Natural Rubber Research, 21 (1&2): 109-118, 2008

AGEING OF MATURE AREA AND DECLINING YIELD PROFILE OF NATURAL RUBBER IN INDIA

Jom Jacob and K. Tharian George*
Rubber Board, Kottayam – 686 002, Kerala, India
*Rubber Research Institute of India, Kottayam – 686 009, Kerala, India

Jacob, J. and George, K.T. (2008). Ageing of mature area and declining yield profile of Natural Rubber in India 21(1&2)109-118.

The paper is focused on the trends in age-composition of mature area under natural rubber cultivation in India from a long-term policy perspective. The analysis is based on official data pertaining to historical planting of natural rubber and commercial yield profile of the clone RRII 105 during its life cycle. The results highlighted a steady growth in area under the yield declining phase and the resultant downward trends in estimated average crop yield since 2001-02. The projected share of area under the yield declining phase is 46 per cent and the projected average yield is 1593 kg/ha for the year 2014-15. Since the estimated average yield and production since 2001-02 are at variance with the official data, there is need for a reliable database on the age-composition of area under rubber for long term policy interventions.

Keywords: Age-composition, *Hevea brasiliensis*, India, Mature rubber plantation, Yield projections, Yielding phases.

INTRODUCTION

The outcomes of trade policy reforms launched in India since the early 1990s varied across different sectors and sub-sectors of the economy. One of the important consequences of the reforms in the plantation sector has been growing market uncertainties mainly due to the market integration process during the past one-decade. Despite the differences in the gravity of issues arising from uncertainty in farm gate prices, policy perceptions on strategies to confront the challenges are primarily focused on reducing the cost of production across the major plantation crops. Among the various options to attain the cost competitiveness, sustained increase in yield has acquired prominence in the agro-management revitalisation programmes. However, for perennial crops there are well-defined biological and technological limitations for sustained improvements in yield for the following three important reasons: (i) higher initial investment (ii) longer gestation period and (iii) a prolonged economic life *vis-à-vis* annual crops (Nerlove, 1979). More precisely, relative flexibility for yield augmenting measures in the short-run is limited and therefore, at any given point of time, the yield and total production of perennial crops are primarily determined by the variety and age-composition of the existing plantations (Akiyama and Trivedi, 1987). As the growers normally choose the high yielding varieties of planting materials either for new planting or

Correspondence: Jom Jacob (Email: jomjacob2004@gmail.com)

replanting, functionally, it is the age-composition of the existing stock which has an explicit influence on the yield and total crop production. Although there could be crop-specific differences in the yield profile at different yielding phases of the life cycle, the inverse relationship between the age profile and yield beyond the peak yielding phase is generally observed. Therefore, from a long-term policy angle, it is imperative to have realistic estimates/projections on the age-composition of perennial crops.

The influence of age-composition on yield of perennial crops has been examined for tea (Akiyama and Trivedi, 1987), coffee (Wickens and Greenfield, 1973), cardamom (Nair *et al.*,1989), cocoa (Trivedi, 1974) and cling peach (French *et al.*, 1985). In the case of natural rubber (NR), the predominant influence of age factor on commercial yield is reported in India for all the important varieties of planting materials (George *et al.*, 1988; Joseph *et al.*, 1999)[1]. For a given agro-climatic condition and farm management practice, coefficient of variation of natural rubber yield ranges from 30 to 47 per cent during the first 10 years, 25 to 37 per cent during the first 15 years and 22 to 26 per cent during the first 20 years of tapping depending on clones. Age factor alone accounts for as much as 64 to 100 per cent of the variations in yield (George *et al.*, 1988).

However, so far no systematic attempt has been made to estimate/project yield and production or replanting requirements on the basis of the changing age profile of mature area under NR (*Hevea brasiliensis*) in India. In order to fill this gap, a preliminary attempt was made to estimate the age-composition of mature area under rubber cultivation in India and to examine the relationship between changing age-composition and average crop yield so as to provide reliable policy inputs for projecting potential production and replanting requirements.

The specific objectives of the study were (1) to estimate the age-composition of rubber plantations

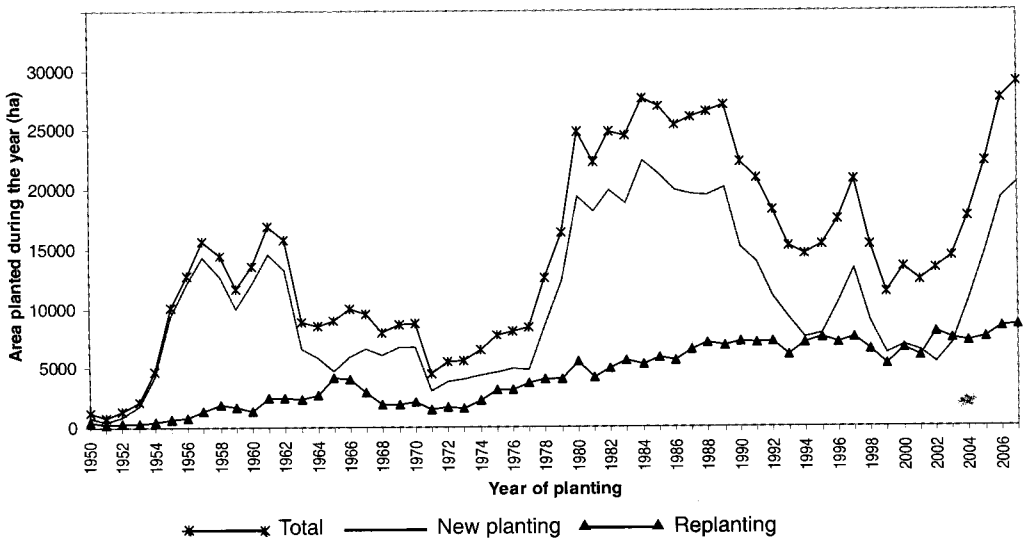

Fig. 1. Trends in newplanting and replanting of NR in India

in India for the period from 1980-81 to 2014-15 (2) to assess the influence of age-composition on the average yield for the period from 2001-02 to 2007-08 (3) to compare the official estimates of national average yield with those based on age-composition, for the period from 2001-02 to 2007-08 and (4) to project the influence of changing age-composition on the average yield for the period 2008-09 to 2014-15.

MATERIALS AND METHODS

Age-composition of rubber plantations in any country in a year is normally determined by the past trends in planting[2]. In a hypothetical situation where the rate of planting remains uniform in all years, the different age groups of trees would also be uniformly distributed in the total mature area. But, the trends in planting in India had not been uniform during the period from 1950-51 to 2007-08 as shown in Figure 1. Hence, the age-composition of mature area is not expected to be uniform. Any cyclic change in planting trend is expected to reflect on the age-composition of mature area and this would have serious implications on potential yield and production of natural rubber in India. This proposition assumes importance in framing future priorities for the NR production sector. This exploratory analysis is an attempt to highlight the need for a reliable database on the age-composition of rubber plantations in the country and its regular monitoring.

Since RRII 105 is the single prominent clone cultivated in India with the highest reported life cycle yield (Chandy and Sreelakshmi, 2008), its yield profile during various yielding phases is assumed to reflect the relationship between age and yield[3]. Hence, the period from 1980-81 to 2007-08 was selected for two important reasons: (i) the year 1980 coincides with the official release and subsequent prominence of RRII 105, the commercial yield potential of which is not seriously challenged till date and (ii) the year coincides with the formal launching of Rubber Plantation Development Scheme integrating replanting and newplanting schemes[4].

The age-composition was estimated from 1980-81 to 2014-15 as the official data on planting are available up to the year 2007-08 (Rubber Board, 2008). The yield and production were estimated based on the age-composition for the period from 2001-02 to 2007-08 and projected from 2008-09 to 2014-15. For estimating the age-composition, reliable data on actual age of replanting are necessary. However, consensus is missing on the actual age of replanting as there has been a growing trend towards postponement of replanting during the past few years owing to: (i) adoption of low-intensity tapping which facilitates low bark consumption and (ii) growing uncertainty in rubber prices. In order to examine the validity of this argument, replanting age was estimated for the period from 1995-96 to 2007-08. As this was a period in which NR prices had taken both unprecedented peaks and downslides, changes in replanting age, if any, in response to price cycle should have been reflected. The replanting age was estimated as explained below:

Tappable area during the year't' may be expressed as

$$(\text{Tappable area})_t = (NP+RP)_{t-7} + (NP+RP)_{t-8} + (NP+RP)_{t-9} + (NP+RP)_{t-10} + \ldots\ldots\ldots\ldots + (NP+RP)_{t-m} + \text{Correction factor},$$

Table 1. **Comparison of estimated (based on replanting at the age of 29) and officially published tappable area**

Year	Tappable area (ha)		Estimated area as % of the
	Estimated	Official	official tappable area
1995-96	348720	356444	98
1996-97	365824	365580	100
1997-98	378602	376970	100
1998-99	391569	387100	101
1999-00	401140	394800	102
2000-01	407596	399901	102
2001-02	417579	400713	104
2002-03	427400	407953	105
2003-04	439249	427935	103
2004-05	453539	439720	103
2005-06	461179	447015	103
2006-07	464426	454020	102
2007-08	469430	458830	102

where 'm' represents the replanting age, NP and RP represent area under new planting and replanting respectively. Ideally, a correction factor also has to be included in the estimation procedure to account for the rubber area discarded. However, to make the problem simple, it is assumed that there was no discarding *i.e.*, there was no permanent crop shift from rubber. The task was to estimate 'm'. The value of 'm' may be different for different years depending on the trends in prices and price expectations. Therefore, the value of 'm' was estimated by a trial and error method. Tappable area was computed for various values of 'm' say 25, 26, 27, 28, 29, 30, 31 and 32. In each case, the computed tappable area was compared with the actual (*i.e.*, the officially published) tappable area. The result obtained for m = 29 is shown in Table 1[5].

It is evident that the estimated tappable area based on replanting at the age of 29 and the officially published tappable area during the period from 1995-96 to 2007-08 are comparable. Therefore, it is plausible to infer that the replanting pattern has not changed

Table 2. **Yielding phases of RRII 105**

Phases	Tapping age (years)	Average yield (kg/ha)	Variability (CV)	Characteristics of yield profile
1	1 to 3	1417	13.8	Lowest average yield, increases with higher variability
2	4 to 13	1811	6.5	Highest average yield, most stable
3	14 to 22	1566	16.8	Lower average yield Decreases with highest variability

Computed from Chandy and Sreelakshmi (2008)

considerably despite the fluctuations in NR prices during the past one decade. Accordingly, composition of the tappable area during the period up to 2014-15 was estimated based on the assumptions that (i) total life span of rubber plantation is 29 years (ii) tapping starts at the age of seven (*i.e.*, beginning of the yielding phase and the first year of tapping) (iii) total yielding phase is 22 years and (iv) there is no significant change in replanting age in response to price changes or other reasons which include advent of new technology in harvesting.

The total tappable area during the year 't' = (Area with tapping age 1) + (Area with tapping age 2) + (Area with tapping age 3) + ...+ (Area with tapping age 22) = (Area planted during the year 't-7') + (Area planted during the year 't-8') + (Area planted during year 't-9') +.... +(Area planted during the year 't-29')

On the basis of commercial yield performance, the productive life span of a plantation of clone RRII 105 can be divided into the three phases (Table 2). The second phase assumes importance because of (i) higher average yield; (ii) better stability of yield and (iii) longer duration of the phase.

Since adequate number of fields cultivated with RRII 105 were not available for all tapping ages, the yield data were estimated by the method of least-square regression. The estimated relationship of yield (y) with tapping age (x) is:

$$y = 94.98\ x - 4.6604\ x^2 + 1348.6$$

$$(R^2 = 0.6609)$$

The observed relationship between tapping age and the yield along with the polynomial estimated are shown in Figure 2. It illustrates the three marked phases in the life cycle yield of RRII 105. Similar pattern of life cycle yield is observed across different prominent rubber clones with annual variations.

The average yield and annual production were estimated/projected by using the estimated age-composition of the tappable area and the yield profile of RRII 105 for the period from 2001-02 to 2014-15.

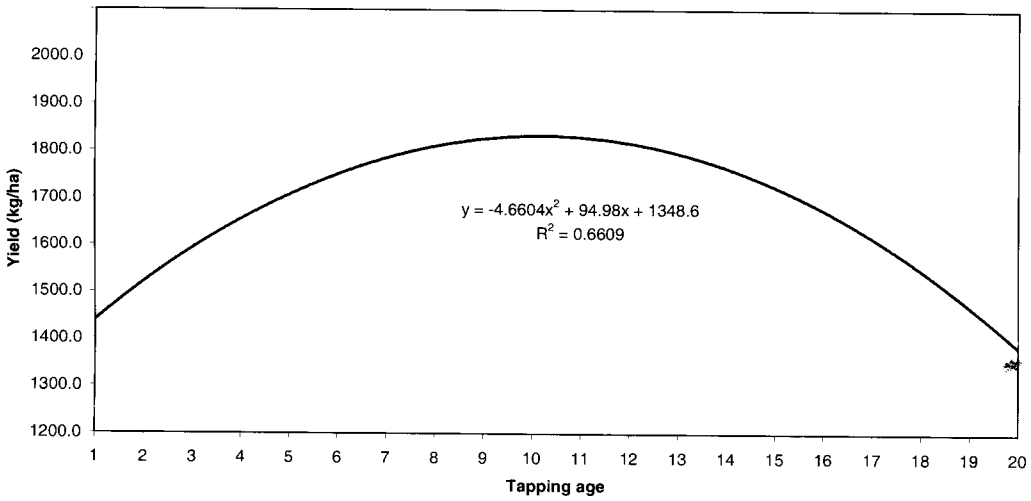

Fig. 2. Commercial yield profile of RRII 105

Table 3. **Relative share of tapping ages and estimates of average yield (2001-02 to 2014-15)**

Tapping age	Relative share of different tapping ages in tappable area (%)													
	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15
1	3.5	3.6	4.0	4.7	3.4	2.5	2.9	2.7	3.0	3.3	4.1	5.3	6.5	6.8
2	3.7	3.4	3.5	3.9	4.6	3.4	2.5	3.0	2.8	3.1	3.4	4.2	5.3	6.5
3	4.4	3.6	3.4	3.4	3.8	4.6	3.3	2.5	3.0	2.8	3.1	3.4	4.2	5.2
Sub-total	11.6	10.7	10.9	12.0	11.8	10.4	8.8	8.2	8.8	9.2	10.6	12.8	15.9	18.5
4	5.1	4.3	3.5	3.3	3.4	3.8	4.6	3.4	2.6	3.1	2.9	3.1	3.4	4.1
5	5.4	5.0	4.2	3.4	3.2	3.4	3.8	4.6	3.5	2.6	3.1	2.9	3.1	3.4
6	6.6	5.3	4.8	4.1	3.4	3.2	3.3	3.8	4.7	3.5	2.7	3.2	2.9	3.1
7	6.4	6.4	5.2	4.7	4.0	3.3	3.2	3.4	3.9	4.8	3.6	2.7	3.2	2.9
8	6.3	6.3	6.2	5.0	4.6	4.0	3.3	3.2	3.5	4.0	4.9	3.6	2.7	3.1
9	6.2	6.2	6.1	6.1	4.9	4.6	4.0	3.4	3.3	3.5	4.1	4.9	3.6	2.7
10	6.5	6.0	6.0	5.9	6.0	4.9	4.6	4.0	3.4	3.3	3.6	4.1	4.9	3.6
11	6.7	6.4	5.9	5.8	5.8	5.9	4.9	4.6	4.1	3.5	3.4	3.6	4.1	4.9
12	5.9	6.5	6.2	5.7	5.7	5.8	5.9	4.9	4.7	4.2	3.6	3.4	3.6	4.1
13	6.0	5.8	6.4	6.1	5.6	5.7	5.8	6.0	5.1	4.8	4.3	3.6	3.4	3.6
Sub-total	61.2	58.2	54.6	50.0	46.7	44.6	43.4	41.3	38.8	37.5	36.1	35.1	34.9	35.5
14	5.4	5.9	5.6	6.2	6.0	5.6	5.7	5.8	6.1	5.1	4.9	4.3	3.6	3.4
15	6.0	5.3	5.7	5.5	6.1	5.9	5.6	5.8	6.0	6.2	5.2	4.9	4.3	3.6
16	4.0	5.9	5.2	5.6	5.4	6.0	5.9	5.6	5.9	6.1	6.3	5.3	4.9	4.3
17	3.0	3.9	5.7	5.0	5.5	5.4	6.0	6.0	5.8	6.0	6.2	6.4	5.3	4.9
18	2.0	3.0	3.8	5.6	4.9	5.4	5.4	6.1	6.1	5.9	6.1	6.2	6.4	5.2
19	2.0	2.0	2.9	3.7	5.5	4.9	5.4	5.4	6.2	6.2	6.0	6.1	6.2	6.3
20	1.9	1.9	1.9	2.8	3.6	5.4	4.9	5.5	5.5	6.4	6.3	6.0	6.1	6.2
21	1.6	1.8	1.9	1.9	2.8	3.6	5.4	4.9	5.6	5.6	6.5	6.4	6.0	6.1
22	1.3	1.5	1.8	1.8	1.9	2.7	3.6	5.5	5.0	5.7	5.7	6.5	6.4	6.0
Sub-total	27.2	31.2	34.5	38.0	41.5	45.0	47.9	50.5	52.4	53.3	53.3	52.1	49.2	46.0
Grand Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Estimated average yield	1706	1701	1692	1680	1668	1656	1642	1630	1626	1617	1609	1600	1595	1593
Officially reported average yield	1576	1592	1663	1705	1796	1879	1799							

RESULTS AND DISCUSSION

The age-composition of mature area for the period from 1980-81 to 2014-15 was estimated and the summary results are given in Figure 3. The share of area in the age group under the second phase (tapping age '4-13 years' with the highest average yield) is a critical factor determining yield and total NR production at any given point of time. Relative shares of the area under second and third

Table 4. **Estimates/projections of NR production (2001-02 to 2014-15)**

Tapping age	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15
	Tappable area ('000 hectare)													
1	15.3	11.3	13.4	12.3	13.3	14.3	17.6	22.3	27.6	29.0	15.3	11.3	13.4	12.3
2	20.8	15.3	11.3	13.4	12.3	13.3	14.3	17.6	22.3	27.6	20.8	15.3	11.3	13.4
3	17.4	20.8	15.3	11.3	13.4	12.3	13.3	14.3	17.6	22.3	17.4	20.8	15.3	11.3
Sub-total	53.5	47.4	40.0	37.0	39.0	39.9	45.2	54.2	67.5	78.9	53.5	47.4	40.0	37.0
4	15.3	17.4	20.8	15.3	11.3	13.4	12.3	13.3	14.3	17.6	15.3	17.4	20.8	15.3
5	14.5	15.3	17.4	20.8	15.3	11.3	13.4	12.3	13.3	14.3	14.5	15.3	17.4	20.8
6	15.2	14.5	15.3	17.4	20.8	15.3	11.3	13.4	12.3	13.3	15.2	14.5	15.3	17.4
7	18.2	15.2	14.5	15.3	17.4	20.8	15.3	11.3	13.4	12.3	18.2	15.2	14.5	15.3
8	21.0	18.2	15.2	14.5	15.3	17.4	20.8	15.3	11.3	13.4	21.0	18.2	15.2	14.5
9	22.3	21.0	18.2	15.2	14.5	15.3	17.4	20.8	15.3	11.3	22.3	21.0	18.2	15.2
10	27.0	22.3	21.0	18.2	15.2	14.5	15.3	17.4	20.8	15.3	27.0	22.3	21.0	18.2
11	26.5	27.0	22.3	21.0	18.2	15.2	14.5	15.3	17.4	20.8	26.5	27.0	22.3	21.0
12	26.1	26.5	27.0	22.3	21.0	18.2	15.2	14.5	15.3	17.4	26.1	26.5	27.0	22.3
13	25.4	26.1	26.5	27.0	22.3	21.0	18.2	15.2	14.5	15.3	25.4	26.1	26.5	27.0
Sub-total	211.4	203.4	198.1	187.0	171.2	162.4	153.7	148.8	147.9	151.1	211.4	203.4	198.1	187.0
14	27.0	25.4	26.1	26.5	27.0	22.3	21.0	18.2	15.2	14.5	27.0	25.4	26.1	26.5
15	27.6	27.0	25.4	26.1	26.5	27.0	22.3	21.0	18.2	15.2	27.6	27.0	25.4	26.1
16	24.4	27.6	27.0	25.4	26.1	26.5	27.0	22.3	21.0	18.2	24.4	27.6	27.0	25.4
17	24.8	24.4	27.6	27.0	25.4	26.1	26.5	27.0	22.3	21.0	24.8	24.4	27.6	27.0
18	22.3	24.8	24.4	27.6	27.0	25.4	26.1	26.5	27.0	22.3	22.3	24.8	24.4	27.6
19	24.8	22.3	24.8	24.4	27.6	27.0	25.4	26.1	26.5	27.0	24.8	22.3	24.8	24.4
20	16.4	24.8	22.3	24.8	24.4	27.6	27.0	25.4	26.1	26.5	16.4	24.8	22.3	24.8
21	12.5	16.4	24.8	22.3	24.8	24.4	27.6	27.0	25.4	26.1	12.5	16.4	24.8	22.3
22	8.4	12.5	16.4	24.8	22.3	24.8	24.4	27.6	27.0	25.4	8.4	12.5	16.4	24.8
Sub-total	188.2	205.2	218.8	228.9	231.1	231.1	227.2	221.0	208.6	196.1	188.2	205.2	218.8	228.9
Grand total	412.1	421.8	432.7	445.9	453.1	456.0	456.9	452.9	441.4	433.4	426.2	424.0	424.1	426.1
Estimated production ('000 tonnes)	702.9	717.5	732.3	749.0	756.0	754.9	750.3	738.3	717.5	700.8	685.9	678.6	676.6	678.8
Officially reported Production ('000 tonnes)	631.4	649.4	711.7	749.7	802.6	852.9	825.3							

yielding phases are examined for the period from 1980-81 to 2014-15. Figure 3 depicts the change in relative shares of the second and the third phases. It is evident that the relative share of the area under the second phase exhibited a cyclical behaviour during the period under review with explicit patterns of declining trend till the late 1980s as observed by Narayana (1994) and a steady upward movement till the late 1990s. The declining share of this age group set in motion from the late 1990s will be continued till 2013-14. On the other hand, the relative share of the mature area that comes under the tapping age group

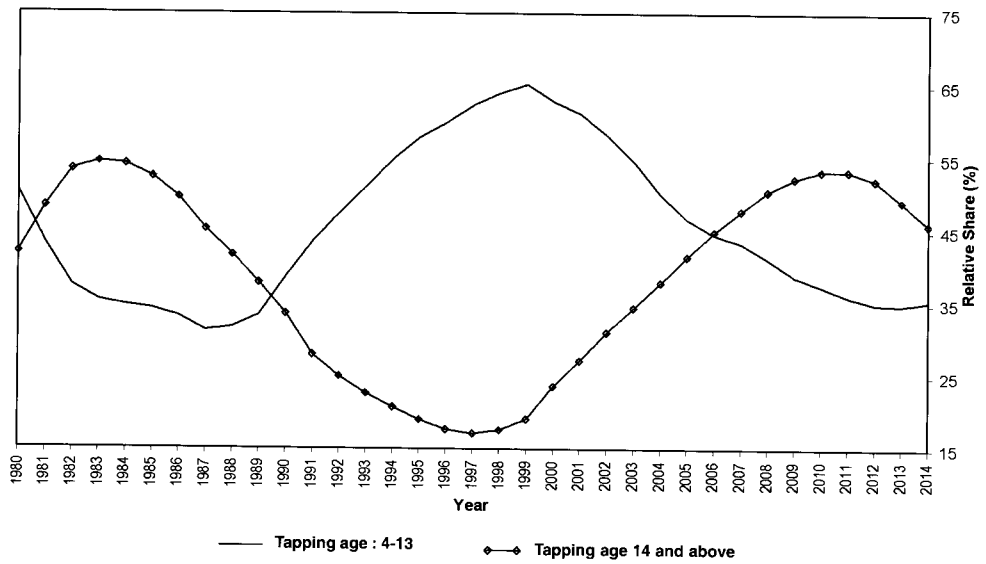

Fig. 3. Trends in the relative shares of second and third yielding phases in tappable area under NR in India

of 14 years and above has been estimated to move in the reverse direction till 2011-12. The observed trends indicate that the age composition during the period from 1980-81 to 1989-90 had been exerting downward pressure on the average yield whereas it contributed to higher average yield during the period from 1990-91 to 2001-02. Conversely, the increasing share of the area under the higher age group during the period from 2002-03 to 2011-12 will lead to a consistent decline in the average yield.

The estimated average yield for the period from 2001-02 to 2007-08 and the projections for 2008-09 to 2014-15 are given in Table 3. The most important observation emerging is that the share of area under the third yielding phase has been steadily increasing during the period up to 2011-12 compared to the declining share of the second yielding phase. Accordingly, the relative share of the third yielding phase will be 53.3 per cent, whereas the share of the second yielding phase will only be 36.1 per cent during 2011-12. This observed trend has important implications on the average yield and production.

The estimates and projections of average yield have been exhibiting a declining trend during the fourteen year period from 2001-02 to 2014-15. The estimated yield for the period from 2004-05 to 2007-08 has been lower than the official data on annual average yield. Estimated production of natural rubber in the country for the period from 2001-02 to 2007-08 and the projections for 2008-09 to 2014-15 are summarised in Table 4. The estimates/ projections highlight the declining trend in NR production as well as the differences between the officially reported production with the estimates. The observed gap was more than 10 per cent during 2007-08. However, contrary to the trends in the estimated average yield, the estimated production of NR has been increasing till 2005-06 and thereafter the trend

is reversed with a steep decline in the production till 2013-14. The major contributory factor for the observed trend has been the divergence between the increase in tappable area and the trends in its age-composition.

CONCLUSION

Major inferences drawn from the analysis of the estimates/projections of the trends in average yield and production are (1) although the statistics of planting are indicative of a sharp downtrend in average yield due to ageing of trees, this is not reflected in the official yield data; (2) the emerging trends in the age-composition of the mature area indicate an explicit downward movement in the average yield till 2014-15 and decline in production till 2013-14; (3) the chances of reversing the observed downward trend are rather bleak during the reference period given the trends in replanting and gestation period of NR and (4) therefore, from a long-term policy angle, it is imperative to initiate a systematic replanting programme and to exploit the new planting potential in the non-traditional regions so as to ensure sustainability of NR production in India.

The policy proposition on replanting in the traditional regions and new planting in the in the non-traditional regions involve two inter-related research and development components to ensure compatible results from a long-term policy perspective. These are: (i) a census of existing area under rubber cultivation and (ii) agro-climatic zoning of the area under the crop and the potential areas identified for cultivation. While the results of the census will provide reliable base data on age-wise and clone-wise distribution of area under the crop along with the socio-economic profile of the farming households, agro-climatic zoning will lead to reliable projections on yield and production across different rubber growing regions in the country. This proposition assumes importance in the context of the limitations in the currently followed method of estimating NR yield and production. The massive second national agricultural census initiated in China during January, 2007 is a useful indicator in this direction (Business Line, 2007).

A multidisciplinary approach to generate reliable base data is essential to address the issues observed in the analysis with meaningful results. The base data generated should thereafter be regularly monitored and updated. Otherwise, inherent contradictions between emerging trends and policy initiatives will nullify the unique research and development achievements of a glorious past.

NOTES

1. The coefficient of variation is 17.0 for GT1 (25 year period), 22.2 for PB 5/139 (21 year period), 24.2 for PB 6/9 (25 year period), 17.3 for PB 86 (25 year period), 18.7 for RRIM 600 (20 year period), 13.5 for RRIM 605 (22-year period) and 16.7 for RRIM 623 (25 year period).

2. It is also determined by postponement and advancement of replanting as practiced by growers in relation to extreme changes in prices, or other reasons.

3. RRII 105 accounts for more than 85 per cent of the total rubber area in the smallholdings sector. A rubber smallholding in India is a unit with an area up to 20 ha. The smallholdings sector accounted for 90% of the area and 93% of the production during 2007-08. A rubber estate in India is defined as a unit having an area of more than 20 ha.

4. The choice of the period from 2001-02 to 2014-15 is justified on the ground that the declining phase of yield for RRII 105 planted in 1980-81 starts from 2001-02 and the official data for total planting is available only up to 2007-08 based on which tappable area can be estimated only for the period up to 2014-15.

5. Estimation of ideal tappable area during 2007 is illustrated as

(t = 2007, m= 29, t - m = 1978)

$$(\text{Tappable area})_{2007} = (NP+RP)_{2000} + (NP+RP)_{1999} + (NP+RP)_{1998} + (NP+RP)_{1996} + \ldots\ldots\ldots\ldots + (NP+RP)_{1978} = 469430 \text{ ha.}$$

REFERENCES

Akiyama, T. and Trivedi, P.K. (1987). Vintage production approach to perennial crop supply: An application to tea in major producing countries. *Journal of Econometrics*, **36**(1/2): 133-161.

Business Line (2007). China launches 2nd agriculture census, January 4, p.7.

Chandy, B. and Sreelakshmi, K. (2008). Commercial yield performance of *Hevea* clones in the estate sector in India, Rubber Research Institute of India, Kottayam 686009, Kerala, India.

French Ben, C., Gorden A. K. and Dwight, D. M. (1985). Planting and removal relationships for perennial crops: An application to cling peaches. *American Journal of Agricultural Economics*, **67**(2): 214-223.

George, T. K., Joseph, T. and Joseph, T. (1988). Evaluation of the yield performance of selected rubber planting materials in the context of the planting policy. *Indian Journal of Natural Rubber Research*, **1** (2): 66-78.

Joseph, T., Chandy, B., Viswanathan, P.K. and Lekshmi, S. (1999). Commercial yield performance of *Hevea* clones in India: A comparative analysis, Rubber Research Institute of India, Kottayam, 66 P.

Narayana, D. (1994). Perennial crop production cycle models: Influence of high yielding varieties and prices. *Indian Journal of Natural Rubber Research*, 7 (1): 25-37.

Nair, K. N., Narayana, D. and Sivanandan, P. (1989). Ecology or economics in cardamom development, Oxford & IBH, New Delhi, 119 p.

Nerlove, M. (1979). The dynamics of supply: Retrospect and prospect. *American Journal of Agricultural Economics*, **5**: 874-888.

Rubber Board, (2008): *Indian Rubber Statistics*, **31**:66p.

Trivedi, P. K. (1974). A case study of cocoa new planting and replanting in Bahia, Brazil 1966-85. *Journal of Development Economics*, **39**(2): 279-299

Wickens, M.R. and Greenfield, J.N. (1973). The econometrics of agricultural supply: An application to the world coffee market. *Review of Economics and Statistics*, **55**: 433-440.