SPECTRUM ANALYSIS OF THE PRODUCTION OF DATES IN THE REPUBLIC OF YEMEN

by

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DEDICATION

Dedicated to

My parents,

My wife,

&

My daughter

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First and foremost, I would like to express my sincere and heartfelt gratitude towards Allah the Almighty for endowing me with the power, courage and determination in completing my thesis. I wish to convey my most sincere appreciation to my supervisor, Dr. Anton AbdulBasah Kamil, without whose guidance it would not have been possible for me to complete this thesis in the present form. He has been a helpful guide, a severe critic and a great friend. I will always be indebted to him for his patience, understanding and advice throughout the preparation of this thesis.

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TABLE OF CONTENTS

	PAGE NUMBER
DEDICATION	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	v
LIST OF TABLES	ix
LIST OF FIGURES	xi
LIST OF SYMBOLS	xii
ABSTRAK	xiv
ABSTRACT	xvi
CHAPTER 1 - INTRODUCTION	
1.1 Background	1
1.1.1 The History and Origin of Date Palm	1
1.1.2 Areas of Date Palm Cultivation	3
1.1.3 Date Palm Cultivation in the Republic of Yemen	4
1.1.3.1 Temperature	6
1.1.3.2 Rain	6
1.1.3.3 Air Humidity	7
1.1.3.4 Wind	8
1.1.3.5 Light	9
1.2 Statement of the Problem	9
1.3 Objectives	10

1.4 The Significance of the Study 10

1.5 Research Questions 11

1.6 Limitations of the Study 11

CHAPTER 2 - LITERATURE REVIEW

2.1 Date Palm Tree 13

2.1.1 Botanical Profile 13

2.1.2 Nutritional Value 15

2.1.3 Statistics 15

2.2 Time Series 17

2.2.1 An Introduction 17

2.2.2 Wavelets Model 18

2.2.2.1 Historical Perspective 18

2.2.2.2 Wavelets Theory 20

2.2.2.3 Wavelet Transform Basics 21

2.2.2.4 Wavelet Analysis 22

2.2.3 Cobb-Douglas Production Function 24

2.2.3.1 Cobb-Douglas Theory 25

2.2.3.2 Production Theory Basics 26

2.2.3.3 Production Factors 26

2.2.4 Spectrum Analysis 27

2.2.4.1 Stationary Time Series and Periodic Functions 30

2.2.4.2 Fourier Analysis Basics 32

2.2.4.3 Some Studies Using the Spectrum Analysis Model 33

2.3 Multiple Regression 39
2.3.1 Geometrical Representation 41
2.3.2 Fit of the Multiple Regression Model 42
2.3.3 Statistical Inferences for the Model 43
2.4 Forecasting 44
2.4.1 Exponential Smoothing 45
2.4.1.1 Single Exponential Smoothing 45
2.4.1.2 Double Exponential Smoothing 47
2.4.1.3 Triple Exponential Smoothing 47

CHAPTER 3 - RESEARCH METHODOLOGY

3.1 Data Collection Sources 49
3.1.1 Hadhramout Governorate 50
3.1.2 Al-Hudayda Governorate (Tehamah Plain) 51
3.1.3 Shabwah Governorate 51
3.1.4 Al-Mahra Governorate 52
3.2 Data Collection Procedures 53
3.3 Methods of Analysis 56
3.3.1 Spectrum Analysis 56
3.3.2 The fourier and the Correlogram 58
3.3.3 Forecasting 70
3.3.3.1 Forecasting Formula 70
3.3.3.2 Bootstrapping of Forecasts 71

CHAPTER 4 - RESULTS AND DISCUSSIONS

4.1 Results 73

4.1.1 Forecasting 101

4.1.1.1 Choosing the Smoothing Constant 101

4.2 Discussions 104

CHAPTER 5 - CONCLUSION AND RECOMMENDATIONS

5.1 Summary and Conclusions 111

5.2 Recommendations 113

5.3 Future Research 115

REFRENCES 116

APPENDICES

APPENDIX 1 122

APPENDIX 2 123

APPENDIX 3 125

LIST OF TABLES

Table 2.1	Food value per 100 g of edible portion	15
Table 2.2	Date palm area and production in leading countries (2003)	16
Table 2.3	ANOVA Table for Multiple Regression	44
Table 3.1	Depicts date palm production in Yemen in (100) tonnes from 1985 to 2002	54
Table 3.2	Shows the values of time and climatic factors	55
Table 4.1	Depicts date palm production in Yemen in (100) tonnes	73
Table 4.2	Shows dates production in the Republic of Yemen by 100 tonnes during 1985-2002 and calculation of the correlation coefficient and means	75
Table 4.3	Shows the calculation of trend values measured by 100 tonnes	76
Table 4.4	Shows the calculation of coefficient of determination	77
Table 4.5	Shows the calculated values of angular frequencies (ω_i)	78
Table 4.6	Shows the calculation of the spectrum analysis results and the addition of the components	79
Table 4.7	Shows the calculated values of α_i	80
Table 4.8	Shows the calculated values of β_i	80
Table 4.9	Shows the calculation of the values of amplitude (A_i)	80
Table 4.10	Shows the calculation of θ_i, phase Φ_i, f_i and period p_i	81
Table 4.11	Shows the above results in spectrum analysis Table	82
Table 4.12	Shows the calculation of formula for each component	82
Table 4.13	Shows the calculation of the first component	83
Table 4.14	Shows the calculation of total and exponent variance after adding the first component	84
Table 4.15	Shows the calculation of the second component	86
Table 4.16	Shows the calculation of exponent variance after adding the	

	second component	87
Table 4.17	Shows the calculation of the third component	89
Table 4.18	Shows the calculation of exponent variance after adding the third component	90
Table 4.19	Shows the descriptive statistics of values in Table 3.2	92
Table 4.20	Shows the correlations between production and climate factors	94
Table 4.21	Shows the coefficients or weights of regression	95
Table 4.22	Shows the difference between the observed and predicted scores	97
Table 4.23	Shows computation of root mean square percent error (RMSPE)	98
Table 4.24	The multiple correlation coefficient and coefficient of determination	99
Table 4.25	The ANOVA table of multiple regression	100
Table 4.26	Shows some values of smoothing constant (α)	101
Table 4.27	Shows the actual, predicted and error of predicted values for (1985-2002)	102
Table 4.28	Shows the prediction of production for next five years (2003-2007)	103

LIST OF FIGURES

Figure 2.1	Shows the structure of date palm tree	14
Figure 2.2	Periodic time series	28
Figure 3.1	Shows the situation and climatic zones in Yemen	53
Figure 4.1	Shows scatter points of production by hundred of tonnes during the (1985-2002) periods	74
Figure 4.2	Depicts the trend function values	76
Figure 4.3	Shows the function after the addition of the first component	85
Figure 4.4	Depicts the fluctuation after the addition of the second component	88
Figure 4.5	Depicts the fluctuations after the addition of the third component	91
Figure 4.6	Shows the values of actual and predicted production	98
Figure 4.7	Shows the data after applying spectrum analysis and predicted data	103

LIST OF SYMBOLS

Y: Values of the production of date palms.

$\widetilde{Y}$: Values of production after added the components and trend function values.

C: The periodic component.

T: Values of time.

i: Number of values components.

N: Number of values of phenomenon.

$\sum$: The sum.

μ : The mean of the production.

$\left.\begin{matrix} A \\ \alpha \\ \beta \end{matrix}\right\}$: Amplitude: the distance from the mean value of the series to the peak.

$\left.\begin{matrix} \omega \text{ wave} \\ p \text{ period} \\ f \text{ frequency} \end{matrix}\right\}$: Period frequencies: the distance between each peak and other peak.

$\left.\begin{matrix} \phi \\ \theta \end{matrix}\right\}$: Phase: the distance between the nearest peak and the origin in time (y-axis).

$\bar{y}$: The mean of the production when computing the trend function and correlation.

$\bar{t}$: The mean of time.

R_{ty} : The coefficient of correlation.

a: Constant of the trend function.

b: Constant of trend function which affects the dependent variable.

$\sigma_{ty}{}^2$: The total variance.

$\sigma_{y_i}{}^2$: The exponent variance.

R^2: The coefficient of determination.

ANALISIS SPEKTRUM KE ATAS PENGELUARAN TAMAR DI REPUBLIK YAMAN

ABSTRAK

Kajian ini bertujuan menganalisis perubahan (naik-turun) dalam pengeluaran tamar di Republik Yaman bagi jangkamasa 18 tahun, yang dikatakan berhubung-kait dengan faktor semulajadi dan rawak. Kajian ini juga bertujuan untuk meramalkan tahap pengeluaran tamar di Republik Yaman bagi tempoh lima tahun berikutnya (2003-2007).

Untuk menganalisis permasalahan kajian ini, kaedah analisis spektrum digunakan. Keputusan yang diperolehi berdasarkan penggunaan kaedah ini diperlihatkan melalui jadual, carta dan graf yang mengutarakan perubahan-perubahan yang berlaku terhadap pengeluaran tamar dalam jangka masa yang telah ditetapkan.

Keputusan kajian menunjukkan bahawa hubungkait di antara masa dan pengeluaran tamar pada peringkat permulaan adalah tidak kukuh.

Perhubungan ini (masa dan pengeluaran) tidak dapat digunakan sebagai alat peramal yang baik untuk mengesan perubahan dalam proses pengeluaran. Sebaliknya, hubungkait antara masa dan pengeluaran tamar dapat dikenal pasti menunjukkan perubahan ketara dengan menggunakan kaedah analisis spektrum yang melibatkan penggunaan tambahan sembilan komponen tertentu.

Setiap komponen tersebut melibatkan aspek-aspek seperti perbezaan alam semulajadi, aspek semulajadi dan faktor rawak yang turut mempengaruhi proses pengeluaran tamar.

Faktor-faktor tersebut ialah seperti suhu, kelembapan relatif, hujan, cahaya, angin dan lain-lain.

Perubahan ketara dalam menjelaskan hubung kait di antara masa dan tahap pengeluaran tamar ini membenarkan data berkenaan dapat digunapakai untuk menerangkan perhubungan antara tahap pengeluaran tamar dan perubahan (turun-naik) yang bermusim dalam tempoh jangka masa 18 tahun. Dengan aras yang sama, ia dapat digunakan untuk meramalkan peningkatan dalam pengeluaran tamar bagi tempoh lima tahun berikutnya. Peramalan ini adalah berdasarkan keputusan yang diperolehi daripada penggunaan tambahan sembilan komponen tersebut dalam kaedah yang digunakan.

SPECTRUM ANALYSIS OF THE PRODUCTION OF DATES IN THE REPUBLIC OF YEMEN

ABSTRACT

This study attempts to analyse the fluctuations in the production of date palm in the Republic of Yemen within a period of eighteen years. These fluctuations are due to natural and random factors. The study also aims to predict the production in the next five years (2003-2007).

The spectrum analysis model was employed to analyse this problem. The results obtained by using this model are presented in tables, charts, and graphs which highlight the changes in date palm production over that period of time.

The results of the study indicate that the coefficient of determination between time and date palm production was initially weak. This relation cannot be utilised as a good predictor for the changes in production. On the contrary, the coefficient of determination between time and date palm production improved gradually using the spectrum analysis model which involves the addition of three components. Each component included specific parts of different natural and random factors which influence the date palm production. These factors are temperature, relative humidity, rain, light, wind and so forth.

The strong improvement in the coefficient of determination between time and production allows the data to be used to explain the relationship between production of date palms and seasonal fluctuations within a period of eighteen years (1985-2002). Similarly, it was predicted that the production will improve in the next five years (2003-2007). This

prediction was based on the results obtained from the addition of the third component in the spectrum analysis model.

CHAPTER 1

INTRODUCTION

This chapter begins with the background of the study which includes the historical perspective of date palm trees. This is followed by an overview of date palm cultivation areas in the world and geographical and agro-climatic aspects of the Republic of Yemen. The chapter concludes with a discussion on the statement of the problem, objectives of the study, significance of the study, research questions, and limitations of the study.

1.1 Background

The background of the study presents the history and origin of date palm tree. It progresses to provide an overview of areas of date palm tree cultivation in the world. It concludes by giving a sketch of the geographical and agro-climatic aspects with reference to date palm cultivation in the Republic of Yemen.

1.1.1 The History and Origin of Date Palm

It is still unknown from which plant species the date palm originates from. It may have come from a mutation among the palm of the cockscomb which inhabits vast areas ranging from West India to the Canary Islands (Al-Baker, 1972 and Jelan, 2003). However, another opinion points out that the palm is a type of wild plant and the production of the date palm is the result of a succession of natural hybridization between these different types. In addition, man played a role in the existence of palms by the continuous selection and artificial hybridization of the best types of trees. Nevertheless, these assumptions are yet unconfirmed as a palm tree has yet to be found in the wild. Moreover, there are a lot of similarities between some types of palms (Al-Baker, 1972 and Jelan, 2003). The exact origin of the date palm (Phoenix Dactylifera) is considered to be lost in antiquity. However, it is certain that the date palm was cultivated as early as 4000 B.C. since it was used for the construction of the temple of the moon god near Ur in Southern Iraq – Mesopotamia (Zaid and Jimenez, 2002). Al-Baker (1972) and Abraheem (1998c), considered the leading expert in studying the palm family, mentions that the original habitat of the palm was the Arab Gulf. Decandole (in Al-Baker, 1972), said that palm originated in the prehistoric era in the temperate and tropical region that extends from Senegal to Andalusia (Spain), which is located between latitudes 12^0N to 30^0N, therefore, investigation of the origin and habitat of palm should be carried out in the region which Decandole referred to as the most intensively cultivated date palm area.

The date palm tree, Genus Phoenix, which is from the palmaceae family, is one of the most important fruit trees in the Republic of Yemen. Its history in Yemen can be traced back to about 7000 years ago (Aljuraidi, 2002).

Finally and from a spiritual perspective, the religion that has stressed the holiness of the date and date palm is Islam. The Holy Quran mentioned the date and date palm in 17 Suras (chapters), of the original 114 Suras and 20 verses of 6,263 verses (Zaid and Jimenez, 2002, Bin-Break, 2002, Abraheem, 1998a, Al-hilali, 1417A.H and Al-Hadrami, 1992).

(Bakhwar, 1998b, Abraheem, 1998b, Falhoom, 2002 and Al-Baker, 1972) Prophet Muhammed (P.B.U.H) is reported to have said that the best property is the date palm. He also stated that dates are a palliative for many disorders, and he enjoined Muslims to eat the date and tend it with care.

1.1.2 Areas of Date Palm Cultivation

The date palm is one of the oldest and most well-known agricultural products in the world. It has great social and economic value. Moreover, it is an essential source of required nutrients that provides human beings with the energy for physical activities. It is worth mentioning that accurate statistics on the number of date palms are not always available and not easy to compile. However, the total number of date palms in the world is approximately 100 million, distributed in 30 countries, and producing between 2.5 and 4 million tonnes of fruit per year (Zaid and Jimenez, 2002 and Medhej, 1998).

Asia occupies the first position in global date palms distribution, with 60 million date palms (Saudi Arabia, Bahrain, UAE, Iran, Iraq, Kuwait, Oman, Pakistan, Turkmenistan and Yemen, etc.); while Africa is in the second position with 32.5 million date palms (Algeria, Egypt, Libya, Mali, Morocco, Mauritania, Niger, Somalia, Sudan, Chad and Tunisia, etc.). In terms of countries, Iraq leads with 22 million palms, followed by Iran, 21 million and Saudi Arabia, 12 million, Algeria, 9 million, Egypt and Libya, 7 million each, Yemen, 5 million, Pakistan and Morocco, 4 million each. The remaining date growing countries have less than 1 million palms each (Zaid and Jimenez, 2002 and Falhoom, 2002). Mexico and the USA have 600,000 palms followed by Europe (Spain) with 32,000 and Australia with 30,000 (Zaid and Jimenez, 2002).

However, date growing countries located in the southern area of the Mediterranean Sea have approximately 35 million palms (35% of the world's total). The total acreage of date palm cultivation in the world has increased more than threefold (from 238,522 ha in 1961 to 770,795 ha in 1996) during a 35 year period which amounts to an average annual increase of about 8.6% in date palm acreage. In 1996, the top 11 producing countries with regard to harvested areas were: Iran (153,000 ha), Iraq (116,000 ha), Saudi Arabia (95,000 ha), Algeria (87,000 ha), Pakistan (73,915 ha), Morocco (44,400 ha), United Arab. Emirates (31,005 ha), Tunisia (29,480 ha), Oman (28,000 ha), Egypt (26,000 ha) and Yemen (15945 ha). The total cultivated acreage of these 11 countries comprises approximately 88% of the world's total cultivated area (Zaid and Jimenez, 2002 and Baghizal, 2002).

Regarding planting density, there is again a controversy about the prevailing cultivation systems. There are modern plantations with fixed spacing as in the case of Tunisia or the forest-type traditional planting system as in the case of Morocco, Pakistan, Somalia, for example. In each case, the planting density varies tremendously from 50 palms/ha (Morocco and Bahrain) to 577 palms/ha (Somalia). Between these two extremes, there are Yemen, Algeria, Libya and Tunisia with density values of 400, 200, 254 and 133 palms/ha, respectively (Zaid and Jimenez, 2002 and Baghizal, 2002).

1.1.3 Date Palm Cultivation in the Republic of Yemen

The Republic of Yemen is located in the southwest corner of the Arabian Peninsula covering a land area of 537,000 km^2. According to the 1994 census, the total population of the country is estimated at 15.8 million, with an annual growth rate of 3.7% and a population density of 28/km^2. The five main Agro-ecological zones reflect variations of the elevation from sea level to about 3,700 m and give rise to five Agro-ecological regions: The Coastal Low Lands, the Southern Uplands, the Central Highlands, the Northern Highlands and the Eastern Region (El-Hassan, 2000).

The Agro-climatic conditions in Yemen are classified as semi-arid, arid, and extremely arid. The aridity depends on the topographical features. More rain and luxuriant vegetation with rich bio-diversity are related to altitude, aspect, edifice and biotic factors (Munibari *et al.*, 1998). Agriculture is still largely subsistence oriented and heavily dependent on climatic conditions. Effects of climate and other environmental factors resulted in diversity and heterogeneity of the vegetative cover structure and its density. This led to diversity in natural vegetation. This diversity can be classified according to topography into five zones: coastal areas, southern uplands, northern highlands, central uplands and Hadhramout plateau rangelands (El-Gouri *et al.*, 1996 and Khanbarei, 2002). There is a great variation in the annual rainfall; the coastal area receives 50-100 mm of rainfall. In comparison, the highlands receive more rainfall of between 400-1000 mm. Despite the shortage of rainfall, the coastal area contributes approximately 39% to the total agricultural production of the country. It has been reported that rain dependant agriculture has decreased by 40%. Consequently, up to 30,000 wells have been bored in Yemen and most of these wells are used for irrigation (Munibari *et al.*, 1998).

The climate in Yemen, especially in the date palm cultivation areas, is characterized as tropical with two distinctive seasons; a hot season from April to September with a maximum temperature of 39.8^{0}C and a cold season from October to March with a minimum temperature of 14.9^{0}C (Medhej, 2002).

More importantly, there are different climatic factors that influence date growth and production in Yemen. These factors are temperature, rain, air humidity, wind and light. The following sections explain the effect of each of these factors on date production.

1.1.3.1 Temperature

Temperature is considered the first climatic factor which affects the growth of dates. The date growing areas are located in the regions with the highest maximum temperatures and low humidity.

The mean annual temperature ranges from less than 12^0C in the highlands to above 30^0C in the coastal areas. In summer, the temperature may rise up to 40^0C in the low lands and above 40^0C in the deserts of the eastern region. In winter, the temperature may decrease below zero ^{0}C in the highlands, ranging from 30^0C in arid zones of the eastern region to above 45^0C in coastal areas. Generally, temperatures decline in winter between January and April (El-Gouri *et al.*, 1996). The daily evaporation and relative humidity are related to the temperature and atmospheric pressure of the day and the monsoon season (Al-Gahwari, 2003).

1.1.3.2 Rain

Rain has an effect on pollination and fruiting. After pollination, rain is considered as a cleansing agent that washes away most of the applied pollen. Another negative effect of rain on fruiting, results from low temperatures that accompany or follow rain. A third factor is the reduction of the flower's receptivity when in contact with water (Zaid and Jimenez, 2002).

Date growers must assume that the rain will affect pollination/fruiting and any pollination process must be repeated within 4 to 6 hours if preceded or followed by rain. Rain is also responsible for increasing relative air humidity, thus creating favourable conditions for cryptogrammic diseases that result in the rotting of inflorescences (Zaid and Jimenez, 2002).

In Yemen, in areas of date palm cultivation, rainfall and evaporation in spring and autumn, on an average, do not exceed 76 mm. In fact, rainfall may exceed 100 mm between once to 16 times annually (Falhoom, 2002, Mahdar, 1998, Khanbarei, 2002 and Rweeshed and Raweeshed, 1998).

1.1.3.3 Air Humidity

Air humidity is considered as the third climatic factor where various advantages and/or disadvantages are found. The date palm ecosystem is mostly of an arid nature where relative humidity has a large influence (Zaid and Jimenez, 2002). Relative humidity also affects date quality during the maturation process. At high humidity, fruits become soft and sticky, while at low humidity they become very dry. This phenomenon is further strengthened when low humidity is coupled with wet and dry winds. The relative air humidity in Yemen is about 46% and the number of the daily sunny hours is 9.5 per day (Medhej, 2002).

1.1.3.4 Wind

Another influential factor is the wind which carries dust and sand that adheres to the date fruits in their soft stage (Rutab and Tamar). In most date growing areas, the latter part of the pollination season is usually characterized by severe hot and dry winds, which dry out the stigmas of the female flowers. Cold winds disturb the pollen germination. The falling down of an old date palm may be caused by strong winds but only in the following cases (Zaid and Jimenez, 2002):

- if the palm is very tall with a large crown and grows in shallow soil;
- if a large number of offshoots are removed from the trunk of a palm at one time leaving the palm without basal support; and
- if rats have gnawed away the roots on one side of the palm.

In Yemen, the strength of the wind may cause the dates to fall, break some date bunches, and perhaps cause the fall of weak trees under certain circumstances. On the one hand, wind also help in spreading some diseases such as *Oligonychus Afrasiaticus* (Abdahoseen, 1985, Baangood and Bashieh, 1998 and Obad *et al.*, 2003). However, it may help in the pollination, carrying the seeds between flowers; probably from one date palm to another. It is preferable that tall trees be planted in the cultivated areas to serve as wind breakers as strong wind are liable to damage date palm.

1.1.3.5 Light

The growth of the date palm is inhibited by light rays at the violet and yellow end of the spectrum, but enhanced by rays at the other end of the spectrum i.e. red light. These latter rays are most active in promoting photosynthesis.

Clouds could reduce light intensity, but unfortunately, the sky is un-clouded in the date growing countries during the ripening period (July to October in the Northern Hemisphere and February to May in the Southern Hemisphere) (Zaid and Jimenez, 2002).

1.2 Statement of the Problem

As mentioned in Section 1.1.3, several climatic factors and constraints might affect the future of Yemen date palm industry, including:

- The increase in the average rainfall
- The strength of air humidity
- The percentage of temperature
- Wind
- The intensity of light

Such climatic factors and changes affect the production of dates negatively which led to frequent production fluctuations. These date production fluctuations, in turn, affect the national and personal incomes of the Yemeni farmers. Therefore, it is necessary to study these fluctuations with an appropriate model to solve this problem. To this end, spectrum analysis by Fourier time series was utilized because it is regarded to be the best model in analyzing fluctuation phenomena which help in improving the level of production (Hujeir, 1997 and Bolch and Huang, 1974). This model will be discussed in more detail in Chapter Two.

1.3 Objectives

The main objective of this study is to look at the possibility of using the spectrum analysis model to analyse the production of date palms in the Republic of Yemen. Under the climatic conditions specifically, the study aims:

- To investigate the fluctuations in date production.
- To identify the causes for these fluctuations.
- To forecast the dates production in Yemen for several years.

1.4 The Significance of the Study

As mentioned in Section 1.1.3, date palm cultivation in Yemen has a long history. Yet, the efforts exerted by the Yemeni researchers on date palm production although significant, are still insufficient and fall below expectations. In general, the product quantity is still low, the field and post-harvest losses are high and the date products and by products utilization need improvement. Therefore, the current status of date palm cultivation in Yemen and the enhancement of production can be overemphasized.

To address the above mentioned constraints, Yemen ranked date palm as one of high research priority as reflected in the priority setting for agricultural research in Central and West Asia and North Africa. Therefore, the study on fluctuations in the production of dates, in Yemen, is still very minimal and there is no statistical study that has been done yet in this domain. This study is significant since it is the first study that addresses these issues. Research literature in this area is minimal. Moreover, there are not many studies being carried out, using the adopted model in this study- Spectrum Analysis Model. Therefore, it is necessary that more studies are conducted in this area.

1.5 Research Questions

The main questions of this study are:

- What were the fluctuations in date production in Yemen?
- Why did these fluctuations occur?
- How will production during the coming five years become?

1.6 Limitations of the Study

This study focused on fluctuations of date palm production within a specific period of time (1985-2002). Here, it is worth mentioning that the first year of the study (1985) was chosen on the basis that it was the year for which full data records were found on date production in the Republic of Yemen compared to its preceding years.

The study was restricted only to date production and it did not deal with climate and workers data where the adopted model studies the fluctuations of date palm production within the aforementioned period of time. This model investigates the effect of natural and random factors on the production. The effect was identified through the increase in the value of the coefficient of determination between production and time after adding the spectrum analysis components. In other words, if the coefficient of determination improves, this indicates that the production is affected by the natural and random factors and vice versa.

In this study, the single exponential smoothing method was used to predict the production of date palm from the year 2003 to 2007. The reason for adopting this method was that the available data was limited. For further information see Section 3.2, Chapter 3.

CHAPTER 2

LITERATURE REVIEW

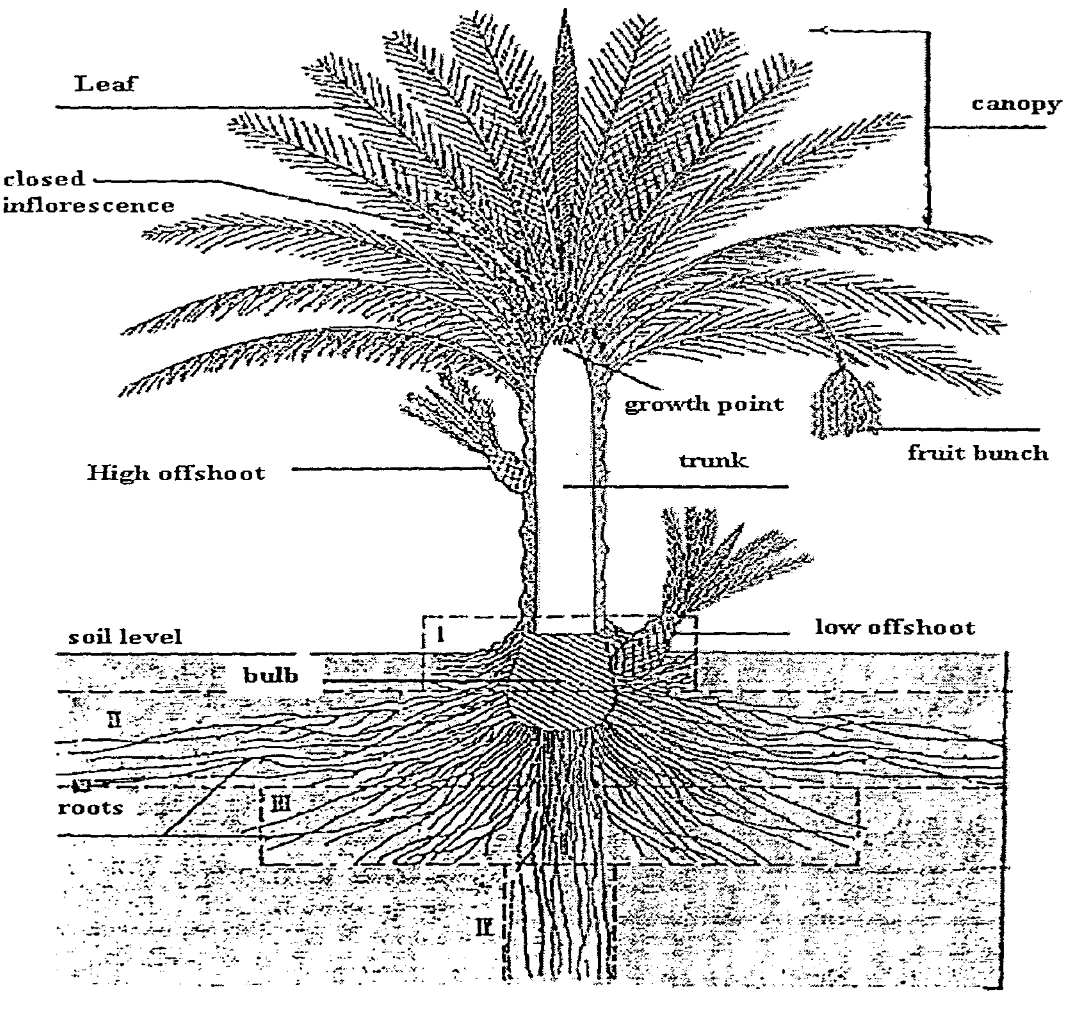
This chapter begins with a brief overview of the date palm tree. This is followed by a discussion on some models of time series, i.e. the Wavelets model, the Cobb-Douglas production function model and the spectrum analysis model. This is followed by a summary of some studies using the spectrum analysis mode!. Then, the chapter presents with an emphasis on the spectrum analysis model and justifies the adoption of such a model as a theoretical basis for the present study. Then, the chapter presents a multiple regression model. The chapter concludes with a discussion on the single exponential method which was employed in forecasting date palm production in Yemen.

2.1 Date Palm Tree

In the Arabian Peninsula (AP) in which Yemen is situated, date palm varieties had evolved over a long period, to adapt with environmental conditions. It is the most tolerant tree to the harsh environments of the AP. The next sections describe the botanical structure of the tree, culture and propagation of date palm, nutritional value of dates, statistics of date palm tree, and climatic requirements of date palm.

2.1.1 Botanical Profile

Date Palm belongs to the species *Phoenix Dactilyfera* and has about 19 known genetic relatives. The most important ones are Canary Island Palm (P. canariensis); Senegal Date Palm (P. reclinata) and Indian Sugar Date Palm (P. sylvestris). The genus Phoenix belongs to the plant family Arecaceae and all are Monocotyledons (William *et al.*, 2005). Date palms are dioecious; i.e. the male and female parts are on separate plants. The date palm is the tallest of the Phoenix species growing up to 30m in some places. The trunk, in cultivation, is surrounded from the ground upwards in a spiral pattern of leaf bases. The leaf fronds are large, 4-5m, alternate, sheathing in dense terminal rosette; the ends of leaf fronds are needle sharp protecting the growth tips from grazing animals. The fruit is a Berry type (known also as Drupe) with a single seed in each fruit. The fruit is born on clusters called Bunches and it is the largest among all other species, with a few varieties reaching up to 100x40 mm in size. From the time of pollination, the fruit takes 150 - 200 days to reach the fully ripened stage (Tamar stage). A fully productive palm can support 8 – 10 bunches weighing as much as 60 – 100 kg (Kasapis, 2004 and Hodel and Pittenger, 2003).



Source: Brreveld, 1993 and Zaid and Jimenez, 2002

Figure 2.1: Shows the structure of date palm tree

2.1.2 Nutritional Value

Dates are rich in sugar ranging from 65% to 80% on dry weight basis mostly of inverted form (glucose and fructose). Fresh varieties have a higher content of inverted sugars; the semi dried varieties contain equal amounts of inverted sugars and sucrose, while the dried varieties contain higher amounts of sucrose. Water content is between 7% (dried) and 79% (fresh) depending on the variety (William *et al.*, 2005 and Kasapis, 2004).

Table 2.1: Food value per 100 g of edible portion

	Fresh	Dried		Fresh	Dried
Calories	142	274 -293	Phosphorus	350 mg	63 - 105 mg
Moisture	31.9- 78.5 g	7.0 - 26.1	Iron	6.0 mg	3.0 - 13.7 mg
Protein	0.9- 2.6 g	1.7 -3.9 g	Potassium	-	648 mg
Fat	0.6- 1.5 g	0.1 - 1.2 g	Vitamin A (ß carotene)	110-175 mcg	15.60 mg
Carbohydrates	36.6 g	72.9 - 77.6 g	Thiamine	-	0.03 - 0.09 mg
Fiber	2.6- 4.5 g	2.0 - 8.5 g	Riboflavin	-	0.10 - 0.16 mg
Ash	0.5- 2.8 g	0.5 - 2.7 g	Niacin	4.4-6.9 mg	1.4 - 2.2 mg
Calcium	34 mg	59 - 103 mg	Tryptophan	-	10 - 17 mg

Source: FAO, 2004

2.1.3 Statistics

Date fruit is produced in hot arid regions of the world and is marketed all over the world as a high value confectionery. It is considered an important subsistence crop in most of the desert areas.

Worldwide date production has increased exponentially over the last three decades. In 1963, production was 1.8 million tonnes which increased to 2.6 and 6.7 millions by 1983 and 2003, respectively. The increase of 4.9 million tonnes since 1963 represents an annual expansion of about 6.8%.

The top five producing countries in 2001 were Egypt, Iran, Saudi Arabia, Pakistan and Iraq (FAO statistics 2002). This represents 69% of total world production. If the next six most important countries are included, i.e. Algeria, United Arab Emirates, Sudan, Yemen, Oman, and Morocco, then this percentage rises to 90%. This clearly indicates that most of the world's date production is concentrated in a few countries in the same region.

Most of the major date producing countries had steadily expanded production over the last 10 years, representing an increment of 43% over the period 1994 to 2001. Date exports increased by only 25%, over the same period, especially in Oman, United Arab Emirates, Egypt and Pakistan. Conversely, an output decrease has been observed in Iraq and Morocco. In the Arab world, total date production is estimated to be 4,511,494 tonnes in 2003 (total production for Iraq is estimated at 400,000 tonnes, (FAO, 1997) representing 67% of the global date production.

Some countries produced 1.9 million tonnes in 2003, which represent 28% of the global production (FAO, 2004). Saudi Arabia and Emirates together produced 1.6 million tonnes in 2003.

Table 2.2: Date palm area and production in leading countries (2003)

Countries	Production (Mt)	%	Countries	Production (Mt)	%
World	6,749,356	100.0	Yemen	32,500	0.5
Egypt	1,115,000	16.5	Mauritania	24,000	0.4
Iran	875,000	13.0	Chad	18,000	0.3
Saudi Arabia	830,000	12.3	USA	17,600	0.3
UAE	760,000	11.3	Bahrain	16,508	0.2
Pakistan	650,000	9.6	Qatar	16,500	0.2
Algeria	420,000	6.2	Kuwait	10,400	0.2
Iraq*	400,000	5.9	Turkey	9,400	0.1
Sudan	330,000	4.9	Niger	7,700	0.1
Oman	238,611	3.5	Palestine,	5,500	0.1
Libyan	140,000	2.1	Spain	3,732	0.1
China	120,000	1.8	Mexico	3,600	0.1
Tunisia	115,000	1.7			
Morocco	54,000	0.8	Others	536,305	7.9

Source: FAO statistics, 2003

2.2 Time Series Analysis

2.2.1 An Introduction

Time series analysis and its applications have become increasingly important in various fields of research, such as business, economics, engineering, medicine, environometrics, social sciences, politics, and others. Olson (2000) mentions that since Box and Jenkins (1970, 1976) published the seminal book *Time Series Analysis: Forecasting and Control*, a number of books and a vast number of research papers have been published in this area.

A time series is a collection of observations of well-defined data items obtained through repeated measurements over time. An observed time series can be decomposed into three components: the trend (long term direction), the seasonal (systematic, calendar related movements) and the irregular (unsystematic, short term fluctuations) (Liang, 2002).There are several techniques that are useful for analyzing time series data. These techniques include sequences of measurements that follow non-random orders. Unlike the analyses of random samples, according to Hujeir (2001), the analysis of time series is based on the assumption that successive values in the data file represent consecutive measurements taken at equally spaced time intervals.

Time series analysis has two main goals: (a) identifying the nature of the phenomenon represented by the sequence of observations, and (b) forecasting (predicting future values of the time series variable) (Bolch and Huang, 1974). Both of these goals require that the pattern of observed time series data is identified and more or less formally described. Once the pattern is established, it can be interpreted and integrated with other data (i.e., use it in our theory of the investigated phenomenon, e.g., date palm fluctuations). Regardless of the depth of our understanding and the validity of our interpretation (theory) of the phenomenon, the identified pattern can be extrapolated to predict future events (Hameza, 1994 and Al-Jaaony *et al.* 1998). Most importantly, there are different models used for the study of time series. In this study, some of these models will be focused on, e.g. the wavelets model, the Cobb-Douglas model, and the spectrum analysis model.

2.2.2 Wavelets Model

Wavelets are mathematical functions that cut up data into different frequency components, and then study each component with a resolution matched to its scale. Cody (1994) states that such functions have advantages over traditional Fourier methods in analyzing physical situations where the signal contains discontinuities and sharp spikes. Wavelets were developed independently in the fields of mathematics, quantum physics, electrical engineering, and seismic geology. Interchanges between these fields during the last ten years have led to many new wavelet applications such as image compression, turbulence, human vision, radar, and earthquake prediction (Frazier, 1999).

2.2.2.1 Historical Perspective

In the history of mathematics, wavelet analysis shows many different origins (Meyer, 1993). According to Meyer, much of the work was performed in the 1930s, and, at the time, the separate efforts did not appear to be parts of a coherent theory. Before 1930, the main branch of mathematics leading to wavelets began with Joseph Fourier (1807) with his theories of frequency analysis, now often referred to as Fourier synthesis. He asserted that any *2x* periodic function *f(x)* is the sum

$$a_0 + \sum_{k=1}^{\infty}\left(a_k \cos kx + b_k \sin kx\right) \qquad (2.1)$$

of its Fourier series. The coefficients a_0, a_k, and b_k are calculated by

$$a_0 = \frac{1}{2\pi}\int_0^{2\pi} f(x)dx\,,\ a_k = \frac{1}{\pi}\int_0^{2\pi} f(x)\cos(kx)dx\,,\ b_k = \frac{1}{\pi}\int_0^{2\pi} f(x)\sin(kx)dx \qquad (2.2)$$

Fourier's assertion played an essential role in the evolution of the ideas mathematicians had about the functions. He opened up the door to a new functional universe. After 1807, by exploring the meaning of functions, Fourier series convergence, and orthogonal systems, mathematicians gradually were led from their previous notion of frequency analysis to the notion of scale analysis. It turns out that this sort of scale analysis is less sensitive to noise because it measures the average fluctuations of the signal at different scales (Meyer, 1990 and Candes, 1998).

The first mention of wavelets appeared in an appendix to the thesis of A. Haar (1909). One property of the Haar wavelet is that it has compact support, which means that it vanishes outside of a finite interval. Unfortunately, Haar wavelets are not continuously differentiable which somewhat limits their applications. In the 1930s, several groups working independently researched the representation of functions using scale-varying basis functions. Understanding the concepts of basis functions and scale-varying basis functions is the key to understanding wavelets. By using a scale-varying basis function called the Haar basis function, Paul Levy, a 1930s physicist, investigated the Brownian motion, a type of random signal (Meyer, 1993 and Wickerhauser, 1994). They found the Haar basis function superior to the Fourier basis functions for studying small complicated details in the Brownian motion. Another 1930s research effort by Littlewood, Paley, and Stein involved computing the energy of a function *f(x)*:

$$energy = \frac{1}{2}\int_0^{2\pi} |f(x)|^2 dx \qquad (2.3)$$

The computation produced different results if the energy was concentrated around a few points or distributed over a larger interval. This result disturbed the scientists because it indicated that energy might not be conserved. The researchers discovered a function that can vary in scale and can conserve energy when computing the functional energy. Their work provided David Marr with an effective algorithm for numerical image processing using wavelets in the early 1980s.

Between 1960 and 1980, mathematicians Guido Weiss and Ronald R. Coifman studied the simplest elements of a function space, called atoms, with the goal of finding the atoms for a common function and finding the "assembly rules" that allow the reconstruction of all the elements of the function space using these atoms. In 1980, Grossman and Morlet, a physicist and an engineer, broadly defined wavelets in the context of quantum physics. These two researchers provided a way of thinking for wavelets based on physical intuition (Donoho and Duncan, 2000).

In 1989, Stephane Mallat gave wavelets an additional jump-start through his work in digital signal processing. He discovered some relationships between quadrature mirror filters, pyramid algorithms, and orthonormal wavelet bases (more on these later). Inspired in part by these results, Meyer (1993) constructed the first non-trivial wavelets. Unlike the Haar wavelets, the Meyer wavelets are continuously differentiable; however they do not have compact support. A couple of years later, Ingrid Daubechies used Mallat's work to construct a set of wavelet orthonormal basis functions that are perhaps the most elegant, and have become the cornerstone of wavelet applications today.

2.2.2.2 Wavelets Theory

The Wavelet theory is also a form of mathematical transformation, similar to the Fourier Transform (FT) in that it takes a signal in time domain, and represents it in frequency domain. Wavelet functions can be distinguished from other transformations in that they not only dissect signals into their component frequencies, but also vary the scale at which the component frequencies are analyzed. Therefore wavelets, as component pieces used to analyze a signal, are limited in space. In other words, they have definite stopping points along the axis of a graph--they do not repeat to infinity like a sine or cosine wave does (Wickerhauser, 1994). As a result, working with wavelets produces functions and operators that are "sparse" (small), which makes wavelets excellently suited for applications such as data compression and noise reduction in signals. The ability to vary the scale of the function as it addresses different frequencies also makes wavelets better suited to signals with spikes or discontinuities than traditional transformations such as the FT.

2.2.2.3 Wavelet Transform Basics

Basically, the wavelet transform (WT), according to Mallat, (1999), Truchetet (1998), Vetterli and Kovacevic, (1995), Unser and Blu (2003), WT is a means of obtaining a representation of both time and frequency content of a signal. But in WT, the window function width is dependent on the central frequency. Therefore, for a given analysis function, the best trade-off between time and frequency resolution can be automatically obtained. A wavelet is a kernel function used in an integral transform. The wavelet transform (WT) of a continuous signal *x (t)* is given by:

$$W_{a,b}(x) = \int_{-\infty}^{+\infty} x(t)\psi^{*}{}_{a,b}(t)dt \qquad (2.4)$$

with the wavelet function defined by dilating and translating a "mother" function as:

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right) \qquad (2.5)$$

$\psi(t)$ being the "mother" wavelet, *a* is the dilation factor and *b* is the translation parameter (both being real positive numbers). For practical reasons, these parameters are often discretized leading to the so-call discrete wavelet transform (DWT). After discretization the wavelet function is defined as:

$$\psi_{j,k}(t) = 2^{-\frac{j}{2}}\psi(2^{-j}t - k) \qquad (2.6)$$

The DWT is given by the inner product between signal and wavelet; the result being a series of coefficients:

$$d_x(j,k) = \langle x, \psi_{j,k} \rangle \qquad (2.7)$$

j and *k* being integer scale and translation factors. Daubechies (1992) and, in another manner, Sweldens (1995), gave way to fast algorithm implementation of DWT (the only one to be in use for computer imaging applications).

2.2.2.4 Wavelet Analysis

According to Liang (2002), the Wavelet analysis is to decompose a given function $x(t) \in L2$ into a sum of wavelet functions. It involves a mother wavelet $\psi(t)$, which may be any real or complex continuous function that satisfies certain conditions, such as

$$\int_{-\infty}^{\infty} \psi(t)dt = 0 \text{ and } \int_{-\infty}^{\infty} \psi(t)^2 dt \leq \infty \qquad (2.8)$$

Then, wavelets are themselves derived from their mother wavelet $\psi(t)$ by translations and dilations. The Haar function can be a mother wavelet defined by

$$\psi(t) = \begin{cases} 1, & for \ 0 \leq t \leq 1/2 \\ -1, & for \ 1/2 \leq t \leq 1 \\ 0, & otherwise \end{cases} \qquad (2.9)$$

Another commonly used wavelet is the Morlet wavelet defined as

$$\psi(t) = e^{-t^2}\cos(\pi t\sqrt{2/\ln 2}) \cong e^{-t^2}\cos(2.885\,\pi t) \qquad (2.10)$$

Given a mother wavelet $\psi(t)$, an infinite sequence of wavelets can be constructed by varying translations *b* and dilations *a* as below

$$\psi_{a,b}(t) = |a|^{-1/2} \psi(\frac{t-b}{a}) \qquad (2.11)$$

By defining the continuous wavelet transform *W (a, b)* as

$$W(a, b) = \pi \; x(t), \psi_{a,b}(t) \; \phi = \int_{-\infty}^{\infty} x(t) \psi_{a,b}(t) dt, \qquad (2.12)$$

x (t) can be represented as

$$x(t) = \frac{1}{C_1} \int_{0}^{\infty} \int_{-\infty}^{\infty} a^{-2} W(a, b) \psi_{a,b}(t) da db \qquad (2.13)$$

Where $C_1 = \int_{-\infty}^{\infty} \frac{|\psi(\omega)|^2}{\omega} dt$ and $\psi(\omega) = \int_{-\infty}^{\infty} \psi(t) e^{-i\omega t} dt$ (2.14)

When *a* and *b* take on discrete sets of values, the discrete wavelet transform can be obtained similarly as

$$W(m, n) = \pi \; x(t), \psi_{m,n}(t) \; \phi = \int_{-\infty}^{\infty} x(t) \psi_{m,n}(t) dt, \qquad (2.15)$$

and $x(t) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} W_{m,n} \psi_{m,n}(t)$ (2.16)

For an equally spaced time series data *x = (x (1), x(2), ..., x(N))*, approximate wavelet transforms can be taken by replacing (2.15) by an estimate such as:

$$W(m, n) = \int_{-\infty}^{\infty} x(t) \psi_{m,n}(t) dt \qquad (2.17)$$

$$\approx \sum_{I=1}^{N} x(I) \psi_{m,n}(I).$$

It follows that a class of discrete wavelet transform (DWT) for equally spaced time series data can be implemented by using an efficient computational algorithm (Bruce and Gao, 1996).

Finally, the wavelet analysis is very powerful and efficient in the analysis of data or functions, *x (t)* with gradual frequency changes. However, wavelets are not periodic functions. For example, the Morlet wavelet is Fourier based but its oscillations are dampened by the exponential factor e^{-t^2}. Interestingly, the concepts of frequency and periodicity have no precise meaning in wavelet analysis (Priestley, 1996).

2.2.3 Cobb-Douglas Production Function

The early history of the concept is not so well known. Textbooks and survey articles largely ignore an extensive body of eighteenth and nineteenth century work on production functions (Humphrey, 1997). Instead, they typically start with the famous two-factor Cobb-Douglas version

P = b[L.sup.k][C.sup.1-k] (2.18)

That version dates from 1927 when University of Chicago economist Paul Douglas, and professor Charles W. Cobb suggested an equation describing the relationship among the time series on manufacturing output, labour input, and capital input that Douglas had assembled for the period 1889-1922.

For production, the function is $Y = AL^{\alpha} K^{\beta}$ (2.19)

Where:

- *Y* = output
- *L* = labour input
- *K* = capital input
- *A*, α and β are constants determined by technology.

If α plus β = 1, the production function has constant returns to scale (if *L* and *K* are increased by 20%, *Y* increases by 20%). If α plus β is less than 1, returns to scale are