

# Optimal Rotation Interval of Akashmoni (*Acacia auriculiformis*) Plantations in Bangladesh

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## ABSTRACT

The rotation interval for akashmoni (*Acacia auriculiformis*) plantations in Bangladesh is discussed for fuel wood and timber under strip plantation, woodlot, and community forest management systems. The rotation interval was calculated on the basis of the market price, the market mechanism, and the costs and returns of akashmoni plantations during 2000–2001. Considering the present management system, the mode of marketing, the market mechanism, and all economic criteria, the rotation interval of akashmoni species may be fixed at 8 years for fuel wood and 13–15 years for timber. The average market price of round wood and fuel wood was US \$147.24 per m<sup>3</sup> and US \$0.72 per md (1 md = 37.3261 kg), respectively. The elimination rate varied from 5 to 90 percent depending on the plantation, the year, and the location, with values of 5 percent in the areas of Dinajpur, Bogra, and Dhaka and more than 50 percent in Tangail and Jessore. If the Net Present Value is considered as the rotation criterion, the rotation interval may be prescribed at age 15 years for timber. If the Internal Rate of Return and the Land Expectation Value are considered, the rotation interval may be fixed at 13 years for timber. Considering available data from plantations aged between 5 and 17 years, the recommended optimum rotation interval for timber and fuel wood was 15 and 8 years, respectively. At 15 years, the plantation was mature for timber use while fuel wood was a priority at 8 years as it was not necessary to use mature plantation wood.

**Keywords:** akashmoni, rotation interval, mean annual increment

## บทคัดย่อ

บทความอภิปรายช่วงเวลารอบตัดฟันของการปลูก akashmoni (*Acacia auriculiformis*) ในบังกลาเทศ สำหรับเป็นไม้เชื้อเพลิงและไม้ซุง ภายใต้การปลูกแบบแถบ สวนป่า และระบบการจัดการป่าชุมชน ช่วงเวลารอบตัดฟันถูกคำนวณบนพื้นฐานของราคาตลาด กลไกตลาด ค่าใช้จ่าย และผลตอบแทนของการปลูก akashmoni ช่วงปีค.ศ. 2000-2001 การพิจารณา

ระบบการจัดการปัจจุบัน การตลาด กลไกการตลาด และเกณฑ์ทางเศรษฐกิจทั้งหมด พบว่าช่วงเวลารอบตัดฟันของชนิดของสกุลพืช akashmoni อาจจะยึดที่ 8 ปี สำหรับเป็นไม้เชื้อเพลิง และ 13 ปีถึง 15 ปี สำหรับเป็นไม้ซุง ราคาตลาดเฉลี่ยของท่อนไม้และไม้เชื้อเพลิง พบว่าเป็นเงิน 147.24 ดอลลาร์สหรัฐ/ลูกบาศก์เมตร และ 0.72 ดอลลาร์สหรัฐ/md (1 md = 37.3261 กิโลกรัม) ตามลำดับ อัตราการถูกกำจัดฟันแปรจาก 5 เปอร์เซ็นต์ถึง 90 เปอร์เซ็นต์ ขึ้นอยู่กับ

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ปีที่ปลูกและสถานที่ปลูก ผลการศึกษาพบว่า 5 เปอร์เซ็นต์ที่อยู่ในพื้นที่ของ Dinajpur, Bogra และ Dhaka และมากกว่า 50 เปอร์เซ็นต์ในพื้นที่ Tangail และ Jessore ถ้ามูลค่าปัจจุบันสุทธิ (NPV) ถูกนำมาพิจารณาในเกณฑรอบตัดฟัน ช่วงเวลารอบตัดฟันอาจจะกำหนดได้ว่า อายุ 15 ปี สำหรับไม้ซุง ถ้าอัตราผลตอบแทนภายใน (IRR) และมูลค่าความคาดหวังของเงิน (Le) ถูกนำมาพิจารณา ช่วงเวลารอบตัดฟันอาจจะคิดที่ 13 ปี สำหรับไม้ซุง การพิจารณาข้อมูลที่มีระหว่างการปลูก 5 ปี และ 17 ปี พบว่าช่วงเวลาที่เหมาะสมในรอบตัดฟันสำหรับไม้ซุงและไม้เชื้อเพลิงอาจจะอยู่ที่อายุ 15 ปี และ 8 ปี ตามลำดับ ที่อายุ 15 ปี นั้น การปลูกจะได้ต้นไม้โตเต็มที่สำหรับใช้เป็นไม้ซุง และทำนองเดียวกันจะได้สิ่งที่ตามมาสำหรับเป็นไม้เชื้อเพลิงที่อายุ 8 ปี โดยไม่ต้องการการเจริญเติบโตเต็มที่

**คำสำคัญ:** akashmoni ช่วงเวลารอบตัดฟัน จำนวนที่เพิ่มขึ้นประจำปีเฉลี่ย

## INTRODUCTION

Akashmoni (*Acacia auriculiformis*) is a medium sized, heavily branched, evergreen tree with a short, forked bole. It is an exotic, mostly planted on roadsides and railway embankments and in parks and gardens in Bangladesh. The Bangladesh Forest Department established plantations from 1980 to 1990 (Das & Alam, 2001, p. 10). In Bangladesh, its normal plantation spacing has been fixed at 2 m × 2 m. However, the spacing is reduced to 1.3 m × 1.3 m for fuel wood and pulpwood. It attains a height of 25–30 m and a diameter of up to 60 cm on favorable sites in Bangladesh. Its wood is ideal for fuel wood and charcoal making and is also suitable for furniture. It has proved to be a good pulpwood.

Rotation determination is one of the most important and oldest problems in forestry (Pearse, 1967, p. 178). The main objective of the current study was to find out the rotation interval of akashmoni depending on various economic criteria.

The harvesting or rotation age of a plantation depends mainly on the growth rate of the species and the intended uses of the trees after clear-felling. The term ‘uses’ indicates economic uses as well as the maturity of the trees. To explain the maturity of the trees with respect to their economic uses, ‘rotation interval’ criteria are applied. There is no information about the rotation interval of akashmoni plantations in Bangladesh. To find out the rotation interval of akashmoni plantations, various economic criteria were applied—namely, Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost ratio (B/C), Efficiency Index (EI), Land Expectation Value (Le), and Equal Annual Equivalent (EAE).

## LITERATURE REVIEW

The optimal rotation interval for long term investment in forest plantations is determined solely by economic criteria such as NPV, IRR, B/C, Le etc that originated from the Faustmann-Pressler-Ohlin Theorem (Johansson & Löfgren, 1985, p. 74). These criteria have been utilized for estimating the optimal rotation interval for timber as well as fuel wood of akashmoni species planted in different locations in Bangladesh.

Akashmoni is a native of Australia and Papua New Guinea (Das, 1986). The species has been planted in different parts of the tropical world. In Java (Indonesia), the species has been planted since 1962 and in Sabah (Malaysia) and West Bengal (India) since 1973 (Banerjee, 1973). Das (1986) stated as “it is sure that about 25-30 years ago it was first planted as a shade tree in the tea estates of the Sylhet district” (p. 1). In Bangladesh, the species has been considered as a large scale plantation species from the early 1980s.

In tropical regions, it attains a height of 25–30 m on favorable sites and 6–20 m under very adverse conditions with the diameter of the trunk up to 60 cm (Das, 1986, p. 1). In Indonesia, it has been found to produce 15–20 m<sup>3</sup>/ha annually at a rotation of 10–12 years and 5–10 m<sup>3</sup>/ha annually at a rotation of 10–15 years (Das, 1986, p. 19).

The first yield table of *Acacia auriculiformis* in Java indicated that in a 10 to 12 year rotation, a total wood yield (4 cm top diameter) of over 20 m<sup>3</sup>/ha annually can be achieved (Wiersum & Ramlan, 1982, p. 18). Nicholson (1965) reported a mean annual increment (MAI) of 17 m<sup>3</sup>/ha. On the Island of Madura, plantations of 7-12 years had an average annual increment of 7.6–9.0 m<sup>3</sup>/ha (Setiadi & Samingan, 1978, p. 6). In West Bengal (India), plantations aged 10–12 years produced only 2–6 m<sup>3</sup>/ha annually. The rotation should be fixed to produce an MAI of about 15–16 m<sup>3</sup>/ha annually (Banerjee, 1973).

It is important to know the growth performance of akashmoni plantation in Bangladesh. The growth behavior of akashmoni differs substantially at different geographical locations in Bangladesh. Determination of the optimal rotation interval is related to growth performance.

Compared to *Pinus caribaea* and *Dipterocarpus turbinatus*, the MAI data of Akashmoni plantations were found to be best in both height and diameter growth. The heights of 4- and 5-year-old Akashmoni plantations were 2.45 m and 1.55 m, respectively, and the corresponding diameters at breast height (DBH) were 1.66 cm and 1.13 cm, respectively (Hoque, Osman, & Mia, 1991, p. 109). The total height of a 4-year-old Akashmoni tree was 7.0 m while its DBH was 6.3 cm (Rahman & Kamaluddin, 1995, p. 105). The MAI values for DBH and height for an Akashmoni plantation at 5 years were less than those at 4 years (Ahmmed, Mizbahuzzaman, & Ali, 1998, p. 55). With 97 percent survival of Akashmoni (which was the second highest rate among selected species), it has been recommended for short rotation plantation programs in denuded forest areas (Muhammed, Hossain, & Miah, 2000, p. 101).

## RESEARCH METHODOLOGY

### Survey method

The survey was conducted in 2000–2001.

Eleven forest divisions were selected subjectively—namely, Rajshahi, Tangail, Dinajpur, Potuakhali, Barisal, Jessore, Bogra, Dhaka, Comilla, Cox's Bazar and Chittagong. From each forest division, three to five plantations, aged 5 years or older were selected subjectively. From each plantation year, three sample plots of 0.01 ha each were randomly selected for collecting data on DBH and total height. The costs of seedling raising in the nursery, plantation establishment, weeding, thinning, vacancy filling, and maintenance were collected from the respective Divisional Forest Offices. The mode of marketing and the market prices of sawn wood, round wood, and fuel wood of akashmoni were collected from the market places nearest to the selected plantations using a designed questionnaire. The types of plantations were wood lot and strip plantation under community forestry. The plantation areas were recorded in acres and hectares. All planted areas were converted into hectares. Different planting spacings were used, ranging from 1.3 m × 1.3 m to 3.3 m × 3.3 m.

### Analysis methods

To determine the rotation interval and other economic parameters of the akashmoni plantations, the following formulas in Equations 1-3 (Gittinger, 1974, p. 98) were used in the analysis:

$$\text{NPV (Net Present Value)} = \sum \frac{R_n}{(1+i)^n} - \sum \frac{C_n}{(1+i)^n} \quad (1)$$

$$\text{IRR (Internal Rate of Return)} = \sum \frac{R_n}{(1+i)^n} - \sum \frac{C_n}{(1+i)^n} = 0 \quad (2)$$

$$\text{Benefit Cost Ratio (B/C)} = \frac{\sum \frac{R_n}{(1+i)^n}}{\sum \frac{C_n}{(1+i)^n}} \quad (3)$$

Where  $R_n$  is the returns every  $n$  years,  $C_n$  is the cost every  $n$  years,  $n$  is the number of years, and  $i$  is the interest rate.

Equation 4 (Gunter and Haney, 1984, p. 68) and Equation 5 ((Gunter and Haney, 1984, p. 72) were also used:

$$EAE = NPV \left[ \frac{i(1+i)^t}{(1+i)^t - 1} \right] \quad (4)$$

Where EAE is the Equal Annual Equivalent, NPV is the Net Present Value,  $i$  is the interest rate, and  $t$  is the rotation period, where  $t = 1, \dots, n$ .

$$L_e = \frac{Y_r + T_b(1+i)^{r-b} + I \left[ \frac{(1+i)^r - 1}{i} \right] - C_c(1+i)^{r-c} - e \left[ \frac{(1+i)^r - 1}{i} \right]}{(1+i)^r - 1} \quad (5)$$

Where  $Y$  is the net yield at rotation age,  $T$  is the net value of intermediate cuttings,  $b$  is the age at which revenue is received,  $I$  is the annual income,  $C$  is the net value of intermediate cost,  $c$  is the age at which cost is incurred,  $e$  is the annual expenses,  $r$  is the length of rotation, and  $i$  is the interest rate as a decimal.

Tree volume under bark ( $V_{ub}$ ) was estimated using Equation 6 (Latif, Rahman & Das, 1995, p.22):

$$\log(V_{ub}) = -10.2398 + 2.100244 \cdot \log(D) + 0.780214 \cdot \log(H) \quad (6)$$

Where  $V_{ub}$  is the volume under bark ( $m^3$ ),  $D$  is the DBH (cm),  $H$  is the tree height (m), and  $\log$  is the logarithm base 10.

The term 'elimination' is used to mean unauthorized felling. The elimination rate was determined using Equation 7:

$$Er = Is - (Ps + Tt + Nd) \quad (7)$$

Where  $Er$  is the elimination rate in percentage,  $Is$  is the initial planted seedling,  $Ps$  is the present stock,  $Tt$  is the number of trees thinned, and  $Nd$  is the number of trees that have naturally disappeared.

### Assumptions

The interest rate, the cost of harvesting as a percentage of the total value, the cost of processing as a percentage of the total value, and the number of trees per hectare were assumed to be 10%, 10%, 5%, and 1,000 (for MAI), respectively.

## RESULTS AND DISCUSSION

Both mixed and mono plantations were

studied. In mixed plantations, the average number of akashmoni seedlings varied from 20 percent to 90 percent of the total plants except in the oldest plantations established in 1983–86. The akashmoni planted areas were proportionately derived from the total planted seedlings of akashmoni and other species. The yield per hectare was estimated by multiplying the existing number of trees per hectare by the volume per tree.

The market survey was conducted in 2000–2001. The market prices of timber and fuel wood of akashmoni at 11 locations are shown in Table 1. The average market prices for sawn wood, round wood, and fuel wood were US \$253 per  $m^3$ , US \$147 per  $m^3$ , and US\$ 0.72/md (1 md = 37.3261 kg), respectively. The market prices of round wood and fuel wood were used in the analysis. The basic information for different plantation years is shown in Table 2.

The average number of seedlings per hectare was 3,200. The number of planted seedlings per hectare was greatest in the 1992–1993 plantations in Jessore and least in the 1982–1983 plantations in Dhaka. The elimination rate varied from 5 to 90 percent depending on the plantation year and location. The elimination rate was 5 percent in Dinajpur, Bogra, and Dhaka. Elimination rates greater than 50 percent were found in Tangail and Jessore. Further study is needed to address the causes of elimination which may be disguised.

Table 3 shows data on the height, diameter and volume of akashmoni plantations according to location and age.

The mean height and mean diameter were 15.56 m and 28.37 cm in plantations aged 10 and 16 years, respectively. The number of existing trees per hectare was highest in the 14-year-old plantation in Dinajpur and lowest in the 17-year-old plantation in Dhaka. This may have been due to unauthorized felling, the spacing, and the conversion of kilometers along roadsides into hectares. The conversion of kilometers into hectares has been done by multiplying the length of the plantations on roadsides and embankments by their average width.

It was found that the highest plantation MAI was at age 14 years in Dinajpur and the second highest at age 8 years in Dinajpur, Potuakhali and Cox's Bazar. Based on the criterion of MAI, the rotation age should be 8 years for fuel wood and 14 years for timber.

Table 4 shows the NPV, B/C, IRR, EI, Le and two types of EAE value of different plantations according to location and age.

In almost all areas, the NPV was negative for the plantations aged 5, 6 and 7 years. For 8-year-old plantations, the IRR was 48 percent in Cox's Bazar, 27 percent in Potuakhali and 16 percent in Dinajpur. The 16-year-old plantations of Bogra and Dhaka and the 13-year-old plantation of Jessore showed better results with respect to the NPV. Based on the IRR, the 11-year-old plantation of Dinajpur and the 16-year-old plantations of Dhaka and Bogra revealed better performance. Considering Le, the 13-year-old plantation of Jessore and the 16-year-old plantation of Bogra showed the highest values. The 13-year-old plantation in Jessore and the 15- and 16-year-old plantations of Bogra showed better results with respect to the EAE based on the NPV ( $EAE_{NPV}$ ). From these figures, it can be inferred that the rotation interval may be fixed at 13

–16 years for timber and 8 years for fuel wood.

The rotation age and economic criteria for akashmoni plantations in Bangladesh as a whole are shown in Table 5.

From the analysis, the highest NPV (US \$21,456), IRR (65%), B/C ratio (6.51), EI (US \$0.10) and Le (US \$7,718) came from plantations aged 15, 13, 17, 17, and 13 years, respectively. If only NPV were considered, then the rotation interval would be fixed at age 15 years, while if Le and IRR were considered, then the rotation interval would be fixed at age 13 years. On the other hand, if EI and B/C ratio were considered, the rotation interval would be 17 years. The fact that the NPV was negative in the plantations at age 5 and 7 years indicated that the benefits at these two ages were smaller than the investment costs of operations due to insufficient growth of the plantations which may have been because of the location, spacing, and climatic conditions. Among the economic criteria, NPV, IRR and Le were the most important for assessing the rotation interval. In this context, the rotation interval should be 13–15 years for timber and 8 years for fuel wood. Under the present socio-economic forestry management system, the rotation interval may be based on economic and end-use criteria.

**Table 1** Market prices of timber and fuel wood of akashmoni at different locations

| Location    | Market price (Tk/m <sup>3</sup> ) |           | Market prices (Tk/md) |
|-------------|-----------------------------------|-----------|-----------------------|
|             | Round wood                        | Sawn wood |                       |
| Rajshahi    | 8,121                             | 12,712    | 35                    |
| Tangail     | 6,945                             | 13,242    | 40                    |
| Dinajpur    | 8,121                             | 12,712    | 35                    |
| Potuakhali  | 5,257                             | 10,152    | 35                    |
| Barisal     | 7,768                             | 12,359    | 35                    |
| Jessore     | 8,298                             | 14,124    | 45                    |
| Bogra       | 8,121                             | 13,242    | 35                    |
| Dhaka       | 9,887                             | 19,421    | 40                    |
| Comilla     | 7,062                             | 15,890    | 50                    |
| Cox's Bazar | 7,945                             | 13,242    | 45                    |
| Chittagong  | 8,827                             | 13,242    | 35                    |
| Bangladesh  | 7,945                             | 13,667    | 39                    |

US \$1.00=Tk. 53.96 in 2000–2001. Source: Economic Trend (2001)(1 md = 37.3261 kg)

**Table 2** Basic information on akashmoni plantations in Bangladesh

| Variable \ Plantation year               | Tangail |         |         | Dinajpur |         |         |         |         |         |
|------------------------------------------|---------|---------|---------|----------|---------|---------|---------|---------|---------|
|                                          | 1992-93 | 1993-94 | 1994-95 | 1985-86  | 1986-87 | 1988-89 | 1991-92 | 1992-93 | 1993-94 |
| Total seedling (number)                  | 2,154   | 8,400   | 3,200   | 16,000   | 2,155   | 6,000   | 54,450  | 66,680  | 28,205  |
| Akashmoni seedling                       | 39%     | 21%     | 25%     | 20%      | 45%     | 60%     | 80%     | 80%     | 37%     |
| Akashmoni seedling (number)              | 840     | 1,475   | 800     | 3,200    | 970     | 3,600   | 43,560  | 53,344  | 16,073  |
| Total area (ha)                          | 0.71    | 2.14    | 1.43    | 3.57     | 0.57    | 20.00   | 1,800   | 40.00   | 16.78   |
| Akashmoni area (ha)                      | 0.28    | 0.40    | 0.36    | 0.71     | 0.26    | 12.00   | 14.40   | 32.00   | 9.63    |
| Elimination                              | 47%     | 28%     | 60%     | 25%      | 30%     | 5%      | 10%     | 20%     | 21%     |
| Existing akashmoni tree (number)         | 445     | 1,266   | 320     | 2,400    | 679     | 34,200  | 39,204  | 42,675  | 11,309  |
| Volume under bark (m <sup>3</sup> /tree) | 0.1722  | 0.1175  | 0.0822  | 0.0343   | 0.1299  | 0.0740  | 0.0740  | 0.0427  | 0.0420  |
| Yield (m <sup>3</sup> /ha)               | 275     | 378     | 74      | 115      | 343     | 211     | 202     | 57      | 60      |

  

| Variable \ Plantation year               | Barisal | Jessore |         |         |         |         | Bogra   |         |         |         |
|------------------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
|                                          | 1994-95 | 1983-84 | 1986-87 | 1992-93 | 1993-94 | 1994-95 | 1983-84 | 1984-85 | 1992-93 | 1993-94 |
| Total seedling (number)                  | 3,340   | 9,678   | 9,108   | 17,545  | 10,965  | 8,000   | 8,851   | 8,280   | 22,400  | 2,400   |
| Akashmoni seedling                       | 50%     | 11%     | 3%      | 15%     | 25%     | 25%     | 4%      | 5%      | 13%     | 58%     |
| Akashmoni seedling (number)              | 1,670   | 1,059   | 313     | 2,632   | 2,741   | 2,000   | 354     | 414     | 3,000   | 1,400   |
| Total area (ha)                          | 1.78    | 2.43    | 2.28    | 2.86    | 1.78    | 1.78    | 2.30    | 2.30    | 5.00    | 1.07    |
| Akashmoni area (ha)                      | 0.89    | 0.27    | 0.08    | 0.43    | 0.45    | 0.45    | 0.09    | 0.11    | 0.67    | 0.62    |
| Elimination                              | 18%     | 90%     | 40%     | 60%     | 20%     | 75%     | 20%     | 24%     | 5%      | 38%     |
| Existing akashmoni tree (number)         | 1,378   | 106     | 188     | 1,053   | 2,193   | 500     | 283     | 315     | 2,850   | 868     |
| Volume under bark (m <sup>3</sup> /tree) | 0.1038  | 0.2976  | 0.3044  | 0.1172  | 0.1320  | 0.0495  | 0.4098  | 0.2962  | 0.0787  | 0.1050  |
| Yield (m <sup>3</sup> /ha)               | 161     | 37      | 728     | 288     | 649     | 55      | 1,263   | 811     | 335     | 146     |

  

| Variable \ Plantation year               | Dhaka   |         |         |         | Comilla |         |         | Potuakhali |         |
|------------------------------------------|---------|---------|---------|---------|---------|---------|---------|------------|---------|
|                                          | 1982-83 | 1983-84 | 1992-93 | 1993-94 | 1989-90 | 1990-91 | 1994-95 | 1991-92    | 1994-95 |
| Total seedling (number)                  | 9,075   | 72,600  | 33,340  | 66,680  | 121,000 | 60,000  | 6,664   | 2,400      | 52,800  |
| Akashmoni seedling                       | 15%     | 25%     | 67%     | 100%    | 61%     | 61%     | 100%    | 30%        | 40%     |
| Akashmoni seedling (number)              | 1,361   | 18,150  | 22,338  | 66,680  | 73,810  | 36,600  | 6,664   | 720        | 21,120  |
| Total area (ha)                          | 10.00   | 24.00   | 20.00   | 40.00   | 40.00   | 39.20   | 4.00    | 1.07       | 11.78   |
| Akashmoni area (ha)                      | 1.50    | 6.00    | 13.40   | 40.00   | 24.40   | 23.91   | 4.00    | 0.32       | 4.71    |
| Elimination                              | 40%     | 40%     | 5%      | 5%      | 40%     | 20%     | 20%     | 20%        | 15%     |
| Existing akashmoni tree (number)         | 871     | 10,890  | 21,221  | 63,346  | 44,286  | 29,280  | 5,331   | 576        | 17,952  |
| Volume under bark (m <sup>3</sup> /tree) | 0.2467  | 0.3731  | 0.0640  | 0.0668  | 0.1194  | 0.1150  | 0.0347  | 0.4636     | 0.1178  |
| Yield (m <sup>3</sup> /ha)               | 134     | 677     | 101     | 106     | 217     | 141     | 46      | 831        | 449     |

| Plantation year<br>Variable              | Cox's Bazar |         |         |         |         | Chittagong |         |         | Rajshahi |         |
|------------------------------------------|-------------|---------|---------|---------|---------|------------|---------|---------|----------|---------|
|                                          | 1990-91     | 1991-92 | 1992-93 | 1993-94 | 1994-95 | 1990-91    | 1993-94 | 1994-95 | 1983-84  | 1984-85 |
| Total seedling (number '000')            | 148         | 148     | 370     | 88.80   | 148     | 60.45      | 119.44  | 119.44  | 5.10     | 10.35   |
| Akashmoni seedling                       | 5%          | 100%    | 100%    | 100%    | 90%     | 60%        | 100%    | 100%    | 65%      | 50%     |
| Akashmoni seedling (number '000')        | 7.40        | 148     | 370     | 88.80   | 133.20  | 36.27      | 119.44  | 119.44  | 3.31     | 5.17    |
| Total area (ha)                          | 40.00       | 40.00   | 100.00  | 24.00   | 40.00   | 20.24      | 40.00   | 40.00   | 1.72     | 2.87    |
| Akashmoni area (ha)                      | 2.00        | 40.00   | 100.00  | 24.00   | 36.00   | 12.14      | 40.00   | 40.00   | 1.12     | 1.44    |
| Elimination                              | 35%         | 30%     | 20%     | 20%     | 15%     | 10%        | 20%     | 20%     | 40%      | 30%     |
| Existing akashmoni tree (number '000')   | 4.81        | 103.60  | 296     | 71.04   | 113.22  | 32.64      | 95.55   | 95.55   | 1.99     | 3.62    |
| Volume under bark (m <sup>3</sup> /tree) | 0.1624      | 0.1907  | 0.0490  | 0.0614  | 0.0353  | 0.0834     | 0.0647  | 0.0359  | 0.3027   | 0.2438  |
| Yield (m <sup>3</sup> /ha)               | 391         | 494     | 145     | 182     | 111     | 224        | 155     | 86      | 538      | 615     |

**Table 3** Height, diameter and volume of akashmoni plantations according to location and age

| Location                                                              | Age | Total height (m) |       |       | DBH (cm) |       |       | Vub (m <sup>3</sup> /ha) | Total trees (m <sup>3</sup> /ha) | Total yield (m <sup>3</sup> /ha) | MAI (m <sup>3</sup> /ha) |
|-----------------------------------------------------------------------|-----|------------------|-------|-------|----------|-------|-------|--------------------------|----------------------------------|----------------------------------|--------------------------|
|                                                                       |     | Max              | Min   | Mean  | Max      | Min   | Mean  |                          |                                  |                                  |                          |
| Dhaka                                                                 | 17  | 18.29            | 9.14  | 13.98 | 42.71    | 15.37 | 24.15 | 0.25                     | 545                              | 134.45                           | 15                       |
| Bogra, Dhaka                                                          | 16  | 14.83            | 7.98  | 14.48 | 32.98    | 15.20 | 28.37 | 0.28                     | 1,677                            | 469.78                           | 18                       |
| Jessore,Rajshahi,                                                     |     |                  |       |       |          |       |       |                          |                                  |                                  |                          |
| Bogra, Rajshahi                                                       | 15  | 16.31            | 10.21 | 13.68 | 34.91    | 18.57 | 25.81 | 0.27                     | 2,631                            | 710.37                           | 18                       |
| Dinajpur                                                              | 14  | 10.67            | 6.10  | 8.81  | 16.99    | 8.49  | 13.03 | 0.44                     | 4,250                            | 1,479.28                         | 31                       |
| Dinajpur, Jessore                                                     | 13  | 17.83            | 7.93  | 13.71 | 31.96    | 13.75 | 22.29 | 0.22                     | 2,517                            | 546.57                           | 17                       |
| Dinajpur, Jessore, Comilla                                            | 12  | 16.53            | 8.93  | 13.31 | 26.90    | 12.54 | 18.11 | 0.16                     | 2,425                            | 380.50                           | 13                       |
| Dinajpur, Comilla                                                     | 11  | 15.24            | 9.91  | 14.92 | 21.85    | 11.33 | 13.92 | 0.10                     | 2,333                            | 225.55                           | 9                        |
| Comilla                                                               | 10  | 17.68            | 10.67 | 15.56 | 22.65    | 11.73 | 16.36 | 0.12                     | 1,224                            | 140.76                           | 12                       |
| Chittagong, Cox's Bazar                                               | 9   | 15.39            | 10.67 | 12.55 | 23.46    | 14.36 | 18.25 | 0.12                     | 2,547                            | 312.96                           | 14                       |
| Dinajpur,Potua khali, Cox's Bazar                                     | 8   | 19.30            | 10.87 | 14.70 | 32.90    | 14.29 | 21.31 | 0.24                     | 2,369                            | 575.03                           | 30                       |
| Dinajpur, Bogra, Tangail, Jessore, Dhaka, Cox's Bazar                 | 7   | 14.55            | 8.47  | 11.02 | 23.18    | 11.53 | 14.87 | 0.09                     | 2,366                            | 206.54                           | 12                       |
| Tangail, Jessore, Comilla,Chittagong Potuakhali, Barisal, Cox's Bazar | 5   | 12.22            | 5.28  | 10.09 | 17.34    | 8.57  | 13.49 | 0.06                     | 1,896                            | 111.79                           | 12                       |

Max = Maximum, Min = Minimum, Vub = Volume under bark

**Table 4** Economic information of akashmoni plantations in Bangladesh according to location and age

| Location    | Age<br>(years) | Economic criteria |      |      |         |         |                   |                    |
|-------------|----------------|-------------------|------|------|---------|---------|-------------------|--------------------|
|             |                | NPV (Tk)          | IRR  | B/C  | EI (Tk) | Le (Tk) | EAE <sub>Le</sub> | EAE <sub>NPV</sub> |
| Tangail     | 7              | 8,869             | 19%  | 1.44 | 0.44    | 9,348   | 1,920             | 1,822              |
|             | 6              | 14,801            | 17%  | 1.28 | 0.28    | 19,184  | 4,405             | 3,394              |
|             | 5              | 6,180             | -1%  | 0.70 | -0.30   | -10,123 | -2,671            | -1,630             |
| Dinajpur    | 14             | 205,093           | 51%  | 5.92 | 4.92    | 73,313  | 9,952             | 27,841             |
|             | 13             | 663,505           | 48%  | 5.61 | 4.61    | 270,568 | 38,090            | 93,407             |
|             | 11             | 499,691           | 65%  | 5.95 | 4.95    | 269,649 | 41,516            | 76,934             |
|             | 8              | 6,236             | 16%  | 1.31 | 0.31    | 5,453   | 1,022             | 1,169              |
|             | 7              | -1,908            | 5%   | 0.81 | -0.19   | -2,011  | -413              | -392               |
| Potuakhali  | 6              | -11,394           | -10% | 0.46 | -0.54   | -14,768 | -3,391            | -2,616             |
|             | 8              | 58,194            | 27%  | 2.15 | 1.15    | 50,888  | 9,539             | 10,908             |
|             | 5              | 940               | 10%  | 1.01 | 0.01    | 1,539   | 406               | 248                |
| Barisal     | 5              | -48,896           | -22% | 0.36 | -0.64   | -80,090 | -21,128           | -12,899            |
| Jessore     | 16             | 32,602            | 18%  | 1.93 | 0.93    | 9,069   | 1,159             | 4,167              |
|             | 13             | 1,379,094         | 61%  | 6.16 | 5.16    | 562,374 | 79,170            | 194,147            |
|             | 7              | -24,621           | -3%  | 0.61 | -0.39   | -25,952 | -5,331            | -5,057             |
|             | 6              | 38,686            | 28%  | 1.67 | 0.67    | 50,139  | 11,512            | 8,883              |
|             | 5              | -18,573           | -19% | 0.40 | -0.60   | -30,421 | -8,025            | -4,899             |
| Bogra       | 16             | 2,072,968         | 62%  | 6.41 | 5.41    | 652,441 | 85,779            | 272,541            |
|             | 15             | 1,325,147         | 55%  | 6.25 | 5.25    | 417,074 | 54,834            | 174,222            |
|             | 7              | -11,339           | 5%   | 0.81 | -0.19   | -11,952 | -2,455            | -2,329             |
|             | 6              | -8,442            | 1%   | 0.73 | -0.27   | -10,942 | -2,512            | -1,938             |
| Dhaka       | 17             | 436,924           | 57%  | 6.51 | 5.51    | 107,764 | 13,434            | 54,469             |
|             | 16             | 1,238,238         | 91%  | 6.66 | 5.66    | 344,436 | 44,025            | 158,267            |
|             | 7              | 525               | 11%  | 1.03 | 0.03    | 553     | 114               | 108                |
|             | 6              | 568               | 11%  | 1.03 | 0.03    | 736     | 169               | 130                |
| Comilla     | 10             | 577,811           | 44%  | 5.81 | 4.81    | 362,550 | 59,003            | 94,036             |
|             | 9              | 11,409            | 24%  | 1.91 | 0.91    | 8,402   | 1,459             | 1,981              |
|             | 5              | -6,939            | -7%  | 0.62 | -0.38   | -11,366 | -2,998            | -1,831             |
| Cox's Bazar | 9              | 39,056            | 35%  | 2.90 | 1.90    | 28,761  | 4,994             | 6,782              |
|             | 8              | 58,890            | 48%  | 3.45 | 2.45    | 51,496  | 9,653             | 11,039             |
|             | 7              | 11,144            | 26%  | 1.71 | 0.71    | 11,746  | 2,413             | 2,289              |
|             | 6              | 20,187            | 21%  | 2.21 | 1.21    | 26,164  | 6,007             | 4,635              |
|             | 5              | 9,777             | 14%  | 1.65 | 0.65    | 16,015  | 4,225             | 2,579              |
| Chittagong  | 9              | 11,921            | 22%  | 1.81 | 0.81    | 8,779   | 1,524             | 2,070              |
|             | 6              | 12,547            | 13%  | 1.74 | 0.74    | 16,262  | 3,734             | 2,881              |
|             | 5              | -3,497            | 2%   | 0.84 | -0.16   | -5,728  | -1,511            | -923               |
| Rajshahi    | 16             | 786,118           | 46%  | 5.79 | 4.79    | 218,671 | 27,950            | 100,479            |
|             | 15             | 990,392           | 49%  | 5.82 | 4.82    | 311,714 | 40,982            | 130,211            |

NPV = Net Present Value, IRR = Internal Rate of Return, B/C = Benefit-Cost ratio, EI = Efficiency Index, Le = Land Expectation Value, EAE<sub>Le</sub> = Equal Annual Equivalent based on Le, EAE<sub>NPV</sub> = Equal Annual Equivalent based on NPV

US \$1.00 = Tk 53.96 in 2000–2001. Source: Economic Trend (2001)

**Table 5** Economic information of akashmoni plantations in Bangladesh

| Plantation age (years) | Bangladesh |     |      |        |          |                   |                    |
|------------------------|------------|-----|------|--------|----------|-------------------|--------------------|
|                        | NPV(Tk)    | IRR | B/C  | EI(Tk) | Le (Tk)  | EAE <sub>Le</sub> | EAE <sub>NPV</sub> |
| 17                     | 436,924    | 57% | 6.51 | 5.51   | 107,764  | 13,434            | 54,469             |
| 16                     | 1,032,481  | 54% | 5.20 | 4.20   | 306,154  | 39,728            | 133,864            |
| 15                     | 1,157,769  | 52% | 6.04 | 5.04   | 364,394  | 47,908            | 152,216            |
| 14                     | 205,093    | 51% | 5.92 | 4.92   | 73,313   | 9,952             | 27,841             |
| 13                     | 1,021,300  | 65% | 5.89 | 4.89   | 416,471  | 58,630            | 143,777            |
| 12                     | 760,496    | 60% | 5.92 | 4.92   | 343,060  | 50,073            | 110,356            |
| 11                     | 499,691    | 55% | 5.95 | 4.95   | 269,649  | 41,516            | 76,934             |
| 10                     | 577,811    | 44% | 5.81 | 4.81   | 362,550  | 59,003            | 94,036             |
| 9                      | 20,795     | 27% | 2.21 | 1.21   | 15,314   | 2,659             | 3,611              |
| 8                      | 41,107     | 30% | 2.30 | 1.30   | 35,945   | 6,738             | 7,705              |
| 7                      | -1,889     | 10% | 1.07 | 0.07   | -3,045   | -625              | -593               |
| 6                      | 9,565      | 17% | 1.30 | 0.30   | 12,396   | 2,846             | 2,196              |
| 5                      | -10,481    | 0%  | 0.80 | -0.20  | -174,168 | -4,529            | -2,765             |

NPV = Net Present Value, IRR = Internal Rate of Return, B/C = Benefit-Cost ratio, EI = Efficiency Index, Le = Land Expectation Value, EAE<sub>Le</sub> = Equal Annual Equivalent based on Le, EAE<sub>NPV</sub> = Equal Annual Equivalent based on NPV

US \$ 1.00=Tk. 53.96 in 2000-2001. Source: Economic Trend, September 2001, Bangladesh Bank

## CONCLUSION AND RECOMMENDATIONS

The elimination rate varied from 5 to 90 percent depending on the plantation age and location, with a value of 5 percent in Dinajpur, Bogra, and Dhaka. Elimination rates greater than 50 percent were found in Tangail and Jessore. The inherent guiding factors of elimination may call for further study to explore the real dominating causes of elimination that are perhaps disguised. Considering the present socio-economic forestry management system, the rotation interval might be based on economic and end-use criteria. It was also clear that no single method of analysis can be considered to determine the rotation interval, as this parameter depends on the objectives of the study. Under the present forestry management system, mode of marketing, market mechanism, and all economic criteria, the rotation interval of akashmoni species may be fixed at 8 years for fuel wood and 13–15 years for timber. To date, the rotation interval for

fuel wood and timber has been fixed for existing plantations raised by the Bangladesh Forest Department who have been planting akashmoni seedlings on a large scale every year in all suitable areas. The Forest Department will follow the prescription of the optimal rotation interval for timber and fuel wood. Accordingly, the Department will harvest plantations at ages of 15 and 8 years for timber and fuel wood, respectively. The land will then be prepared for the next plantation using a suitable species. Since the growth of a species varies due to the location, spacing, mixed-mono plantation, and climatic conditions, representative growth and yield data spanning many more years and locations are required to provide the necessary information for conducting future research on optimizing the rotation ages for fuel wood and timber. It is only when such an extensive dataset is available that more refined rotation intervals can be recommended for plantations. However, until then or other recommendations are available, the present results can be utilized.

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