Multi-period dynamic programming analysis determining the optimal replanting age of date palm

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ABSTRACT

The government of Oman has implemented a program to rejuvenate the sector by planting 1 million date palms. Date palm could be planted as new-plantings requiring additional land, water and other resources and/or be replanted substituting aged and unproductive palms without additional commitment the resources. Replanting of perennial crops is an agronomic practice that maximizes and sustains long-term benefits. Although the optimal age of replanting of several perennial crops have been scientifically estimated, the optimal age to replant date palm has not yet been scientifically examined. This study estimated the optimal age to replant date palm. Two alternative analytical models were used to estimate the optimal age of replanting of date palm, namely; Comparison of Equivalent Annual Net Revenue (CEAN) and Multi-Period Dynamic Linear Programming Model (MPDLP). Solution procedures of both models are based on the theory of optimal replacement of capital assets. Data on date palm age-yield relationship and other socio-economic variables were gleaned through a farm survey of 34 large commercial farms, in the Al-Dakhilya governorate. The study estimated the optimal age of replanting date palm as 50-55 years. The optimal age to replant date palm was sensitive only to changes in the interest rates. Low interest rates shortened the optimal age of date palm replanting. The study derived the optimal replanting schedule for date palm for Oman. The incremental revenue to Oman through replanting was estimated to be 7 million OR/ year.

Key words: Interest rates, replacement of capital assets, perennial crops, Sultanate of Oman.

INTRODUCTION

Date palm, which is a perennial crop is culturally, socially and economically the most important fruit crop in the Sultanate of Oman. The Sultanate is ranked ninth in world date *(Phoenix dactylifera L.)* production with a production of 255,871 tons, which represents 3.63% of the world production (FAOSTAT, 2010). Since year 2000 date production has stagnated and/ or declined. Some factors that have contributed to the reduction of date production are the non-availability of skilled labor to carry out field operations, occurrence of pests and diseases, harvest and post-harvest loses and degradation of soil and water quality (Al-Yahyai, 2007). The government of Oman through a decree by His Majesty the Sultan of Oman has embarked on a program of planting one million date palm trees, to rejuvenate the date sector. The planting of date palms could either be on new lands, or be replanting of old unproductive date palms in existing agricultural lands. Replanting of unproductive old plants is an agronomic practice in perennial crop management to maximize and sustain income overtime. Further replanting does not require substantial incremental resources than presently committed. This is particularly important in the Sultanate of Oman where water is extremely scarce. Replanting of date palm provides an opportunity to use the presently committed resources and improve farms towards economic production systems, which will improve the livelihood of farm dependents and increase the contribution to nation's national income. However the agronomic practice of replanting of date palm has not been formally adopted and promoted in the Sultanate of Oman.

Though research literature is replete with methodologies to estimate the optimal replanting age for many other perennial crops, there is no reported research on estimation of the optimal age for replanting of date palm. An estimate of the optimal age of replanting of date palm could contribute in the short-term to the replanting of date palms through one million date palm project and in the long-term the method of analysis and the estimate of optimal replanting age could be adopted by extension services to guide farmers to improve and sustain farm incomes and livelihoods. Replanting of date palm could maximize and sustain income from farming. The objectives of this study are as follow.

1. Estimate the optimal age to replant date palm, through two economic models [Comparison of Equivalent Annual Net Revenue (CEAN) model and Multi-Period Linear Programming Model (MPLP)].
2. Estimate the incremental income that could be obtained through replanting of date palm.
3. Recommend a schedule of optimal age-replant date palm in existing farms to improve income in the Sultanate of Oman.

The earliest and widely quoted research source on proposing analytical techniques to determine optimum replacement age of assets is by (Faris, 1960). The paper presents decisions rules that could be followed in deciding the replacements of assets that have: a short production period with revenue being realized by the sale of the asset (ex: buying and selling feeder cattle); a long production period with revenue being realized by the sale of the asset (ex: forestry); a long production period with revenues being realized throughout the life of the asset (ex: orchards; perennial crops including date palms). The rule of replanting for such crop assets as (Faris, 1960) derives is that the optimum replanting age is when the annual net revenue from "present" trees is equal to the anticipated amortized present value of the net revenue from the "future" trees. (Perrin, 1972) has through mathematical derivations clearly derived and confirmed on continuous time scenario the principles of decision making on asset replacement that was proposed by (Faris, 1960) on discrete scenario.

Analytical methods

Two alternatives analytical methods, using the principles of decision making on asset replacement have been developed and used in this study to estimate the optimal replanting age of date palm. These methods are referred to as Comparison of Equivalent Annual Net revenues (CEAN) and Multi-Period Dynamic Linear Programming (MPDLP) model. The analysis of CEAN model is restricted to data related to a single palm whilst the MPDLP model could analyze a date palm farm with palms of different ages.

Comparison of Equivalent Annual Net Revenues (CEAN) Model

The principles on decision making of asset replacement that were proposed by (Faris, 1960) have been mathematically elucidated by (Perrin, 1972). (Etherington, 1977) has applied (Perrin's, 1972) mathematical exposition on principles on decision making of asset replacement, to analyses decision making of replanting rubber trees. This study has adopted (Etherington's, 1977) exposition to explain the economic principles of deciding the age of replanting of date palm.

Multi-Period Dynamic Linear Programming (MPDLP) Model

Agricultural decision making of particularly perennial crops is characterized with multiple year dynamics, where a present activity/decisions influence future activity/decisions (McCarl and Spreen, 1997). In this study the decision to replant or (not-replant) date palm in a given year (i.e. the time path of replanting) has an influence on the future flow of net revenue from date palm. The easiest way of developing models that incorporate time is to extend the linear models developed from single period models. Using this format, multi-period models can be thought of as a series of single-period models linked by dynamic constraints or "equations of motion" that link the periods. (MPDLP) Models are widely known and used in agricultural systems modeling (Romero and Rehman, 1989). MPDLP models recognize inter temporal linkages in farm activities and maximizes the net present value of profit (or an appropriate objective) given constraints of resources overtime. Each time period is linked through availability of resources and activities as appropriate. In designing MPDLP models decisions ought to be taken on, length of the time horizon, length of intervals within the time horizon, the rate of inter-temporal time preference (interest rate), risk conditions if such is to be considered in decision making (Cembalo, 2002).

Data Collection Methods

The core datum required for this study is the age-yield relationship of date palm varieties cultivated in the Sultanate of Oman. A survey was done to obtain above datum through a purposive sample of farms. The sample included farmers from whom above information could be reliably obtained, i.e., farmers with commercial date palm cultivations with more than 2.4 hectares and are elderly farmers who had a memory of age-yield relationship of date palm. The sample size was limited to 34 farmers given the nature of data collected that required extensive time to interview the respondents and the limitation of other resources as finance and personal.

RESULTS AND DISCUSSION

Base Data Used in CEAN and MPDLP Models

The average yield is higher than nationally reported yields of 45 Kg/Palm, since the sample was purposive and represented large commercial farms. Using the data in table 1 a best-fit curve on the age-yield relationship of the khalas date cultivar was estimated (figure 2). Number of palms per hectare was considered as 125 as found by the survey. It was considered that the same cultivar (khalas) is replanted, hence the same age-yield relationship was considered for the potential replanting palms. Sensitivity analysis for an increase and decrease of 25% of the base yield was done. Using the average price of dates over the period 1961 to 2011 in Oman as reported in (FAO statistics) a trend line on price prediction was estimated. Based on the trend line the predicted price of 0.250 OR/Kg was considered as the base price. A decrease and increase of 25% of the base price was considered for sensitivity analysis. Cost of production estimate of 914 OR/hectare for date palm cultivation provided by the Ministry of Agriculture and Fisheries Wealth, Oman was used as base cost. An increase and a decrease of cost by 25% was considered for sensitivity analysis. A 4 % interest rate was in the study based on the average for the period 2002 to 2010 of the interest rate spread of Oman as reported by the World Bank. Sensitivity analysis was done for 1% and 10% interest rates.

Results from CEAN Model Analysis

It is estimated that on base conditions the optimal age to replant is 52 years. The optimal age of replanting is sensitive only to the interest rate. A decrease in the interest rate (1%) shortens optimal replanting age to 49 years and an increase interest rate (10%) lengthens the optimal replanting age to 56 year.

Results from MPDLP Model Analysis

The MPDLP model was solved for base data and then sensitivity analysis was done on price, yield and interest rate changes. The MPDLP model was solved for the same scenarios solved by the CEAN model. The MPDLP model however produces discrete results on (age as a range of 5 years) whilst the CEAN model is continuous on age. Considering results of both models and results of sensitivity analysis on price, cost, interest and yield changes it could be concluded that date palms should be replanted at about 50 years.

Replanting Schedule Date Palm Plantations in Oman

Data on age distribution of date palm plantation in Oman is not available. An estimation was made using the (FAO STAT) data on area harvested. The area planted with date palm at a given period increases the area harvested after 5 years as fruiting occurs after 5 years of planting. It is estimated that from the extent of date palm area in year 2000 (35508 Ha) at least 14000 Ha (or about 40%) is older than 40 years. The MPDLP model was used to estimate the replanting schedule (extent to replant by periods) for Oman . The extents in hectares in the second column of the table 5 are the extents that should be replanted in the identified periods of the first column. The model estimated that if replanted optimally it will generate net revenue 2218 Million OR and if not replanted the net revenue will be 1856 Million OR in present value over 60 years and 4% interest. The benefit of replanting over not replanting is 361 Million OR in present value, which is equivalent 16 Million OR when amortized over 60 years and 4% interest. This implies that if a replanting is undertaken as scheduled in table 4 Oman could gain 16 Million OR per year in the future. However this is an upper-bound estimate because the sample considered for this study is a purposive sample of large commercial farms reporting an average yield of 132 Kg/Palm. This yield is 3.5 times higher than the national average date palm yield of 38 Kg/Palm. Also the upper-bound estimate assumes that at present farmers do not replant date palm. However the survey found that 65% of the farmers responded of having replanted (at least one palm) date palm in the past years. Thus this is an upper bound estimate of rate of replanting adopted. Given above reasons the upper bound value was subjected to a sensitivity analysis by considering the national average yield of 38 Kg/Palm and a 65% rate of replanting as being currently adopted. Thus, average benefit from replanting date palm based on the sensitivity analysis is 7 Million OR/Year. The revenue from date palm in year 2011 in Oman was 52.6 Million OR (FAO STAT). Thus replanting of date palm could increase the revenue by more than 13% over the current (2011) revenue from date palm, in the Sultanate of Oman.

The optimal age to replant is where discounted marginal net-revenues (MNR) is equal to the annuity formed from the discounted total flow of net-revenues (ANR) from date palm yields of palms replanted over years. The study estimated the optimal age of replanting date palm as 50-55 years. Both models, CEAN and MPDLP gave consistent estimates. The optimal age to replant date palm was sensitive only to changes in the interest rates. Low interest rates shortened the optimal age of date palm replanting. The study derived the optimal replanting schedule for date palm for the Sultanate of Oman given the current age distribution of date palms. On the average, the benefit of replanting date palm for the Sultanate

of Oman is about 7 million OR/year. The study reveals the significant benefit the Sultanate of Oman could gain by initiating a national program to encourage farmers to replant old unproductive date palms. Government would also have to plan extension activities and allocate resources for such a program. Since replanting, unless well planned at the farm level would incur reductions in the farm cash flow for short periods, cash flow support through financial institutions and/or government subsidies could be considered to encourage farmers. The government could also support farmers through propagation and providing such high yielding cultivars with modern technology such as tissue culture etc. The data used for the study was restrictive in terms of the sample size and the due to the adoption of purposive sampling method. This however was rather inevitable given the nature of data to be collected, particularly the age-yield relationship of date palm. It is recommended that agronomic research be undertaken to establish the age-yield relationship of this vital crop. A larger random sample and a more elaborate data collections process, involving more financial, personnel and time resources could have improved the validity of the study. The analytical methodology adopted in the study was theoretically and operationally robust. Both models namely CEAN and MPDLP models can be used by extension officers in developing date palm replanting schedules and advising farmers. Despite some limitations of the study, the findings of the study suggests the need to adopt a date palm replanting program to improve the date palm sectors' contribution to the society and economy of the Sultanate of Oman.

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Figures

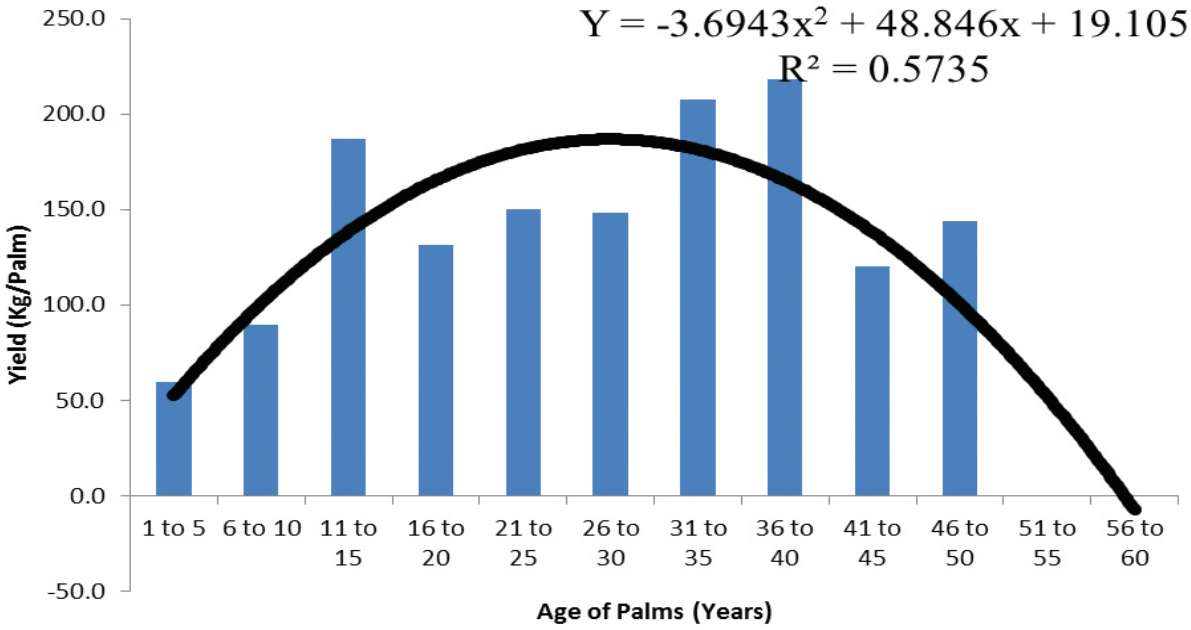

Fig. 1. Age-yield relationship of khalas date cultivar and the estimated function.

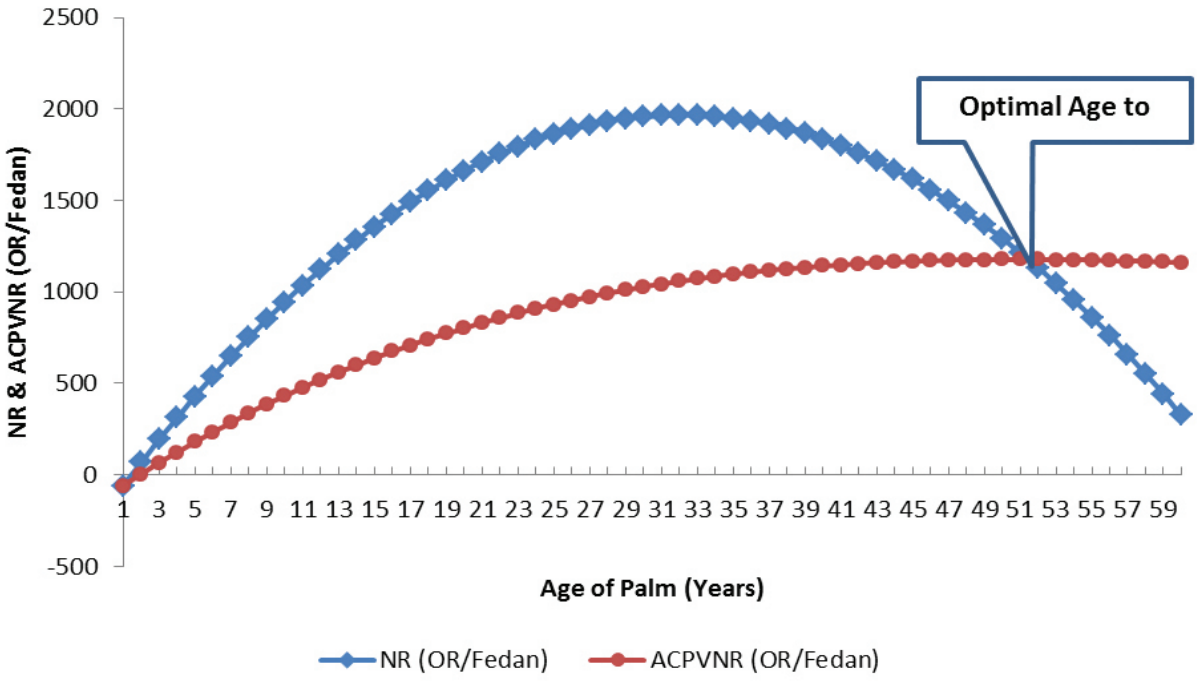

Fig. 2 Results of the base model with age-yield relationship of Khalas cultivar

Tables

Table 1. Age-yield relationship for khalas date cultivar.

Age of Palm (Years)		Yield (Kg/Palm)	
		Survey	Predicted
1 to 5		59.4	62.3
6 to 10		89.5	102.0
11 to 15		187.2	133.7
16 to 20		131.7	157.2
21 to 25		150.0	172.7
26 to 30		148.0	180.0
31 to 35		207.5	179.3
36 to 40		218.0	170.5
41 to 45		120.0	153.6
46 to 50		144.0	128.6
51 to 55		NR	95.6
56 to 60		NR	54.4
Average	145.5	132.5	

Table 2. Results on optimal age of replanting and sensitivity analysis for Khalas cultivar: CEAN Model

Sensitivity Analysis									
Factors	Base Model	Price Change		Cost Change		Interest Change		Change in Yield	
		Increase by 25%	Decrease by 25%	Increase by 25%	Decrease by 25%	Increase	Decrease	Increase by 25%	Decrease by 25%
Age (Year)	60	60	60	60	60	60	60	60	60
Average Yield (Kg/Year/Tree)	132	132	132	132	132	132	132	165	99
Average Yield (Kg/Hectare)	16450	16450	16450	16450	16450	16450	16450	20561	12336
Price (OR/Kg)	0.25	0.31	0.19	0.25	0.25	0.25	0.25	0.25	0.25
Average Gross Return (OR/ Hectare)	4111	5261	3225	4111	4111	4111	4111	5141	3084
Average Cost (OR/Hectare)	914	914	914	1142	686	914	914	914	914
Average Net Return (OR/ Hectare)	3197	4186	2210	2969	3427	3197	3197	4226	2170

Sensitivity Analysis									
Factors	Base Model	Price Change		Cost Change		Interest Change		Change in Yield	
Interest	0.04	0.04	0.04	0.04	0.04	0.10	0.01	0.04	0.04
Year of Replanting	52	52	52	52	52	56	49	52	52

Table 3. Results on optimal period of replanting and sensitivity analysis on age yield relationship of Khalas date palm: MPDLP Model.

Sensitivity Analysis									
Factors	Base Model	Price		Cost		Interest		Yield	
		Increase by 25%	Decrease by 25%	Increase by 25%	Decrease by 25%	Increase to 10%	Decrease to 1%	Increase by 25%	Decrease by 25%
Age (Year)	60	60	60	60	60	60	60	60	60
Average Yield (Kg/Year/Tree)	132	132	132	132	132	132	132	165	99
Average Yield (Kg/Hectare)	16449.6	16449.6	16449.6	16449.6	16449.6	16449.6	16449.6	20560.8	12336
Price (OR/Kg)	0.25	0.31	0.19	0.25	0.25	0.25	0.25	0.25	0.25
Average Gross Return (OR/ Hectare)	4111.2	5260.8	3225.6	4111.2	4111.2	4111.2	4111.2	5140.8	3084
Average Cost (OR/Hectare)	914.4	914.4	914.4	1142.4	686.4	914.4	914.4	914.4	914.4
Average Net Return (OR/ Hectare)	3196.8	4185.6	2210.4	2968.8	3427.2	3196.8	3196.8	4226.4	2169.6
Interest	0.04	0.04	0.04	0.04	0.04	0.10	0.01	0.04	0.04
Age of Replanting (Years)	55	55	55	55	55	55	50	55	55

Table 4. Date palm replanting schedule for the Sultanate of Oman.

Year/Period	Extent (Ha) to be Replanted
2010-2015	13000
2016-2020	0
2021-2025	1000
2026-2030	6100

Year/Period	Extent (Ha) to be Replanted
2031-2035	4900
2036-2040	4000
2041-2045	6508
2046-2050	0
2051-2055	0
2056-2060	0
2061-2065	0
2066-2070	13000

Table 5. Estimated benefits of replanting date palm plantation in the Sultanate of Oman.

Scenario	Present Value (Million OR)	Amortized Value (Million OR)
Without replanting	1856	82
With replanting	2218	98
Benefit of replanting	361	16

Table 6. Sensitivity analysis on benefits of replanting date palm in Oman.

Variables		
Yield (Kg/Palm)	% Current Replanting Rate	Benefit (Million OR/Year)
132.0	0.0	16.0
38.0	0.0	4.6
132.0	60.0	5.6
38.0	60.0	1.6
Average		7.0