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Impact of Conservation Pits on Growth and Yield of Mature Rubber

SHERIN GEORGE*#, JACOB JOHN**, PHEBE JOSEPH*, ANNIE PHILIP*
AND K.I. PUNNOOSE*

Runoff and erosion substantially and seriously limit crop production in a tropical country like India. Appropriate runoff management techniques that enhance water conservation and reduce erosion to acceptable rates minimise these effects. The effect of conservation pits on soil moisture conservation and growth and yield of rubber was evaluated in a field experiment conducted from 1998 to 2005 in a mature rubber plantation in the central region of the traditional rubber growing tract in India. The treatments comprised conservation pits taken at the rate of 100, 150, 200 and 250 ha^{-1} and a control without pits. The experimental field was well drained with an average gradient of 17% – 22%. Growth and yield of rubber were significantly influenced by the presence of pits. Yield of rubber was enhanced by 15% in the plots with 250 pits ha^{-1}. Soil moisture storage estimated at depths of 10, 20, 30, 40, 60 and 100 cm, was substantially higher where pits were at the rate of 250 ha^{-1}, indicating the contribution of pits towards ground water recharge. The presence of pits positively influenced the leaf water potential. The quantity of soil conserved in the pits ranged from 4.58 t ha^{-1} – 10.42 t ha^{-1} as the number of pits increased from 100 to 250. The quantity of nutrient conserved ranged from 12–29, 6–13 and 27–62 kg ha^{-1} of N, P and K respectively. The proposed field water harvesting technique was proved to be quite useful in the conservation of soil and water in rubber.

Key words: runoff; soil erosion; water conservation; natural rubber; moisture; growth; yield; nutrients

Soil and water are basic natural resources whose conservation is of paramount importance. There is a conscious need to efficiently manage and conserve these natural resources in a manner that would allow maximum productivity on a sustainable basis. *Hevea brasiliensis*, the single viable source of natural rubber is a perennial tree crop that has economic and social importance in many tropical and sub-tropical countries like Indonesia, Sri Lanka, Thailand, Malaysia, India, China, Vietnam and Philippines. India is the fourth largest producer of natural rubber accounting for 9.2% of global output. Almost 88% of national rubber area and 94% of production are concentrated in Kerala[1] where it is grown traditionally on laterite and lateritic soils under suitable agro-ecological conditions (mean temperature of 25ºC – 28ºC and annual rainfall ranging from 2000 mm – 4000 mm). The topography of rubber growing tracts in India, especially Kerala, consists of highly undulating

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*Agronomy/Soils Division, Rubber research Institute of India, Kottayam – 686 009, India
**Cropping Systems Research Centre, Thiruvananthapuram – 695 002, Kerala, India.
Corresponding author (e-mail: sherin@rubberboard.org.in)

and steep terrain. The monsoon rainy season is spread over a period of six months; its intensity far exceeds the infiltration rates resulting in runoff and erosion losses from the field. Depending on the slope of land and ground cover, the annual average runoff loss in India varies[2] from 15% to 35%. Runoff, wherever it occurs, results in washing away of the top fertile soil and nutrients, loss of soil moisture and recharge capacity. The consequences of water runoff and soil erosion not only affect crop production, but result in serious problems of water stress, soil degradation and ecological imbalance[3]. In recent years the amount of rainfall has decreased. The infiltration of water into the soil has also decreased because of many man-made factors such as deforestation and compactmentation of soil. Plantations are cleared by earth excavators. These ill planned and destructive farm practices significantly accelerate runoff and loss of top soil. Adoption of feasible water and soil conservation management strategies has become inevitable in rubber plantations. Consequently, conservation measures like contour terracing, excavation of conservation pits and contour bunding are practiced in plantations[4]. Though the practice of digging conservation pits is encouraged, its benefits on soil moisture dynamics and crop response have not been quantified. The present research focuses on the effect of conservation pits on growth and yield of rubber, soil moisture dynamics and conservation of soil and nutrients.

MATERIALS AND METHODS

A field experiment was conducted during 1998 – 2005 at the Manickal division of TR and T estate, Mundakayam, Kottayam District, Kerala (9º 33' N latitude and 76º 54' E longitude), which represents the central region of the traditional rubber growing tract in India. The experimental area consisted of 20 ha of rubber plantation of clone PB 311 aged 12 years. The site is located in a tropical humid zone with a mean annual temperature of 28ºC. The mean annual rainfall (1998 – 2004, *Figure 1*) has a bimodal distribution pattern with major peaks in June – July and September-October. The period December through February/March constitutes the dry season. Soils were classified as Ustic Haplohumult (USDA classification) and had an average pH of 4.85. The organic carbon content (1.5%) and available P content (1.17 mg/100 g) were in the medium range. The available K content (4.21 mg/100 g) was low. The field gradient ranged from 17% – 22%.

Experiment

The design of the experiment was a randomised complete block with four replications. The treatments comprised of conservation pits taken at the rate of 100, 150, 200 and 250 ha^{-1}. Plots without pits served as control. The gross plot size was one tapping block of nearly one hectare. The net plot size was 30 plants. The treatments were allocated to each block on area basis.

Soil Management

Pits of size 120 cm × 45 cm × 75 cm were excavated in each block in a staggered manner along the contour at regular intervals with sufficient space in between (*Figure 2*). The soil from the pit was deposited on the lower side of the pit and compacted well. The first row of pits at the lower most point of each block was used as observation pits in order to assess the quantity of soil lost in spite of taking pits.

Data Collection

Data on monthly block yield were collected from records maintained in the estate. Annual growth measurements were done by recording

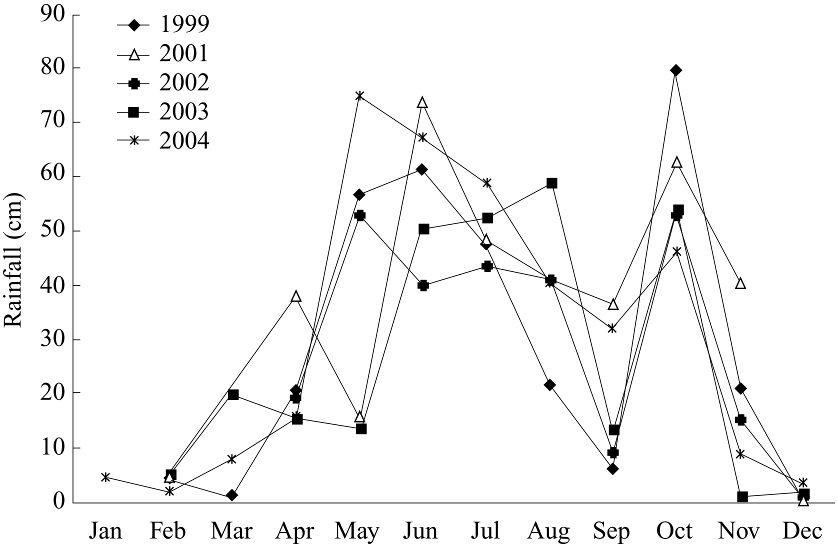

Figure 1. Mean monthly rainfall, TR and T Estate, Mundakayam (1999 – 2004).

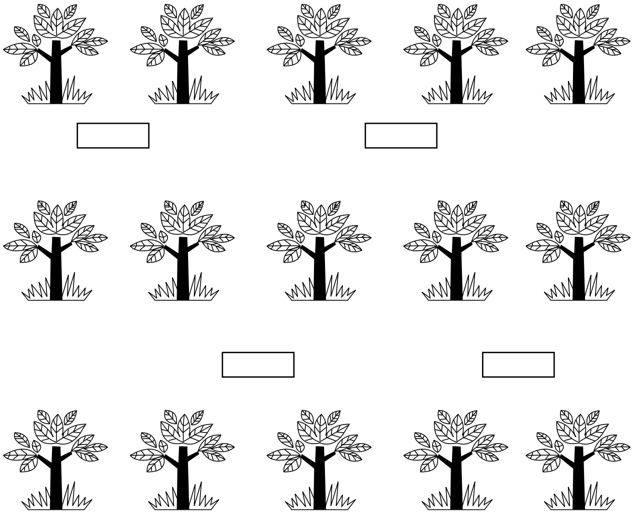

Figure 2. Schematic demonstration of rubber plants and conservation pits. Pits were taken in the middle of the inter-row space in a staggered manner.

the girth of the plants at a height of 150 cm above the bud union. The quantity of soil collected in the conservation pits and observation pits were computed based on a visual rating of the percentage of pit portion filled as 25, 50, 75 and 100. After scoring, the fresh weight of the deposited silt was recorded from two pits in each replication. The dry weight was determined based on moisture content of samples pooled over replications for which soil samples were drawn from each replication. Soil samples were also collected from the field (0 – 30 cm depth) and pits and analysed for total N, P and K as per standard methods[5].

Soil moisture content at 0 – 30 cm and 30 cm – 60 cm was determined gravimetrically during 2002 and 2003. In 2004, access tubes were installed in the plots and moisture content was measured with Profile Probe (Delta-T, UK) attached to a soil moisture meter at depths of 10, 20, 30, 40, 60 and 100 cm. The mid-day leaf water potential was measured during the summer of 2004 and 2005 using C-52 sample chamber psychrometer (Wescor Inc., Logan, Utah, USA) connected to HR 33 T Dew Point Microvoltmeter. The data were subjected to statistical analysis.

RESULTS AND DISCUSSION

Soil Moisture Status

The mean soil moisture content at depth layers 0 – 30 cm and 30 cm – 60 cm recorded during the summer of 2002 and 2003 showed variations in the soil moisture status (*Figure 3*). The differences were more distinct at the lower depths. The soil moisture content in the plot without pits at 30 cm – 60 cm depth was 18% during 2002 and 2003. The corresponding figures for the plots with 250 ha^{-1} were 20% and 23% indicating the effectiveness of the pits in maintaining a higher water status at the subsurface layer. Gravimetrically, we could measure the soil moisture content only up to 60 cm. To study the moisture dynamics at deeper layers, access tubes were installed and the profile probe was used in the summer of 2005. At all depths (10, 20, 30, 40, 60,100 cm) a higher soil moisture content was maintained in the plots with 200 pits ha^{-1} and 250 pits ha^{-1} (*Figure 4*). Up to 150 pits ha^{-1}, there was not much variation in the moisture content in the surface layers (to a depth of 40 cm). Beyond that the soil moisture content differed distinctly even in the surface layers.

The annual average runoff loss varied from 15% to 35% of the total rainfall, depending on contour and ground cover[2]. The field water harvesting techniques like infiltration pits have demonstrated methods to improve the soil moisture storage to prolong the period of moisture availability and enhance the growth of agricultural crops[6]. Silt pits act as a series of storage tanks trapping water from surface runoff and through fall resulting in an increased soil moisture status[7]. Excavation of pits is an efficient runoff management technique wherein part of the runoff is conserved and reused for crop production in a sustainable manner. Rubber being grown in the red and lateritic soils, all water inside these pits gets drained down to the lower layers of the soil, finally contributing to ground water. It is worthwhile to remember that rubber plants transpire large quantities of water and hence conservation of water is the key to high productivity. Drying up of the wells near rubber plantations is a common concern often raised by smallholders. It is evident from the data on soil moisture that the contribution of conservation pits towards ground water recharge is significant.

Leaf Water Potential

Water potential is the most widely used indication of plant water status because it is

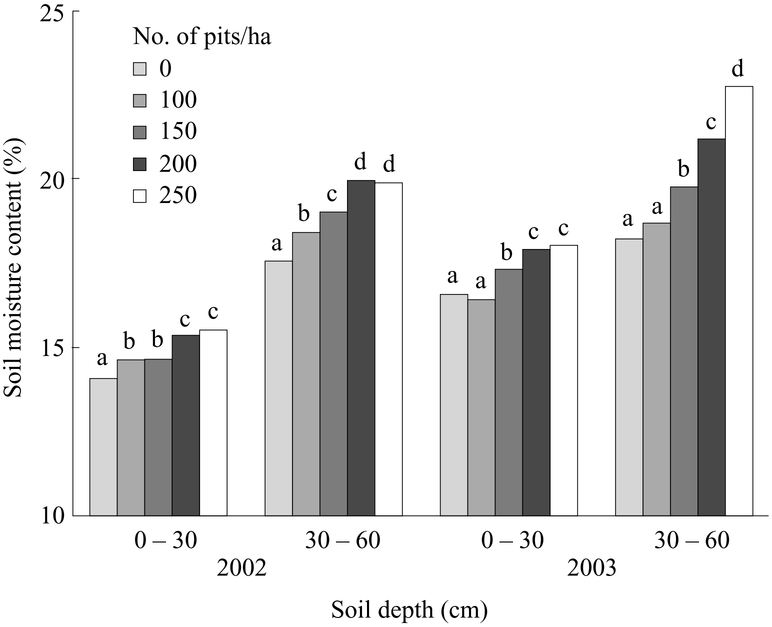

Figure 3. Effect of conservation pits on soil moisture (2002–2003). Different letters are statistically significant at P<0.05.

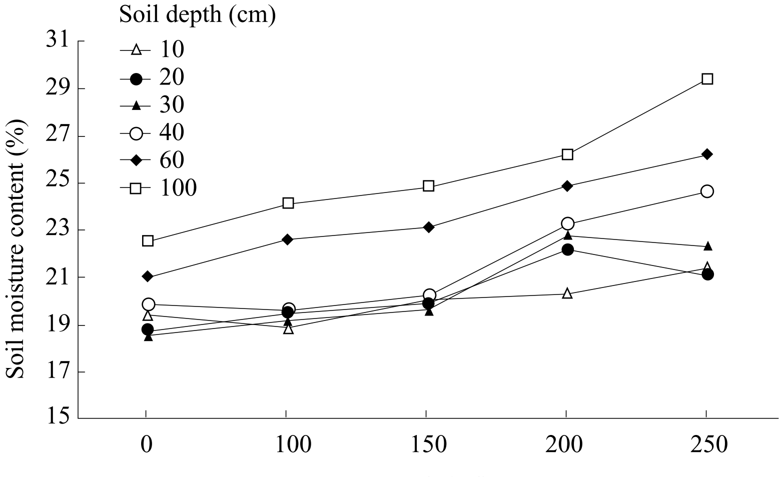

Figure 4. Effect of conservation pits on soil moisture (2005).

the major determinant for water movement through the plant and it can easily be measured[8]. Presence of pits favourably influenced the leaf water potential. During the summer of 2004 and 2005, a higher leaf water potential was maintained in the plots with 250 pits ha^{-1} (*Figure 5*). Leaf water potential was relatively low in the control plots. Maintenance of higher plant water status in the plots with pits is associated with the higher moisture availability under this situation as evidenced by the soil moisture status (*Figures 3* and *4*). Water stress affects several aspects of plant physiology such as gas exchange, hormonal relations and mainly water relations[8]. In a study on seasonal effects of water relations and yield in *Hevea*, it was found that all clones studied maintained a higher leaf water potential during the wet season compared to the dry season[9]. A relatively low leaf water potential maintained in the control plots is indicative of the soil water stress which might have occurred in these plots in the absence of pits.

Quantity of Soil Conserved

The quantity of soil deposited in the pits in different years varied significantly among treatments (*Figure 6*). The quantity of surface soil trapped in the pits and thus prevented from being eroded was directly proportional to the number of pits throughout the period under experimentation and ranged from 4.58 t ha^{-1} – 10.42 t ha^{-1} in different years. Accelerated soil erosion is a destabilising factor in all agro-ecosystems and causes major problems of land degradation[3]. Prevention of soil degradation and erosion is of prime importance in rubber plantations as the landscape features and the high rainfall received in the rubber growing tracts of India make the soil vulnerable to erosion hazards. Effective soil erosion management is therefore a vital part of the quest for sustainable agricultural production. The average soil loss in India is estimated to be over 16 t ha^{-1} yr^{-1} which translates to approximately 1 mm each year or 1 cm every decade which far exceeds the permissible limit[2] of 4 t ha^{-1}. Natural processes such as the formation of soil occur at an alarmingly slower rate than the soil can be lost. The rate of new soil formation for tropics was estimated at about 2.5 cm in 300 to 1000 years[10]. The quantity of soil collected in the observation pits in different years which gave an indication about the quantity of soil lost despite taking pits was uniformly higher in the control plots without pits showing the effectiveness of pits in conserving surface soil (*Figure 7*). The runoff along with the top soil is captured in the pits, the runoff infiltrates into the surrounding soils increasing the ground water recharge, retaining precious soil and nutrients in the subsurface level which accumulates over the years and is recycled inside the plantation.

Nutrients Conserved

A considerable quantity of major nutrients were also conserved and made available for recycling in the plantation by taking pits (*Table 1*). The quantities of N, P and K conserved ranged from 12.8 – 29.2, 5.5 – 12.5 and 27.5 – 62.5 kg ha^{-1}, respectively when the number of pits was increased from 100 to 250. Therefore, besides conserving moisture the pits also trap organic residues, nutrients and eroded top soil and help sustain the soil productivity. The annual recommended dose of nutrients for mature rubber under tapping is only 30 : 30 : 30 N, P_2O_5 and K_2O per ha. Though the loss of nutrients can partly be compensated by the addition of fertilizers, it is difficult to restore soil productivity.

Accelerated soil erosion is a selective process of preferential removal of the topsoil[10]. The fertile soil is removed along with the

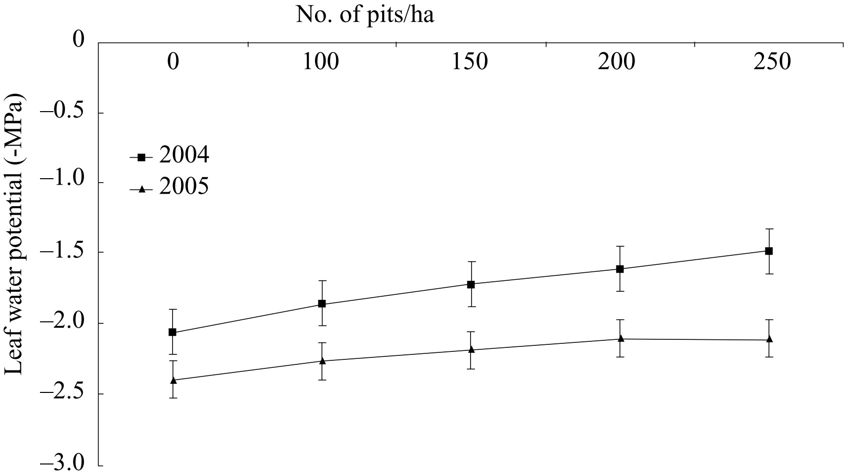

Figure 5. Effect of conservation pits on leaf water potential. Error bars indicate the least significant difference at P<0.05.

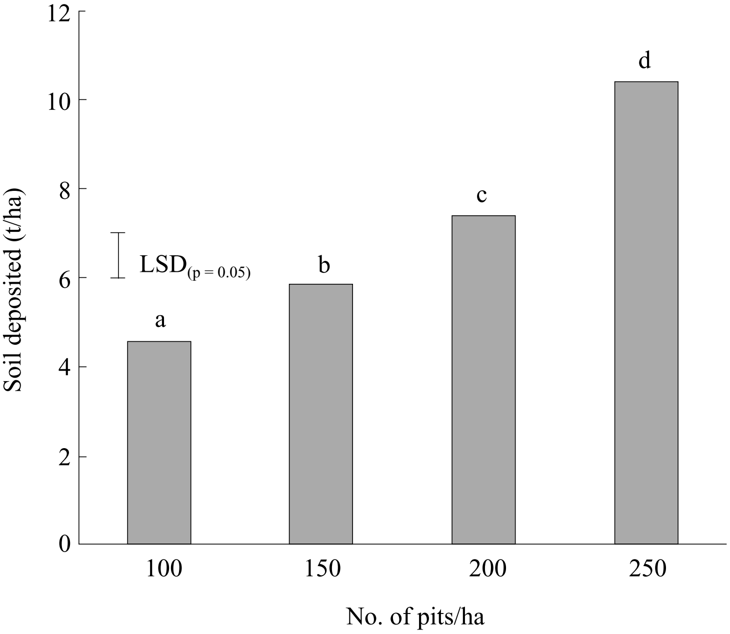

Figure 6. Quantity of soil deposited in the conservation pits. Different letters are statistically significant at P<0.05.

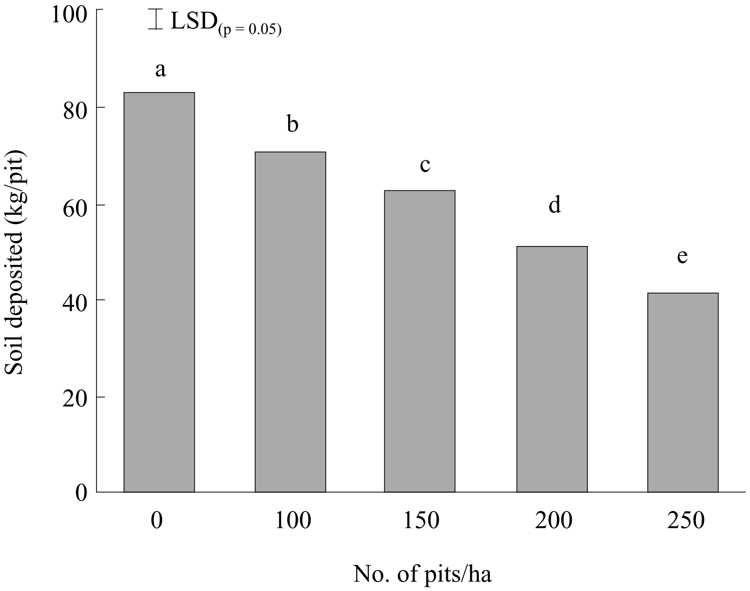

Figure 7. Quantity of soil deposited in the observation pits. Different letters are statistically significant at P<0.05.

TABLE 1. EFFECT OF CONSERVATION PITS ON NUTRIENTS CONSERVED

No. of pits/ha	Nutrients conserved (kg per hectare)		
	Total N	Total P	Total K
100	12.84	5.50	27.52
150	15.84	7.03	35.19
200	19.80	8.83	44.17
250	29.23	12.50	62.55
SE	1.18	0.42	2.10
CD (P=0.05)	3.78	1.35	6.73

nutrients and organic matter which are significant to the growth of plants. There are reports that the organic matter and nitrogen content of the eroded soil was five times as high as that in the original topsoil. Comparable figures for nitrogen and phosphorous were three and two, respectively[11]. Conservation pits provide an efficient runoff management system wherein the precious nutrient rich topsoil which is a finite natural resource is conserved.

Growth and Yield

The factors of production *viz*., the growth and yield of rubber were significantly and positively influenced by the presence of pits (*Table 2*). The cumulative girth increment of mature rubber over a period of six years was significantly higher for 250 pits ha^{-1} followed by 200 pits ha^{-1} and 150 pits ha^{-1} which were comparable. The girth increment was the minimum in the control plots without pits.

TABLE 2. EFFECT OF CONSERVATION PITS ON GROWTH AND YIELD

No. of pits/ha	Girth increment(cm) (1998–2004)	Cumulative yield(Kg/tree) (1998–2005)
0	8.7	15.54
100	10.3	16.08
150	11.69	16.80
200	11.87	17.14
250	13.80	17.95
SE	0.77	0.50
LSD (P< 0.05)	2.37	1.50

The data on cumulative yield of rubber during the period under experimentation (1999–2005) is presented in *Table 2*. Significant positive response was obtained for cumulative yield of rubber. The yield increased progressively with increase in the number of pits. The plots with 250 pits ha^{-1} recorded the highest yield followed by 200 pits ha^{-1}.which were comparable. The increase in yield over control (without pits) in the plots with 200 pits ha^{-1} and 250 pits ha^{-1} was 10.3% and 15.5%, respectively.

Water is generally a limiting factor for crop production where irrigation is not available. It can be limiting even in humid and sub-humid regions where there is a theoretical need to dispose the excess water. Dry periods with water deficit frequently occur in these regions and positive responses to moisture conservation techniques are frequently obtained. Better growth and yield of rubber in the presence of pits can be attributed to a better micro-environment in terms of moisture availability and soil nutrient status. It may be noted that the soil moisture content also increased markedly in the plots with 200 and 250 pits per hectare (*Figure 4*). The conservation pits besides conserving soil moisture also trap organic residue, nutrients and eroded top soil, and help in sustaining soil fertility and productivity[12]. The data on moisture dynamics in deeper layers during summer (*Figures 3* and *4*) and the soil and nutrients conserved through pits (*Table 1*) revealed that conservation pits played a significant role in the conservation of soil, water and nutrients in rubber plantations which is reflected in the growth and yield of rubber. Increased girthing in rubber with other conservation practices like mulching has also been reported[13].

CONCLUSIONS

A considerable quantity of water, soil and nutrients were conserved and thus the available water was effectively utilised and the risk of erosion was greatly reduced by excavating conservation pits in rubber plantations. There was definite improvement in the growth and yield of rubber. The improvement in growth and yield were caused not only by the direct effect on soil moisture status but also by sustaining soil productivity as a result of conservation of the eroded topsoil and nutrients which were recycled in the plantation. Therefore, opening of conservation pits was a viable water harvesting and soil conservation technology for the traditional rubber growing regions.

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