vegetation of the plains. In S. A. Ghazanfar and M, Fisher (eds.), *Vegetation of the Arabian Peninsula*, Klumer Academic Publishers, Netherlands, 175-190.

Groom, N. 1981. *Frankincense and Myrrh: A Study of the Arabian Incense Trade*. Longman, London.

Guba, I. and Glennie, K. 1998 Geology and geomorphology. In S. A. Ghazanfar and M, Fisher (eds.), *Vegetation of the Arabian Peninsula*, Klumer Academic Publishers, Netherlands, 175-190.

Harris, L.D., and Gallagher, P.B. 1989. New initiatives for wildlife conservation. In G. Machintosh (ed), *In Defense of Wildlife: Preserving Communities and Corridors*. Defender of Wildlife, Washington, D.C., 11-34.

Hjort, A.1976. Constraints on pastoralism in drylands. In A. Rapp, H. N. Le Houérou, and B. Lundholm (eds), *Can Desert Encroachment be Stopped*. Ecological Bulletins, Swedish Natural Science Research Council, Stockholm pp 71-82.

Hoffman, T.R. 1986. Growing and Propagation of frankincense (Boswellia Carteri). *Plant Propagator*. 32(2):11-13.

Humphry, C., & Sneath, D. 1996, *Cultures and Environment in Inner Asia*. The White Horse Press, Cambridge, UK.

Jansen, J. 1986. *Nomads in the Sultanate of Oman: Tradition and Development in Dhofar*. Westview Press, London.

Jeltsch, F., Milton, S. J., Dean, W.R.J., and Rooyen, N.van. 1997. Simulated pattern formation around artificial waterholes in the semi-arid Kalahari. *Journal*. 8(2): 177-188.

Johnson, D.L. 1969. *The Nature of Nomadism: a Comparative Study of Pastoral Migration in southwestern Asia and Northern Africa*. University of Chicago Press. Chicago, IL.

Khan, M.A. 1972. Propagation of *Boswellia papyrifera* through branch cuttings. *The Indian Forester*. 437-440.

Kozlowski, T.T., Kramer, P.J., and Pallardy, S.G. 1991. *The Physiological Ecology of Woody Plants*. Academic Press, San Siego.

Krishnakumar, R., Sreelatha, S., Thomas, M., Jayasree G., Jacob, J., Sethuraj, M. R. 1999. Biochemical composition of soft bark tissues in Hevea affected by tapping panel dryness. *Indian-Journal of Natural Rubber Research*. 12(1/2): 92-99

Kumar, M., and Bhandari, M. M. 1994. Commiphora wightii - a threatened medicinal plant of the Thar Pradesh. *Ethnobiology in human welfare: abstracts of the fourth international congress of ethnobiology*, Lucknow, Uttar-Pradesh, India, 17-21.

Kumar, M., and Bhandari,M. M. 1992. Impact of protection and free grazing on sand dune vegetation in the Rajasthan Desert, India. *Land Degradation and Rehabilitation*. 3(4): 215-227.

Laird, S. and Guillén, A. 2002 Marketing issues. In P. Shanley, A. Pierce, S. Laird, and A. Guillén (eds), *Tapping the Green Market: Certification and Management of Non Timber Forest Products*, Earthscan Publication Ltd, London, 322-336.

Lange, T., Barbetti, M. and Donahue, D.J. 2001. Radio carbon measurement for tree rings from 14 ka Huon pine. *Radiocarbon*. 43(2); 449-452.

Larsen, H.O., Olsen, C.S., and Boon, T.E. 2000. The non-timber forest policy process in Nepal: actors, objectives and power. *Forest Policy and Economics*. 1(314 ), 267-281.

Larsson, H. 2003. *Water distribution, grazing intensity and alterations in vegetation around different water points, in Ombuga Grassland*, Northern Namibia Minor Field Studies International Office, Swedish University of Agricultural Sciences. (225): 54.

Mahapatra, A., and Mitchell, C.P. 1997. Sustainable development of non-timber forest products: implication of forest management in India. *Forest Ecology and Management*. 94:15-29.

Markakis, J. 1993, *Conflict and Decline of Pastoralism in the Horn of Africa*. Institute of Social Studies, Hampshire, UK.

Meir, A; Tsoar, H. 1996. International borders and range ecology: the case of Bedouin transborder grazing. *Human Ecology New York*. 24(1): 39-64

Merriam, H.G. 1984. Connectivity: a fundamental ecological characteristic of landscape pattern, In *Proceedings of the First International Seminar on Methodology in Landscape Ecological Research and Planning*. Rockilde, Denmark. International Association fpr Landscape Ecology, 5-15.

Mies, B.A., Lavranos, J.J., James, G.J. 2000. Frankincense on Socotra Island (Boswellia, Burseracea; Yemen). *Cactus and Succulent Journal* (U.S.). 72(5):265-278.

Mies, B.A., Lavranos, J.J., James, G.J. 2000. Frankincense on Socotra island (Boswellia, Burseracea; Yemen). *Cactus and Succulent Journa*l (U.S.). 72(5):265-278.

Miller, A.G. and Morris, M. 1988. Plants of Dhofar: *The Southern Region of Oman Traditional, Economic and Medicinal Uses*. The Office of the Adviser for Conservation of the Environment, Diwan of Royal Court, Sultanate of Oman

Milton, S.J. 1992. Effects of rainfall, competition and grazing on flowering of Osteospermum sinuatum (Asteraceae) in arid Karoo rangeland. *Journal of the Grassland Society of Southern Africa*. 9(4): 159-164.

Minore, D. and Weatherly, H.G. 1994. Effects of partial bark removal on the growth of Pacific yew. *Canadian Journal of Forest Research*. 24(4): 860-862

Mulugeta, L., Tarekegn, A., and Olsson, M.2003. Gum and resin resources from some Acacia, Boswellia and Commiphora species and their economic contributions in Liban, south east Ethiopia. *Journal of Arid Environments*. 55(3): 465-482

Murali, K S; Uma-Shankar; Shaanker, R U; Ganeshaiah, K N; Bawa, K S 1996. Extraction of non timber forest products in the forests of Biligiri Rangan Hills, India. 2. Impact of NTFP extraction on regeneration, population structure, and species composition. *Economic Botany*. 50(3): 252-269

Mwalyosi, R.B. 1990. The dynamic ecology of Acacia tortilis woodland in Lake Manyara National Park, Tanzania. *African Journal of Ecology*. 28(3): 189-199

Narendran, K., Murthy, I.K., Suresh, H.S., Dattaraja, H.S., Ravindranath, N.H., and Sukumar, R. 2001. Nontimber forest product extraction, utilization and valuation: a case study from the Nilgiri Biosphere Reserve, southern India. *Economic Botany*. 55(4):528-538.

Narjisse, H. 1999. Rangeland issues and trends in developing countries. In O. Arnald, and S. Archer (eds), *Rangeland Desertification*. Klumer Academic Publishers, Dordrecht, pp 181-195.

Ogbazghi, W. 2001. The *distribution and regeneration of Boswellia papyrifera* (Del.) Hochst. in Eritrea. Wageningen, Netherlands: Landbouwuniversiteit Wageningen (Wageningen Agricultural University).

Ollerton, J. and Lack, A. 1996 Partial predispersal seed predation in Lotus corniculatus L. (Fabaceae)**.** *Seed-Science-Research*. 6(2): 65-69.

Padock, C., and de Jong, W.D. 1989. Production and profit in agroforestry: an example from the Peruvian Amazon. In J.G. Browder (ed), *Fragile Lands of Latin America: Strategies for Sustainable Development*. Westview Press, Boulder, pp. 102-113.

Padmini, S.; Rao, M. N. Ganeshaiah, K. N., and Shaanker, R. U.2001. Genetic diversity of Phyllanthus emblica in tropical forests of South India: impact of anthropogenic pressures. *Journal-of-Tropical-Forest-Science*. 13(2): 297-310.

Phillips, W. 1966. *Unknown Oman*. David McKay Company Inc., New York.

Pierce, A.R., and Shanley, P. 2002. Ecological Issues. In P. Shanley, A. Pierce, S. Laird, and A. Guillén (eds), *Tapping the Green Market: Certification and Management of Non Timber Forest Products*, Earthscan Publication Ltd, London, pp. 267-282.

Rai, S.C. and Sharma, E. 1995. Land-use change and resource degradation in Sikkim Himalaya: a case study from Mamlay Watershed. In: Singh, R.B. and Martin, J.H., Editors, 1995. *Sustainable Reconstruction of Highland and Headwater Regions*, Oxford and IBH Publishing, New Delhi, pp. 265–278.

Rajora, O. P., and Mosseler, A. 2001. Molecular markers in sustainable management, conservation, and restoration of forest genetic resources**.** In G. Muller-Starck, and R. Schubert (eds), *Genetic response of forest systems to changing environmental conditions*. Dordrecht, Netherlands: Kluwer Academic Publishers. pp 187-202.

Ram-Prasad; Kotwal, P C; Manish-Mishra 2002. Impact of harvesting of Emblica officinalis (Aonla) on its natural regeneration in central Indian forests. *Journal of Sustainable Forestry*. 14(4): 1-12

Rowe, A. G. 1999. The exploitation of arid landscape by a pastoral society: the contemporary eastern Badia of Jordan. Applied Geography 19: 345-361.

Sarin, Y. A., and Atal, C. K. 1982. Indian olibanum as perfumery raw materials. *Patai Journal*. 4(2): 13-18.

Schelin, M., Tigabu, M., Eriksson, I., Sawadogo, L., and Oden, P.C. 2004. Predispersal seed predation in Acacia macrostachya, its impact on seed viability, and germination responses to scarification and dry heat treatments. New Forests. 27(3): 251-267.

Schuman, G. E., and Redente E. F. 2002. Rehabilitation of mined surfaces. In A. C. Grice and K. C. Hodgkinson (eds.), *Global Rangeland Progress and Prospects*. CABI Publishing, London, UK pp 147-156

Schwartzman, S. 1989. Extractive reserves in the Amazon. In J.G. Browders (ed), *Fragile Lands of Latin America: Strategies for Sustainable Development*. Westview Press, Boulder, pp. 150-163.

Seif El Din, A.G. 1990. Rangeland management programme: project no. OMA/87/013. UNDP/FAO, Ministry of Agriculture and Fisheries, Sultanate of Oman (Daft).

Skankar, U, Murali, K.S., Shaanker, R.U., Ganeshaiah, K.N., and Bawa K.S. 1996. Extraction of non-timber forest products in the forests of Biligiri Rangan Hills,

India. 3. Productivity, extraction and prospects of sustainable harvest of Amla, *Phyllanthus emblica* (Euphorbiaceae). *Economic Botany* 50:270-279.

Spicer, N. 1999. Pastoral mobility, sedentrization and accessibility of health services in the northeast Badia of Jordan. *Applied Geography* 19: 299-312.

Svoboda, K.P., Hampson, J.B., and Hall, L. 2001. Boswellia from Somalia, a source of high quality frankincense. *Medicinal Plant Conservation* 7:16-19.

Thomas, B. 1932. *Arabia Felix: Across the "Empty Quarter" of Arabia*. Charles Scribner's Sons. New York.

Thomas, B. 1937. *The Arabs: The Life Story of a People Who Have Left Their Deep Impress on the World*. Doubleday Doran and Co., Garden City, New York.

Thulin, M., and Warfa, A. M. 1986. The Frankincense Trees (Boswellia spp. Burseraceae) of Northern Somalia and Southern Arabia. *Kiwi Bulletin* 42(3):445-500.

Tilahun, G. 2001. *Boswellai papyrifera (Del.) hochst. From Western Tigrey: Opportunities, Constraints and Seed Germination Responses*. Swedish University of Agricultural Sciences, Skinnskatteberg (Sweden). Faculty of Forestry.

Western, D., and Maitumo, D. 2004. Woodland loss and restoration in a savanna park: a 20-year experiment. *African Journal of Ecology*. 42(2): 111-121.

Zuidema, P. A., Sayer, J. A., and Dijkman, W. 1996. Forest fragmentation and biodiversity: the case for intermediate sized conservation areas. *Environmental Conservation.* 23(4): 290-297.

http://www.mrmewr.gov.om/naturjebel.ht