Optimum Replacement Time for Cotton Pickers in Greece

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Abstract

In this paper an attempt has been made to determine the optimum replacement time for cotton pickers under the technical and economic conditions in Greece. For this purpose, five relevant methods have been applied to analyze real data taken by 62 cotton

tion is equal to the corresponding repair and maintenance costs or the year when the aforementioned annual expenses of the machine per working hour are minimum. The fourth method considers the year in which the accumulated average total costs per working hour or per hectare harvested is minimum, while the fifth method refers to the year in which the accumulated annual "standardized" net income received from the use of a cotton picker is maximum. Based on the results of this study the optimum replacement time of a cotton picker is the 14th –15th year of its productive life combined with 4500 –5000 working hours and 1450 – 1550 hectares harvested.

Keywords: *cotton pickers, optimum replacement time, costs, net income*

Introduction

The widespread use of mechanization in Greek agriculture started just after the Second World War importing scores of tractors and general use machines. The mechanization of farming continued using any short of specialized machines, e.g. combines, cotton pickers, sugar beet harvesters, tobacco planting machines, et. These machines facilitated many farm activities contributing substantially to the increase of the mechanized crops. However, their use increased the cost of production because of their great annual expenses (depreciation, repairs, maintenance, insurance, interest) and their limited annual use. Taking into account that the main purpose of mechanization is to improve the farmer's income, the most efficient utilization of farm machines is of great importance. Thus, the ultimate goal of the machine manager is to maximize his profit by getting the greatest output from machines at a minimum cost. In practice, this relationship worsens as the machine ages, due to limited performance and the increased repair and maintenance expenses. Machine repair and maintenance rates really determine the time of replacement (Hunt, 1977 and 2001; Mayfield et al, 1981; Morris, 1988; Mygdakos and Gemtos, 2002). Clearly, the determination of optimum replacement time of a machine is a crucial issue, particularly for complex machines (combine harvesters, sugar beet harvesters, cotton pickers etc.), expressed in years of productive life, hours of work or hectares harvested.

The first cotton pickers were introduced in Greece at the beginning of the 60's and reached 3100 by the end of the 90's (Hellenic Cotton Board 1999). The introduction of cotton pickers contributed substantially to the increase of the country's cotton area from

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130.000 hectares to 450.000 hectares and the cotton production from 410000 tons to 1355500 tons respectively (Sitras, 1987; Mygdakos, 1992; Hellenic Cotton Board 1999). This remarkable increase of cotton production has substantially benefit cotton producers, cotton industry and the country's economy, placing cotton growing in the first position in absolute terms of gross value among all crops (Mygdakos 1995; Kitsopanidis and Kamenidis 2003).

There is not much literature on studies regarding optimum replacement time of cotton pickers. Bowers (1970) and Hunt (1977) determine the probable useful life of the cotton pickers to 10 years or 2000 – 2500 hours of work, while in a new addition Hunt (2001) extends it to 3000 hours. The same figures are given in the ASAE standards (ASAE 2002). Sowell (1967), in a theoretical study of the replacement time of cotton pickers, suggests an upper limit of 2000 working hours for U.S.A. conditions. Souter (1972) and Tsatsarelis (1995), determine the useful life of cotton pickers to 10 years or 2000 working hours. The Greek Ministry of Agriculture (1981), has published a number of management tables, in which 10 years are suggested as the useful life of cotton pickers, based on U.S.A. data. Mygdakos (1982) has used the 10 years and the 2500 working hours as the useful life of cotton pickers in a study on the estimation of cotton harvesting cost. In a recent study, Mygdakos and Gemtos (1996) have found that most cotton pickers in Greece have exceeded 3500 hours and the 10 years of use, while a more recent study (Mygdakos et al, 2002) carried out in a region of Central Greece, has shown that a large number of pickers are 15 years old and more, and they have worked up to 5000 hours.

Taking into account the above mentioned the objective of this study is to determine the optimum replacement time for the cotton pickers under Greek conditions, with the aim of enabling cotton producers to keep machinery costs at a low level and increasing their income.

Methods determining optimum time replacement of capital goods

Many capital goods face the problem of optimum time replacement (i.e. the trees of various kinds of orchards, certain productive animals, farm machinery tractors, combines, pickers, stripers, planters etc.), as it is directly or indirectly connected to the profit of the farm business (Upton, 1976; Hunt 1977; Barnard and Nix, 1979). Farm machinery may need replacement due to accidents, obsolescence, inadequate capacity, wear and tear etc. The more common replacement decision is to replace an old machine with a new one in order to increase income and reduce costs. Thus, many methods have been formulated in order to determine optimum time replacement of capital goods and especially the farm machinery ones. The following five methods are considered to be the most suitable for cotton pickers:

a) According to the first method, the most appropriate time for cotton pickers replacement is considered to be the year in which the accumulated annual depreciation is equal to the accumulated annual repair and maintenance costs (Souter, 1972; Tsatsarelis, 1995)

$$\underline{D_{aa}} = RM_{aa,}$$

where: D_{aa} = accumulated annual depreciation,
RM_{aa} = accumulated annual repair and maintenance costs of a cotton picker.

b) According to the second method, the most appropriate time for cotton pickers re-

placement is the year in which the accumulated annual depreciation, repairs and maintenance costs per working hour or per hectare harvested is minimum (Hunt, 1977, 1999, 2001)

$$\frac{D_{aa} + RM_{aa}}{Wh_a / He_a} = minimum$$

where: Wh_a = accumulated working hours,
He_a = accumulated hectares harvested

c) The third method considers as the most appropriate time for cotton pickers replacement to be the year in which the initial value of the machine and its accumulated annual repairs and maintenance cost per working hour or hectare, known as " holding cost", is minimum (Morris, 1964; Upton, 1976; Barnard and Nix, 1979; Husti, 1991)

$$\frac{IV + RM_{aa}}{Wh_a / Hr_a} = minimum$$

where: IV = initial value of a cotton picker

d) The fourth method considers as the most appropriate time for cotton pickers replacement to be the year in which the accumulated average total cost per working hour is minimum (Witney, 1988)

$$ATC_a = \frac{TC_a}{Wh_a} = minimum$$

where: ATC_a = accumulated average total cost per working hour
TC_a = accumulated total cost

e) According to the fifth method, the most appropriate time for cotton pickers replacement is considered to be the year in which the accumulated annual "standardized" net income received by using the machine is maximum (Kitsopanidis, 1990)

$$[(GR - DC) + RV] \; x \; DI = DNI \; x \; AF = ASNI = maximum$$

where: GR = gross return, DC = direct cost, RV = resale value of machine,
DI = discount index, DNI = discounted net income,
AF = annuity factor, $ASNI$ = annual standardized net income.

Application of aforementioned methods for cotton pickers

The technical and economic data available for this study derived from a sample of 62 cotton pickers and especially from the accounting books of the cotton producer groups established under the EU Regulation 389/82, for the period 1983 – 2002. The data refer to the number of working hours per year, the number of hectares harvested per year, the picking charge per hectare of cotton harvested, the driver's wages, the fuel and lubricants costs, the annual depreciation, the repairs and maintenance of the machine, the interest of capital invested etc. All economic data were transformed from current to 1983 prices.

The first method is based on the comparison of the accumulated annual depreciation and the corresponding costs of repairs and maintenance. Since the repair and maintenance costs vary significantly, the following equation was introduced in order to decrease the fluctuation of these costs:

$$Z = a + bX - cX^2 + dX^3,$$

where: Z = annual repair and maintenance costs,
X = machine age in years.

A similar analysis has been applied for estimating annual depreciation indirectly through the estimation of the actual value (in percentage) year by year during the life of the machine, by using the following equation

$$Y = e^{-a-bX}$$

where: Y = percentage of the machine's initial value,
X = machine age in years.

Table 1 gives the accumulated annual depreciation, repairs and maintenance costs of a cotton picker for a period of 20 years, as well as its working hours and hectares harvested. As it can be seen in this table, the accumulated annual depreciation is about equal to the accumulated annual repairs and maintenance for the period between the 13th and 14th year of the productive life of the machine. Indeed, in a period of 13.5 years the accumulated annual depreciation (14963 €) is almost equal to the accumulated annual repairs and maintenance (14930 €). This year corresponds to 1410 (1358.5 – 1461.4) hectares of cotton harvested and to 4430 (4280 – 4580) hours worked.

According to the second method, the optimum replacement time of cotton pickers is achieved when the accumulated annual depreciation, repairs and maintenance per working hour and per hectare harvested is minimum (Table 2). In this study, the minimum cost per hour worked (6.73 €) and per hectare harvested (21.1 €) corresponds to 4280 working hours and 1561.1 hectares harvested. The 4280 working hours of the machine correspond to the 13th year of its productive life and the 1561.1 hectares harvested are achieved in the 15th year of productive life. Combining the minimum cost per hour and

Table 1. Accumulated annual depreciation and repair and maintenance costs of cotton pickers, according to their productive life, hours worked and hectares harvested

Year of work	Accumulated depreciation (euro)	Accumulated R & M (euro)	Accumulated hours of work	Cost of work (euro/hour)		Accumulated hectares harvested	Harvested cost (euro/he.).	
				Depre-ciation	R & M		Depre-ciation	R & M
1	1613	284	279	5,78	1,02	90.4	17,8	3.1
2	3146	1332	577	5,39	2,31	185.3	17.0	7.2
3	4598	2331	891	5,16	2,61	284.1	16.2	8.2
4	5939	3376	1218	4,90	2,77	386.3	15.5	8.7
5	7260	4168	1555	4,67	2,68	491.2	14.8	8.5
6	8469	5262	1900	4,46	2,77	598.3	14.1	8.8
7	9599	6327	2249	4,27	2,81	707.2	13.6	9.0
8	10647	7482	2600	4,09	2,88	816.8	13.0	9.2
9	11615	8727	2950	3,94	2,96	926.8	12.5	9.4
10	12503	10181	3296	3,79	3,09	1036.6	12.1	9.8
11	13309	11353	3635	3,66	3,12	1145.5	11.6	9.9
12	14035	12759	3964	3,54	3,22	1253.0	11.2	10.2
13	14680	14133	4280	3,43	3,30	1358.5	10.8	10.4
14	15245	15727	4580	3,33	3,43	1461.4	10.4	10.8
15	15729	17211	4862	3,23	3,54	1561.1	10.1	11.0
16	16132	18935	5123	3,15	3,69	1657.0	9.7	11.4
17	16455	20594	5359	3,07	3,84	1748.5	9.4	11.8
18	16697	22382	5568	3,00	4,02	1835.0	9.1	12.2
19	16858	24300	5747	2,93	4,23	1915.9	8.8	12.7
20	16939	26153	5893	2,87	4,44	1990.6	8.5	13.1

per hectare with the productive life of the machine, it is clear that the optimum replacement time is the 14th year.

The third method is based on the "holding cost" of the machine, namely on the combination of its initial value and the accumulated annual repairs and maintenance. This means that by this method the optimum replacement time of cotton pickers takes place in the year when the holding cost per working hour or per hectare harvested is at the minimum level. This estimation is achieved arithmetically, shown in Table 3, where the optimum replacement time is found in the 17th year or 5359 working hours, and where the holding cost per working hour is minimum (7.62 €).

The fourth method determines the optimum replacement time of cotton pickers, the year in which the accumulated average total cost per working hour is minimum. In this study, this cost is minimized in the 15th year and at 4862 working hours (Table 4). Indeed, the minimum point of the average total cost corresponds to the 15th year and the 4862 working hours.

The fifth method for estimating the optimum replacement time of cotton pickers is based on the time when the annual "standardized" net income reaches its maximum level. This time refers to the 14th year of the productive life of the machine and corresponds to 4580 working hours. As Table 5 shows, the relevant data for a period of 20 years are: annual gross return from the machine, its annual direct cost, annual resale value of the machine, a deflecting factor (9%) for transforming all values in the year 1983 and an annuity factor (9%), which better fits the data used and gives the annual "standardized" net income during a period of 20 years.

Table 2. Accumulated annual depreciation and repair and maintenance costs of cotton pickers and costs per hour worked or hectare harvested according to their productive life

Year of work	Accumulated depreciation and Repair and Maintenance (euro)	Accumulated hours of work	Cost (euro/ hour)	Accumulated hectares harvested	Cost (euro/ hectare)
1	1897	279	6,80	90.4	21.0
2	4478	577	7,76	185.3	24.2
3	6929	891	7,78	284.1	24.4
4	9345	1218	7,67	386.3	24.2
5	11428	1555	7,35	491.2	23.3
6	13731	1900	7,23	598.3	22.9
7	15926	2249	7,08	707.2	22.5
8	18130	2600	6,97	816.8	22.2
9	20343	2950	6,90	926.8	22.0
10	22684	3296	6,88	1036.6	21.9
11	24956	3635	6,86	1145.5	21.8
12	26794	3964	6,76	1253.0	21.4
13	28814	4280	6,73	1358.5	21.2
14	30973	4580	6,76	1461.4	21.2
15	32941	4862	6,77	1561.1	21.1
16	35068	5123	6,84	1657.0	21.2
17	37049	5359	6,91	1748.5	21.2
18	39079	5568	7,02	1835.0	21.3
19	41159	5747	7,16	1915.9	21.5
20	43092	5893	7,31	1990.6	21.7

Table 3. *Initial value of a cotton picker, accumulated annual repair and maintenance costs and cost per hour of work, according to its productive life*

Year of work	Initial value (euro)	Accumulated Repair and Maintenance (euro)	Initial value and Repair and Maintenance (euro)	Accumulated hours of Work	Cost (euro/hour)
1	19075	868	19943	279	71,48
2	19075	1787	20862	577	36,16
3	19075	2758	21833	891	24,50
4	19075	3780	22855	1218	18,76
5	19075	4854	23929	1555	15,39
6	19075	5979	25054	1900	13,19
7	19075	7156	26231	2249	11,66
8	19075	8384	27459	2600	10,56
9	19075	9663	28738	2950	9,74
10	19075	10994	30069	3296	9,12
11	19075	12376	31451	3635	8,65
12	19075	13810	32885	3964	8,30
13	19075	15295	34370	4280	8,03
14	19075	16832	35907	4580	7,84
15	19075	18420	37495	4862	7,71
16	19075	20059	39134	5123	7,64
17	19075	21750	40825	5359	7,62
18	19075	23492	42567	5568	7,64
19	19075	25286	44361	5747	7,72
20	19075	27131	46206	5893	7,84

Table 4. Accumulated total cost, hours of work and average total and marginal cost of a cotton picker according to its productive life

Year of work	Accumulated total cost (euro)	Accumulated hours of work	Average total cost (euro/hour)
1	6201	279	22,23
2	12113	577	20,99
3	17788	891	19,96
4	23200	1218	19,05
5	28437	1555	18,29
6	33470	1900	17,62
7	38287	2249	17,02
8	42942	2600	16,52
9	47448	2950	16,09
10	51826	3296	15,72
11	56085	3635	15,43
12	60244	3964	15,20
13	64315	4280	15,03
14	68316	4580	14,92
15	72260	4862	14,86
16	76164	5123	14,87
17	80042	5359	14,93
18	83909	5568	15,07
19	87777	5747	15,27
20	91661	5893	15,55

Table 5. Gross return, direct cost, «net income», resale machine value and annual net «standardized» income of a cotton picker

Year of work	Gross return (euro)	Direct cost (euro)	Net income (euro)	Resale machine value (euro)	Sum of net income and resale machine value (euro)	Discount index (9%)	Discounted net income (euro)	Accumulated discounted net income (euro)	Annuity factor (9%)	Accumulated discounted annual «standardized» net income (euro)
0	–	–	–	19076	-19076	1,0000	-19076	-19076	0,0000	-19076
1	3987	1223	2765	17462	20227	0,9174	18556	-519	1,0000	-519
2	5437	1529	3907	15930	19837	0,8417	16697	16178	0,5685	9197
3	6261	1839	4423	14478	18901	0,7782	14708	30886	0,3951	12203
4	7236	2105	5131	13089	18237	0,7084	12919	43805	0,3087	13523
5	7951	2267	5683	11816	17499	0,6499	11373	55178	0,2571	14186
6	9123	2312	6811	10606	17417	0,5963	10386	65564	0,2229	14614
7	10330	2573	7757	9477	17234	0,5470	9427	74991	0,1987	14901
8	13036	3245	9791	8428	18220	0,5019	9144	84135	0,1807	15203
9	15557	4215	11342	7460	18802	0,4604	8657	92792	0,1668	15478
10	17138	5658	11480	6573	18053	0,4224	7625	100417	0,1558	15645
11	18281	6061	12220	5766	17986	0,3875	6970	107387	0,1469	15775
12	19287	6383	12903	5040	17944	0,3555	6379	113766	0,1397	15893
13	19421	6593	12828	4395	17223	0,3262	5618	119384	0,1336	15950
14	19552	6874	12678	3830	16508	0,2992	4939	124323	0,1287	15963
15	19621	8036	11585	3345	14931	0,2745	4099	128422	0,1241	15937
16	19761	8590	11171	2943	14114	0,2519	3555	131977	0,1203	15877
17	19896	9143	10753	2620	13373	0,2311	3096	135068	0,1170	15803
18	19844	9697	10148	2378	12526	0,2120	2656	137723	0,1142	15728
19	20091	10250	9841	2217	12058	0,1945	2345	140068	0,1117	15646
20	20411	10745	9666	2136	11803	0,1784	2106	142174	0,1095	15568

Comparison of the methods used for estimating optimum replacement time of cotton pickers

The first three methods used for estimating optimum replacement time of cotton pickers are based directly or indirectly on the accumulated annual depreciation and repairs and maintenance costs of these machines, because it is believed that these expenses are the most important. According to Morris (1988), repair and maintenance costs combine with depreciation to jointly account for about 70% of total machine costs. Also repair and maintenance costs, amount to 60-120% (Boyce et al, 1976) or 52-137% (Mygdakos et al, 2002) of the machine's initial value over its life. More specifically, the first two methods are based exclusively on depreciation, repairs and maintenance, while the third one takes into account the same items plus the initial value of these machines. The fourth method is based on the minimization of the accumulated average total cost per working hour, while the fifth one uses an optimum replacement time the year in which the maximum annual "standardized" net income is achieved by these machines.

The comparison of the five methods described above displays no great difference among the four of them (first, second, fourth, and fifth), since the optimum replacement time given fluctuates between the 14^{th} and the 15^{th} year or between 4280 and 4862 working hours or between 1358.5 and 1561.1 hectares harvested. On the contrary, the third method gives quite different results (17^{th} year, 5359 working hours and 1748.5 hectares harvested). Among the five methods employed, the last two seem to be the most important ones as the fourth one takes into consideration the total cost of the machine and not a part of it, and the fifth one is based on the net income received. Finally, the fifth method is considered to be the most reliable, since it uses as a criterion the maximum annual "standardized" net income instead of the minimum total cost of the fourth method, which does not mean necessarily maximum income.

Summary, conclusions and prospects

In this paper an attempt is made to determine the optimum replacement time for cotton pickers under technical and economic conditions existing in Greece. The data used in this study are selected from a sample of 62 cotton pickers and cover a period of 20 years (1983-2002).

For this purpose, five methods have been applied; the first three methods are based on the year when the accumulated annual depreciation and repairs and maintenance costs are equal or the year when the aforementioned annual expenses reach their minimum level; the fourth method is based on the year in which the accumulated average total cost per working hour or per hectare harvested is the minimum one; finally, the fifth method refers to the year in which the accumulated annual "standardized" net income achieved by a cotton picker is the maximum one.

Comparing the results obtained by the application of the aforementioned five methods, no great differences are found among the four of them except the third one. More specifically, the optimum replacement time for cotton pickers fluctuates when using the four methods between the 13^{th} and the 15^{th} year of productive life or between 4280 and 4862 hours of work or between 1358 and 1561 hectares harvested. On the contrary, the corresponding figures when the third method is used are: 17^{th} year, 5359 working hours and 1748.5 hectares harvested.

The above results indicate that the theoretical figures used up to now, as an optimum time for cotton pickers replacement e.g. 10 years of productive life or 2000 –2500 hours of work, do not correspond to Greek actual practice and must be revised. Based on the results of this study, the optimum replacement time of cotton pickers is the 14^{th} – 15^{th} year of its productive life in combination with 4500 – 5000 working hours and 1450 – 1550 hectares harvested. Taking into account that there is not any other relevant study in Greece on this subject, the above results prove to be very useful to researchers, to owners of cotton pickers and to policy makers.

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