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Research Article

ECONOMIC ROTATION OF *VACHELLIA NILOTICA* (KIKAR) AND *EUCALYPTUS CAMALDULENSIS* (SUFEIDA) IN PUNJAB, PAKISTAN

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Abstract

The economic rotation of two different tree species was calculated during 2020 in two different tehsils (sub-districts) namely Gujranwala and Khushab which are located in Punjab province of Pakistan. *Vachellia* is a common tree grown on the farmlands of Gujranwala while *Eucalyptus* is a common tree growing on the farmlands of Khushab. So that these two tree species were selected from two different tehsils of Punjab. *Vachellia* is grown at a rotation of 10 to 20 years while *Eucalyptus* is grown on 5 to 12 years rotation. For the evaluation of economic rotation of both tree species, net present worth and benefit cost ratio was calculated. 300 trees of both tree species were randomly selected from their respective tehsils. Different rotations of *Eucalyptus* were tested viz., 12 years rotation, 6 + 6 = 12 years, 8 + 4= 12 years and 4 + 8 = 12 years, while the total span (12 years) was kept same in all rotations. The total span was kept at 12 years because this tree is grown at a maximum rotation of 12 years on the farmlands. Similarly, different rotations were tested in case of *Vachellia*nilotica viz., 10 years, 5 + 5 = 10 years and 6 + 4 = 10 years with the same total span of 10 years. In case of Eucalyptus, net present worth was found to be Rs. 4035.525, 4506.45, 4310.375 and 4379.175 at a rotation of 12, 6+6 = 12, 8+4=12 and 4+8 = 12 years, respectively. However, best rotation was found to be 6 + 6 = 12 years with highest net present worth. Similarly in case of *Vachellia*, net present worth was found to be Rs. 4844.532, 5155 and 5675.322 at a rotation of 10 years, 5 + 5 = 10 years and 6 + 4 = 10 years, respectively. rotation of 6 + 4 = 10 years was found to be best. It is recommended that farmers of Khushab should grow Eucalyptus trees at a rotation of 6 + 6 = 12 years. The farmers of Gujranwala are recommended to raise *Vachellia* trees on a rotation of six years followed by another short rotation of 4 years for more financial benefits.

Keywords: *Eucalyptus camaldulensis*, *Vachellia nilotica*, Net Present Worth, Benefit Cost Ratio, Rotation.
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1. INTRODUCTION

Growing of trees and farm crops side by side is very common practice especially in developing countries, such as Pakistan. At the early age, trees usually produce biomass at a greater rate while their growth rate declines, later on. Farmers usually grow the trees along with crops and harvest them when they are in some economic crisis and their harvesting is known as rotation. Regardless to maximum net income, biological rotation ensures maximum production of wood at a high rate as well (Taha, 2000; Uzunoz and Akcay 2006). The scientists have calculated biological rotations of various tree species growing in variety of climates. However, economic rotations of many trees are usually not well studied. Farmers of Pakistan are mostly illiterate, so they do not have the capacity to calculate economic rotation of trees growing on their lands. So, they follow various rotations mostly based on their observation and not on scientific study which often leads to economic loss to the farmers. Economic rotation ensures that income with maximum net present worth is obtained from trees. So, this is need of the time to calculate economic rotations of different tree species under varied type of climates. So, that farmers may be saved

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from economic loss (Elhadi, 2009; Wondie and Mekuria, 2018; Mekonnen, 2009; Hakeem *et al.,* 2020).

Eucalyptus camaldulensis (sufeida) is a fast-growing tree species. It is widely planted on a variety of soils including fertile agricultural lands, marginal lands and problematic soils like water logged, saline, sandy and compact soils. Farmers grow Eucalyptus trees on their farmlands because it is a fast growing tree and gives handsome money in a relatively small period of time. It is successfully grown in sandy areas regardless of the fact that it is considered as a highly water consuming plant. No doubt, in the initial stages, it requires water in large quantity but later on, its roots go very deep into the soil and it successfully withstands high air and soil temperature in sandy tracts. Presently Eucalyptus is grown in many artificial forests of Pakistan at various rotations. In these plantations, its rotation of 15-16 years is considered as ideal. Contrary to the rotation of 15-16 years, farmers often grow it on their farmlands as boundary trees at a rotation of 5-6 years. In plantations, the growth rate of trees is slow because there are large number of trees per unit of land. On the other hand, in farmlands, the growth rate of trees is very fast because number of trees per unit area are less. Moreover, in plantations, no fertilizer is applied to the trees while on farmlands, fertilizer is applied to the crop and some part of it, is consumed by the trees. That's why rotation of trees vary to a large extent in farmlands and in plantations. Some farmers also grow it in alley cropping pattern in which Eucalyptus trees are grown inside the field in rows. Between the rows, various crops like sugarcane, wheat and gram etc. are also grown (Yitaferu et al., 2013)

Vachellia nilotica (kikar) is grown on large scale in the fertile agricultural lands of Punjab province of Pakistan. Inspite of slow growing tree species, its wood is best for making furniture after *Dalbergia sissoo* (Tahli). It is usually grown on agricultural lands with a flexible rotation of 10 to 20 years. When farmer of Punjab needs urgent money, it sells the standing trees including kikar and sufeida to fulfill their needs. Kikar is a tree which is very liked by the farmer and it is one of the best trees providing revenue in emergency conditions to the farmers. It is an evergreen broad leaved tree with very hard/durable wood (Naseem et al., 2007).

Previously, many researchers in various countries have calculated economic rotations of commercially important farm tree species. But in Pakistan, economic rotations of various tree species has not been calculated yet. Roy et al., (2021) investigated economic return of *Vachellia nilotica* at 22 years rotation, income from plantation was 915687 Bangladeshi Tikkas. While, the income increased to 1017430 Tikkas when rotation was reduced to 11 years. Results clearly indicate that short rotation of Acacia are more economically efficient as compared to long rotation. However, sometimes income increases and sometimes, it decreases with increasing or decreasing rotation, respectively. A hard wood forest in Australia was subjected to economic analysis to see the difference between the incomes which had been obtained at various rotations. 10 years rotation led to net present worth of the forest to 2086 US dollars per hectare and increasing the rotation to 20 years led to decrease in the net income (net present worth) to 860 dollars (Venn, 2005). In contrast to result of Venn (2005), net present worth of plantation of Cordiamyxa was determined 102 Mexican Pesos at 40 years rotation and increase in net worth of income to 265 Pesos observed when rotation was increased by 20 years with total period of 60 years (Roja et al., 2005).

Positive sign was noted during the economic analysis of a *Tectona grandis* tree plantation with net income of 2713 US dollars (Friday et al., 2000). *Vachellia*

nilotica cultivation on both fertile and degraded lands is considered very profitable business. Yadav et al., (2014) found the net income of Rs.1.88 Lakhs per hectare, BCR 2.37 and IRR 24.70 of *Vachellia nilotica* based silvopastoral system in Himalayas of India.

Elazaki and Gang (2019) carried out economic evaluation of a natural forest of *Vachellia nilotica*, in Sudan. They found that NPW of Vachellia's fuel wood cultivation was 156.26 US Dollars per hector while that of honey production was 868.35 US Dollars per hector.So, combined NPW of fuel wood and honey production was 712.09 US Dollars ha-1, respectively. It is evident that NPW of compact plantation of *Vachellia nilotica* is negative and economically unprofitable. However when NPW of a non-timber forest product (honey) is included, it becomes positive. Nigussie et al. (2020) calculated the economic value of sole *Acacia nilotica* cultivation and its intercropping with a crop namely teff. Results found that NPW of sole *Vachellia* plantation was 68089 ETB ha-1while that of sole teff crop was 57005 ETB ha-1. On the other hand, NPW for *Vachellia* and teff intercropping was 79285 ETB per hector which clearly indicate that intercropping of *Vachellia* with teff crop is the best combination in terms of profitability.

Due to high economic returns of *Eucalyptus camaldulensis* as well as protection of crops, farmers in developing countries like Pakistan, India, Bangladesh, Columbia, and Tunisia frequently grow Eucalyptus as shelter belts and with farm crops (Anonymous, 2020). Khattabi (1999) reported that in Morocco, 48% of total timber production is contributed by *Eucalyptus camaldulensis*. Cultivation of *Eucalyptus camaldulensis* also generates business of 13.5 million US Dollar per annum.

Foroughbakhch et al. (2017) recommended that Eucalyptus in Northeastern Mexico should be grown at a rotation of 20 years to get maximum production. The income from this commercially important tree grown in degraded soils of north eastern Mexico was calculated 58.55m3ha-1 at a rotation of 20 years. Ebretsadik (2013) observed mean volume per tree was 0.06 m3 year-1 and at the rotation of 14 years calculated wood volume 12.88 m3ha-1year-1 while maximum net income was also obtained at 14 years rotation. Cuonget al., (2020) reported that at 10% discount rate, net present worth from a government plantation consisting of *Acacia mangium* and *Eucalyptus camaldulensis* was 33.30 and 36.82 million Vietnam Dollars per hectare, respectively. It is evident that NPW of *Eucalyptus camaldulensis* is higher than the other tree species. It was also reported that internal rate of return (IRR) of Eucalyptus plantation was between 25-35% at various rotations. That is why Eucalyptus is preferred to be planted on the farmlands by the government agencies as well as private farmers in Vietnam. Akram (1995) studied economic feasibility of growing *Eucalyptus camaldulensis* as shelterbelt and block/compact plantation. Net present worth (NPW) was positive both in shelter belt and block cultivation and benefit cost ratio (BCR) was also more than one in both cases. Eucalyptus cultivation as border plant and as compact plantation is financially feasible and highly acceptable.

Silva et al., (2020) calculated economics of a Eucalyptus Forest plantation in Brazil at the rotation of 7 years. Discount rate used in calculations was 10%. NPW, BCR and IRR were found to be 1925.10 Brazillian reals ha-1, 1.31 and 16 percent, respectively. The scientist found that cultivation of Eucalyptus at a financial rotation of 7 years was very suitable. Similarly, Virgenset et al., 2016) also carried out economic analysis of *Eucalyptus* plantation. NPW was found to be 1279.01 ha-1Brazillian Reals. BCR was 1.20 and IRR 9.2%.

Sembajju (1999) evaluated the economic benefits of *Eucalyptus* plantation in Uganda. NPW at a rotation of 4 years and 3 years was 8000,000 and 3703500 Uganda Shilling ha-1respectively. NPW per tree was 3200 and 1500 Shilling at a rotation of 4 and 3 years, respectively. Wannawohg (1991) reported that NPW of a *Eucalyptus* plantation in Thailand was 151 Baht acre-1 and BCR was 1.2. When Eucalyptus was grown along with cassava crop, NPW became 3968.3 Baht acre-1 and when it was grown in combination with mungbean, NPW became 340.90 Baht acre-1.

Keeping in view all above discussion, it is evident that economic rotation of trees must be calculated, so that farmer may get maximum net income keeping in view the inflation. So present study was designed with the objective to calculate the economic rotation of *Vachellia nilotica* (kikar) trees in Gujranwala and *Eucalyptus camaldulensis* (sufeida) trees in Khushab. A detailed survey was carried out in 2020 in various districts of Punjab Province, Pakistan to collect data on various farm grown tree species. The purpose of this exercise was to calculate economic rotation of these tree species so that farmer may get maximum revenue in shortest possible period of time. The economic rotations of these tree species in the respective areas are not available in the literature. So economic rotations of these two commercially important tree species, were calculated in the present study.

Objectives: The objectives of this study were as follows: (1) to determine the economic rotation of *Eucalyptus camaldulensis* in Khushab, Punjab, Pakistan (2) to determine the economic rotation of *Vachellia nilotica* in Gujranwala, Punjab, Pakistan.

2. MATERIALS AND METHODS

The methodology described by Anjum *et. al.,* (2013) was adopted during present study. It is explained below:

2.1. Selection of trees

Three hundred trees of each of *Eucalyptus camaldulensis* and *Vachellia nilotica* were selected randomly from 15 villages of Khushab and 13 villages of Gujranwala respectively. The detail of number of trees of various ages selected is shown in the table-1 while average price of both tree species belonging to various ages is shown in table-2. The trees of age 1 year were very small and not marketable, so they were excluded from the study.

2.2. Determination of age and Price of trees

The survey was carried out and data were recorded on the age and price of each standing tree. The price of trees was inquired form the farmers because farmers commonly sell their trees in standing form. Moreover, farmers being practical persons, have a correct idea about the price of trees. The data was organized, tabulated and economic analysis was carried out.

2.3.Economic tools

Net present worth (NPW) and Benefit cost ratio (BCR) were used as economic tools.

NPW was calculated by using following formula:

NPW = Present worth of gross returns – Present worth of expenditures

If NPW of an investment project is positive, then the project is economically acceptable and vice versa.

Benefit cost ratio (BCR) was calculated by using the following formula:

BCR = Present worth of gross benefits/ present worth of costs

If BCR of a project is equal to or more than 1, the project is accepted, otherwise rejected.

2.4. Discounting

Discounting was carried out @ 8% to adjust the inflation. All the values of costs and incomes were multiplied with the discount factor of the respective year to calculate its present worth. The discount factor was calculated by using the following formula:

Discountfactor = 1/ (1+i) n

Where,i = interest rate
And n = number of year (1 for first year, 2 for second year and so on).

3. RESULTS

3.1. Price of trees

Average price of trees of *Vachellia nilotica* (kikar) belonging to 2 years age was 1015 rupees while that of *Eucalyptus camaldulensis* (Sufeida) was 1050 rupees (table-2). Kikar trees of 5 years age have average price of Rs.4523.67 while that of sufeida have price of Rs. 3470. Trees of kikar have maximum age of 10 years while that of sufeida have 12 years. 10 years old trees of kikar have price of Rs.10483.33 while 12 years old trees of sufeida have price of Rs. 10200.

3.2. Various rotations of *Eucalyptus camaldulensis*

NPW of *Eucalyptus* at a rotation of 12 years was 4035.525 while BCR was 291.848 (table-3). As NPW is positive and BCR is more than 1, so cultivation of Eucalyptus at a rotation of 12 years is economically acceptable.

NPW of *Eucalyptus camaldulensis* at rotation of 6+6 = 12 years, was Rs.4506.45 and BCR was 200.224 (table-4). As NPW is again positive, so rotation of 6+6 = 12 years is acceptable. BCR (200.224) is also more than 1 which also indicates profitability of growing Eucalyptus at above mentioned rotation. It is important to note that NPW at 6+6 = 12 years is more than the same at 12 years rotation. It indicates that 2 rotations of 6 years each are more profitable than a single rotation of 12 years. NPW at rotation of 8+4 = 12 years is Rs.4310.375 and BCR is 202.654 (table-5). It is evident that rotation of 8 years followed by a shorter rotation of 4 years (total 12 years) is economically beneficial. These results are in line with the findings of Virgenset al. (2015) who found that NPW of a Eucalyptus plantation forest was 1279.01 ha-1Brazilian reals and BCR was 1.20 in both studies, NPW is positive and BCR is more than 1. That's why, both projects/investments are financially acceptable.

NPW at a rotation of 4+8 = 12 years is Rs. 4379.175 and BCR 182.897 (table-6).

3.3. Comparison of various rotations of *Eucalyptus camaldulensis*

Economic comparison of various rotations of Eucalyptus is shown in table-7. NPW is maximum (Rs. 4506.45) at 6+6= 12 years rotation followed by 4+8 =12 years (Rs. 4379.175), 8+4 = 12 years (Rs.4310.375) and 12 years (Rs. 4035.525). Although BCR is maximum (291.848) at rotation of 12 years but net income/NPW is maximum at rotation of 6+6= 12 years. So, it is recommended that in Khushab, farmers should grow Eucalyptus trees at a rotation of 6+6= 12 years.

3.4. Sensitivity analysis

Sensitivity analysis for growing *Eucalyptus camaldulensis* at various rotations is shown in table-8. It indicates that NPW is maximum (Rs.4053.543) at rotation of 6+6= 12 years when benefits are decreased by 10%. NPW becomes Rs. 3600.636, Rs. 3147.729 and Rs. 2694.822 when benefits are decreased by 20, 30 and 40% respectively, at rotation of 6+6=12 years.

3.5. Various rotations of *Vachellia nilotica*

PW of costs of *Vachellia nilotica* at a rotation of 10 years was Rs. 925 while PW of income/benefits was Rs. 4853.782 per tree (table-9). Net present worth was Rs.4844.532 and benefit cost rotation was 524.733.

Table 1. Age and Number of trees selected from the farmlands of Khushab and Gujranwala

Age (Years)	Number of trees	
	Eucalyptus camaldulensis	*Vachellia nilotica*
1	18	14
2	28	32
3	24	30
4	22	33
5	31	28
6	28	38
7	16	28
8	26	34
9	26	31
10	29	32
11	24	0
12	28	0
Total	300	300

Table 2. Average price of trees of *Eucalyptus camaldulensis* and *Vachellia nilotica* belonging to various ages

Age (years)	Price of trees (Rs.)	
	Eucalyptus camaldulensis	*Vachellia nilotica*
1.	----	----
2.	1050	1015
3.	1830	2417.67
4.	2750	3403.33
5.	3470	4523.67
6.	4410	6331.33
7.	5220	7031.68
8.	6000	8470
9.	7280	9384.33
10.	8430	10483.33
11.	9150	----
12.	10200	----

Table 3. Present worth of benefit stream and cost stream, net present worth (NPW) and Benefit cost ratio (BCR), of *Eucalyptus camaldulensis* at rotation of 12 years and Discount rate of 8%

Age (years)	Costs (Rs.)	Benefits (Rs.)	Discount factor @ 8%	PW of costs (Rs.)	PW of benefits (Rs.)
1	15	0	0.925	13.875	0
2	0	0	0.857	0	0
3	0	0	0.793	0	0
4	0	0	0.735	0	0
5	0	0	0.680	0	0
6	0	0	0.630	0	0
7	0	0	0.583	0	0
8	0	0	0.540	0	0
9	0	0	0.50	0	0
10	0	0	0.463	0	0

11	0	0	0.428	0	0
12	0	10200	0.397		4049.40
			Total =	13.875	4049.40
NPW=	4035.525				
BCR=	291.848				

Table 4. Present worth of benefit stream and cost stream, net present worth (NPW) and benefit cost ratio (BCR), of *Eucalyptus camaldulens* is at rotation of (6 + 6= 12) years and Discount rate of 8%

Age (years)	Costs (Rs.)	Benefits (Rs.)	Discount factor @ 8%	PW of costs (Rs.)	PW of benefits (Rs.)
1	15	0	0.925	13.875	0
2	0	0	0.857	0	0
3	0	0	0.793	0	0
4	0	0	0.735	0	0
5	0	0	0.680	0	0
6	0	4410	0.630	0	2778.30
7	15	0	0.583	8.745	0
8	0	0	0.540	0	0
9	0	0	0.50	0	0
10	0	0	0.463	0	0
11	0	0	0.428	0	0
12	0	4410	0.397	0	1750.77
			Total =	22.62	4529.07
NPW=	4506.45				
BCR=	200.224				

Table 5. Present worth of benefit stream and cost stream, net present worth (NPW) and benefit cost ratio (BCR), of *Eucalyptus camaldulens* is at rotation of (8 + 4= 12) years and Discount rate of 8%

Age (years)	Costs (Rs.)	Benefits (Rs.)	Discount Factor@ 8%	PW of costs (Rs.)	PW of benefits (Rs.)
1	15	0	0.925	13.875	0
2	0	0	0.857	0	0
3	0	0	0.793	0	0
4	0	0	0.735	0	0
5	0	0	0.680	0	0
6	0	0	0.630	0	2778.30
7	15	0	0.583	8.745	0
8	0	6000	0.540	0	3240
9	15	0	0.50	7.5	0
10	0	0	0.463	0	0
11	0	0	0.428	0	0
12	0	2750	0.397	0	1091.75
			Total =	21.375	4331.75
NPW=	4310.375				
BCR=	202.654				

Table 6. Present worth of benefit stream and cost stream, net present worth (NPW) and benefit cost ratio (BCR), of *Eucalyptus camaldulens* is at rotation of (4 + 8= 12) years and Discount rate of 8%

Age (years)	Costs (Rs.)	Benefits (Rs.)	Discount Factor @ 8%	PW of costs (Rs.)	PW of benefits (Rs.)
1	15	0	0.925	13.875	0
2	0	0	0.857	0	0
3	0	0	0.793	0	0
4	0	2750	0.735	0	2021.25
5	15	0	0.680	10.20	0
6	0	0	0.630	0	0
7	0	0	0.583	0	0
8	0	0	0.540	0	0
9	0	0	0.50	0	0
10	0	0	0.463	0	0
11	0	0	0.428	0	0
12	0	6000	0.397	0	2382
			Total =	24.075	4403.25
NPW=	4379.175				
BCR=	182.897				

Table 7. Economic comparison of different rotations of *Eucalyptus camaldulensis*

Rotation (Years)	PW cost (Rs.)	PW benefits (Rs.)	NPW (Rs.)	BCR
12	13.875	4049.40	4035.525	291.848
6+6 = 12	22.62	4529.07	4506.45	200.224
8+4=12	21.375	4331.75	4310.375	202.654
4+8= 12	24.075	4403.25	4379.175	182.897

Table 8.Sensitivity analysis for growing *Eucalyptus camaldulensis* at different rotations

Decreasing benefits by 10%				
Rotation (Years)	**Gross benefits (Rs.)**	**Costs (Rs.)**	**NPW (Rs.)**	**Benefit cost ratio**
12	3644.46	13.875	3630.585	262.663
6+6 = 12	4076.163	22.62	4053.543	180.202
8+4=12	3898.575	21.375	3877.20	182.389
4+8= 12	3962.925	24.075	3938.85	164.607
Decreasing benefits by 20%				
12	3239.52	13.875	3225.645	233.479
6+6 = 12	3623.256	22.62	3600.636	160.179
8+4=12	3465.40	21.375	3444.025	162.123
4+8= 12	3522.60	24.075	3498.525	146.318
Decreasing benefits by 30%				
12	2834.58	13.875	2820.705	204.294
6+6 = 12	3170.349	22.62	3147.729	140.157
8+4=12	3032.225	21.375	3010.85	141.858
4+8= 12	3082.275	24.075	3058.20	128.028
Decreasing benefits by 40%				
12	2429.64	13.875	2415.765	175.109

6+6 = 12	2717.442	22.62	2694.822	120.134
8+4=12	2599.05	21.375	2577.675	121.592
4+8= 12	2641.95	24.075	2617.875	109.738

Present worth of costs at a rotation of 5+5 = 10 years is Rs. 15.55 and that of income/benefits is Rs.5170.55 (table-10). NPW is Rs. 5155 and BCR is 332.511. As net present worth is positive, the project is economically feasible/ acceptable. It is important to note that NPW at 10 years rotation is Rs. 4844.532 while it is Rs. 5155 at rotation of 5+5 = 10 years. It means that when single rotation of 10 years is replaced with two rotations of 5 years each, the net present worth increased. So, rotation of 5+5 = 10 years is better than a single rotation of 10 years.

The difference is due to different growth rates of various tree species (Wondie, 2018). Present worth of costs at a rotation of 6+4=10 years is Rs. 15.08 while that of benefits is Rs. 5690.402 (table-11). NPW is Rs. 5675.322 and BCR is 377.347.

3.6. Comparison of various rotations of *Vachellia nilotica*

A comparison of NPW and BCR at different rotations of *Vachellia nilotica* has been made (table-12). It is observed that NPW at a rotation of 10, 5+5 =10 and 6+4 = 10 years rotation is Rs. 4844.532, Rs. 5155 and Rs. 5675.322 respectively. Although BCR is more in case of single rotation of 10 years than the other two rotations options. But the net income (NPW), in case of 6+4 = 10 years rotation is maximum. So, rotation of 6 years followed by a shorter rotation of 4 years is economically most feasible. it is the best option to grow trees at a rotation of 6+4 = 10 years.

As the values of NPW and BCR at all rotations of *Eucalyptus* and *Vachellia* are similar, so there is no need to carry out/calculate sensitivity analysis of *Vachellia nilotica*.

Table: 9: Present worth of benefits and cost, net present worth (NPW) and benefit cost ratio (BCR), of *Vachellia nilotica* at rotation of 10 years and Discount rate of 8%

Age (years)	Costs (Rs.)	Benefits (Rs.)	Discount factor @ 8%	PW of costs (Rs.)	PW of benefits (Rs.)
1	10	0	0.925	9.25	0
2	0	0	0.857	0	0
3	0	0	0.793	0	0
4	0	0	0.735	0	0
5	0	0	0.680	0	0
6	0	0	0.630	0	0
7	0	0	0.583	0	0
8	0	0	0.540	0	0
9	0	0	0.50	0	0
10	0	10483.33	0.463	0	4853.782
NPW (Rs.)	4844.532		Total	9.25	4853.782

Table 10: Present worth of benefits and cost, net present worth (NPW) and benefit cost ratio (BCR), at Discount rate of 8%, of *Vachellia nilotica* at rotation of 5+5 = 10 years

Age (years)	Costs (Rs.)	Benefits (Rs.)	Discount factor @ 8%	PW of costs (Rs.)	PW of benefits (Rs.)
1.	10	0	0.925	9.25	0
2.	0	0	0.857	0	0
3.	0	0	0.793	0	0
4.	0	0	0.735	0	0
5.	0	4523.67	0.680	0	3076.095

6.	10	0	0.630	6.30	0
7.	0	0	0.583	0	0
8.	0	0	0.540	0	0
9.	0	0	0.50	0	0
10.	0	4523.67	0.463	0	2094.45
NPW (Rs.)	5155		Total	15.55	5170.55
BCR	332.511				

Table 11: Present worth of benefits and cost, net present worth (NPW) and benefit cost ratio (BCR), at Discount rate of 8%, of *Vachellia nilotica* at rotation of 6+4 = 10 years

Age (years)	Costs (Rs.)	Benefits (Rs.)	Discount factor @ 8%	PW of costs (Rs.)	PW of benefits (Rs.)
1.	10	0	0.925	9.25	0
2.	0	0	0.857	0	0
3.	0	0	0.793	0	0
4.	0	0	0.735	0	0
5.	0	0	0.680	0	0
6.	0	6331.33	0.630	0	3988.737
7.	10	0	0.583	5.83	0
8.	0	0	0.540	0	0
9.	0	0	0.50	0	0
10.	0	3403.33	0.463	0	1701.665
			Total	15.08	5690.402
NPW (Rs.)	5675.322				
BCR	377.347				

Table 12. Comparison of net present worth (NPW) and Benefit cost ratio (BCR) at different rotations of *Vachellianilotica*

Rotation (years)	NPW (Rs.)	BCR
10	4844.532	524.733
5 + 5 = 10	5155	332.511
6 + 4 = 10	5675.322	377.347

4. DISCUSSION

The present study was conducted to know/calculate economic rotations of *Eucalyptus camaldulensis* and *Vachellia nilotica* in two tehsils of Punjab, Pakistan. Different rotation options were used to calculate net present worth and benefit cost ratio. It was seen that all rotations of *Eucalyptus camaldulensis* has a positive net present worth and more than 1 benefit cost ratio. So, all rotations were acceptable or economically suitable. NPW of trees is mostly negative in plantations because growth rate of trees is slow in plantations. Trees take a long period of time to become mature, in plantations. On the other hand, growth rate of trees is fast on farmlands. So, they become mature in a short period of time. So, their NPW is usually positive on farmlands. However, the rotation of 6 + 6 = 12 years was best with a net present worth of Rs. 4506.45. Similar results has been reported by Silva (2020) who found that NPW from a Eucalyptus forest plantation was 1925.10 Brazillian Reals and BCR 1.31 at a rotation of 7 years. Although rotation of trees is different in his study and our study (7 years and6+6 = 12 years respectively) but positive NPW and more than 1 BCR indicates that plantation of Eucalyptus is profitable in both cases. Similar findings were also reported by Wannawohg (1991) who reported that NPW and BCR of a Eucalyptus plantation forest in Thailand was 151 Baht acre-1 and 1.2 respectively. In both cases, positive NPW and more than 1 BCR indicates that both

investments are profitable and economically attractive. Eucalyptus is a fast growing tree species and on farmlands, its growth is very prompt as fertilizer and water applied to the crops is also picked up by trees. No doubt, crop yield may be effected due to it but production of abundant wood by Eucalyptus compensates this reduction in yield.

In case of *Vachellia nilotica* too, all rotation options were positive/acceptable. But rotation of 6 + 4 = 10 years was most profitable with a net present worth of Rs.5675.322. NPW at all rotations is positive because of relatively fast growth rate. These results are different from the findings of (Anjum et al., 2017) who found that by decreasing the rotation period of trees from 6 to 3 years, NPW decreased from Rs. 1576.74 to Rs. 1474.48 per tree. In some tree species, NPW increases and in other species, it decreases by decreasing the rotation. This may be due to the fact that with more age, trees produce hard (high quality timber). So, the price per unit volume may increase with more age. These results are in line with the findings of (Roy et al.,2021) who found that NPW of Vachellianilotica plantation was 915687 Bangladeshi Tikkas at a rotation of 20 years. It is important to note that although our rotation is different from his rotation, (6 + 4 = 10 years and 20 years respectively) but NPW of both is positive. So, the rotation of (6 + 4 =10 years) in Vachellianilotica is economically best.

5. CONCLUSION

NPW and BCR both indicate that cultivation of Eucalyptuscamaldulensis is beneficial at all rotations tested in this study. However, rotation of 6+6 =12 years is best because maximum NPW was attained at this rotation. That's why, farmers of Khushab are recommended to grow Eucalyptus at a rotation of 6+6 =12 years. Similarly, NPW and BCR in case of Vachellianilotica, indicate that cultivation of this tree species is economically profitable at all rotations. However maximum NPW is obtained at rotation of 6+4 = 10 years. That's why, farmers of Gujranwala are recommended to grow this tree species at this rotation.

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7. CONFLICT OF INTEREST.

The authors declare that there is no conflict of interest.

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