

LAND AND SOIL REQUIREMENTS FOR OPTIMUM GROWTH AND PRODUCTIVITY OF RUBBER UNDER SRI LANKAN CONDITIONS

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Introduction

In Sri Lanka, rubber (*Hevea brasiliensis*), grows on a broad spectrum of edaphic and physiographic situations. These situations range from flooded or muddy soils along riversides to well drained uplands or steep lands with variable soil conditions. Yet, the performance and economic viability of rubber plantations can be affected severely due to a limitation of a particular land or soil characteristic. Under such limiting conditions intensive and costly soil management practices have to be carried out to ensure higher growth and yield levels. In the present circumstances, with high production costs and low rubber prices, the adoption of such expensive agro-management practices seems to be uneconomical. In the height of this, rubber should be planted only on lands with acceptable level of slope and soil characteristics. Therefore, the selection of suitable land with proper soil characteristics is considered as key factor to ensure high returns on investment. This paper examines the criteria to be followed in selecting suitable land for rubber plantations. The main criteria to be followed include; land slope, rockiness, drainage and water table, soil depth, soil texture and structure, soil pH and soil organic carbon.

Land slope

Steep slopes have been recognized as a limitation to growth and productivity of rubber. An increase in land slope increases soil erosion under the high intensity rainfall prevailing in the rubber growing districts (Table 1). Due to erosion and run-off, problems such as low soil fertility, poor chemical and physical soil properties have developed in steep lands of the rubber growing areas in Sri Lanka (Table 2). Length of land slope and slope curvature also enhances the susceptibility to soil erosion significantly (Table 3 and 4). As a result, expensive conservation practices are required to reduce soil losses. Moreover, in steep slopes, where accessibility is a problem, a lower number of trees will be tapped resulting in lower yields. Land slope should therefore, be considered in land selection programmes and gently sloping or rolling terrain between 0-20% is considered suitable for optimum performance (Table 5). In lands with slope between 20% to 45%, planting on contours, cutting drains with silt pits and construction of stone terraces are recommended as soil conservation measures to improve retention of moisture and nutrients. It would also be necessary to establish leguminous ground covers and mulching to reduce surface run-off in the slopes between 20-45%.

Table 1. Effect of land steepness on soil loss

Gradient (%)	Terrain	Soil loss (during 1 st year) (MT/ha)
0-20	Flat to Undulating	10
20-45	Hilly	42
>45	Very steep	79

Table 2. Effect of slope length on soil loss

Length (m)	Soil loss (during 1 st year) (MT/ha)
0-50	08
50-100	30
100-150	72
150-200	132

Table 3. Effect of slope curvature on soil loss

Curvature	Soil loss (during 1 st year) (MT/ha)
Concave	193
Convex	258

Table 4. Effect of slope on some soil chemical and physical parameters

Slope class	Soil N (%)	Organic C (%)	Porosity (%)	SMSC* (cm)
0-20%	0.16	1.2	53	22.4
>45%	0.10	0.5	45	17.5

*Soil Moisture Storage Capacity (SMSC) for 90cm soil profile

Table 5. Land suitability recommendation on land slope

Slope class	Recommendation
0-20%	Suitable
20%-45%	Suitable if soil conservation measures are taken up
>45%	Avoid planting

Rockiness

Most of the rubber lands in Sri Lanka have rock out crops on the surface. In addition, they also occur on very steep slopes. Besides affecting the performance of the rubber tree, rockiness influence the establishment at planting, causing slow establishment and significant casualties at planting. Moreover, rockiness directly reduce the effective land area making lower stand per hectare. The selected land for planting rubber should not, therefore, exceed more than 50% of rock out crops in a unit area of land.

Drainage and water table

Poor and impeded soil drainage and stagnation of water on the soil surface after rain can result from land being at low-lying terrain with high water table.

At planting, young rubber plants tend to die under flooded condition which needs re-supplying of dead plants. Trees growing on soils with high water table, generally anchor poorly. Due to poor tap root formation loss of trees due to falling can be a major problem, especially if the clones with heavy canopies are established. Moreover, lateral roots traverse near the surface and thereby restrict nutrient and water uptake which result in poor growth and low yields, although the rubber trees could withstand some degree of impeded drainage. Hence, height of water table is one of the major factors that determines *Hevea* productivity and depth of water table should be atleast 100cm to sustain optimum productivity (Table 6).

Table 6. Effect of soil water table on yield of clone PB 86

Depth of water table	Yield	
	(kg/ha/yr)	(%)
100cm	1190	100.0
50cm	970	81.5

Depending on the drainage problem, main drains which lead to the outlet drain should be cut at intervals of 100-200m. If necessary field drains at intervals of 50m should be cut subsequently. However, these field drains should not be cut to the full depth at once, but deepened gradually, year by year, until a permanent water-table of not less than 1m is obtained.

During rainy season stagnation of water on the soil surface resulting from poor infiltration can be corrected by proper soil management. The permeability of these soils should be improved and maintained in that state by establishing fast growing and deep rooting legumes. These legumes provide high organic matter content to the soil which in turn improves the structure of the soil. Although, poor soil drainage and stagnation of water on soil surface can be corrected to some extent by management practices, lands which are susceptible to flooding and stagnation of water for more than 3 days at surface even after light rain (prolonged water logging problem) will not be suitable for planting rubber (Table 7 and 8).

Table 7. Land suitability recommendation on stagnation of water at surface after rain

No of days	Suitability
0	Suitable
1-3	Suitable if control measures are taken up
>3	Not suitable

Table 8. Land suitability recommendation on susceptibility to flooding

Situation	Suitability
No floods	Suitable
Floods after heavy rain	Suitable if control measures are taken up
Floods after light rain	Not suitable

Soil depth

The depth of a soil profile up to the parent material layer determines the volume of exploitable soil available to the rubber tree. The size of this exploitable volume will be critical for a tree crop like rubber, which extends its roots far and deep. Deeper soils provide greater soil volume for better development of main and lateral roots. As soil surface area increases, there is also better exploitation of moisture and nutrients in both the top and sub soils, resulting in more efficient nutrient uptake. Basically, a deep soil is found to sustain better tree growth, yield and leaf nutrient content than a shallower soil (Table 9 and 10).

Table 9. Effect of soil depth on girth and yield of rubber

Soil depth	Girth		Yield	
	(6 yrs after planting)		. (g/t)	(%)
	(cm)	(%)		
50cm	48.1	100	26.8	100
>100cm	50.5	105	28.0	104

Table 10. Effects of soil depth on leaf nutrient status of rubber

Soil depth	Leaf nutrient content (%)			
	N	P	K	Mg
50cm	2.96	0.19	1.50	0.29
>100cm	2.98	0.22	1.55	0.29

A reduction in yield per unit area of land can occur due to a decline in tree density. In the case of shallow soils rubber trees are susceptible to wind damage resulting from poor anchorage (Table 11). Moreover, rubber plants tend to form stunted and knotty roots when

grown on shallow soils. Shallowness of a soil can also be the result of the presence of a bed rock underneath the soil surface, compact hard pan or loosely packed gravel layer in the soil profile or due to soil compaction. These less penetrable zones impede downward root penetration. Generally, growth of rubber plants becomes significantly limited when the impenetrable layer occurs within 25cm depth from the surface (Table 12). For the sustainable growth and productivity of rubber the selected land for planting rubber should have a depth of atleast 100cm without any bed rock or compacted hard pan.

Table 11. Comparison of tree damage by wind under different soil depths

Depth category	Loss in stand due to poor anchorage (%)
Deep	Nil
Shallow	7.3

Table 12. Effect of an impenetrable compacted layer on girth of rubber plants

Depth	Girth (2 yrs after planting)	
	(cm)	(%)
<25cm	14.1	100
>25cm	15.3	108

Soil texture

Physically, soil is made up of sand, silt and clay in different proportions. Soil texture refers to the relative proportion of these primary particles of sand (0.02-2.0mm), silt (0.002-0.02mm) and clay (<0.002mm). Other inclusions like gravel and stones are larger than 2mm in diameter. The sand fraction consists of quartz, but may contain other minerals also. Silt is of intermediate size between sand and clay and resembles sand particles in terms of mineralogy and physical properties. The clay fraction represents the smallest particles, being formed during the course of weathering of primary minerals in the original rock. The various combinations of sand, silt and clay give rise to different textures. For example, a clayey soil has a dominant clay content while, a sandy soil has a dominant sand content.

Texture of soils influences their physical properties and behaviour under cultivation. For example, a sandy loam soil is usually loose, drained and retains less available water for growth of rubber plants. It has high permeability to downward water movement because of its sandy nature. To ameliorate such situations, it would be necessary to discriminate these areas and apply extra and split application of fertilizer to reduce leaching losses and enhance nutrient uptake for better tree performances. Further,

establishment of leguminous ground covers and mulching would be beneficial. Better growth and establishment of rubber are obtained on clayey than sandy soils. This is expected since the inherent physical and chemical characteristics of clay give it the capacity to retain nutrients and water. When water is limiting, establishment rate of young plants at planting, growth of young plants and yield of rubber can also be lower on sandy soil compared to clayey soil.

Soil texture with sufficient clay, preferably a minimum amount of 35% to retain adequate moisture and nutrients and about 30-50% sand to allow for expression of good physical soil properties like aeration and drainage can be considered as desirable for successful optimum rubber cultivation.

Soil structure

Soil structure is perhaps the most important physical property. It refers to the arrangement and organization of the solid particles. The clay and silt fractions bind the soil together and various combinations of sand, silt and clay can give rise to different shapes and sizes of soil structure. Soils are made up of natural soil aggregates, also known as soil peds.

A soil has a friable consistency if the soil peds are easily broken and if the peds can barely be crushed, the consistency is firm. From the aspect of soil management, soil structure is the property of a soil that regulates a continuous array of various sizes of inter connected pores and their stability. It governs retention and movement of water, regulates gaseous diffusion and controls root proliferation and development.

Soil structural properties has major influence on root growth. A soil with good structure and friable consistency is a good medium for root growth. This will allow the soil to be exploited fully. As such, the tree can have a good anchorage and be able to have a large source of water and nutrients. In fact, good soil structural properties have a better effect on the growth of rubber than high soil chemical fertility. In other words, rubber trees will grow better on a well structured soil of lower chemical fertility than on a poorly structured soil with very high chemical fertility. This is obvious since the presence of an insufficient amount of roots in a poorly structured soil will mean that the tree cannot exploit the high fertility to its maximum. Furthermore, the low chemical fertility status of a soil can easily be amended with fertilizer application.

Soil structure which gives 50-60% porosity can be considered optimum for better movement of water and gas in the soil and for the better root development and thereby for successful rubber cultivation. The availability of water to the plants is determined not only by the intensity and distribution of rainfall, but also by the quantity of water that is actually retained in the soil. The capacity of the soil to hold water is termed water holding capacity (WHC) and there should be 30-40% WHC to sustain higher performance of rubber.

Soil pH

Rubber generally grows well in acid soils in Sri Lanka. However, extreme pH conditions are not favourable for good performance of rubber trees and stunted growth has been observed. The effect of soil pH on plant growth is partly through its effects on root

function and on soil properties. Soil pH between 4-6 is considered optimum for successful cultivation of rubber (Table 13).

Table 13. *Land suitability recommendation on soil pH*

pH range	Suitability
4.0-6.0	Optimum
3.5-4.0 and 6.0-6.5	Tolerable
<3.5 or >6.5	Should be corrected by soil amendments

Soil organic carbon

Changes in soil management affect the quantity of organic matter in two ways, by altering the annual input of organic matter from dead plants and animals and by altering the rate at which this organic matter decays. It is known that rubber plantations can undergo a very effective self sustaining recycling system where the soil organic matter content is maintained, although the tropical soils in Sri Lanka contain relatively low amounts of organic matter. To overcome this problem of low amount of organic matter in soil, an integrated approach including the proper organic matter/crop residue management appears to hold promise. Soil organic carbon content is one of the key parameters that gives an indication of the soil fertility level and soil organic carbon content between 2-3% is considered optimum for successful cultivation of rubber (Table 14).

Table 14. *Land suitability recommendation on soil organic carbon content*

Range	Suitability
2-3%	Optimum/Suitable
<2	Should be corrected by soil management

Computer programme to assess land suitability for rubber cultivation

Arrangements have been made to incorporate these information to develop user friendly computer programme to assess the feasibility of lands for rubber cultivation. The programme will indicate the overall assessment of the land indicating the suitability/unsuitability with appropriate correction measures to be adopted. A brief outline of land and soil properties to be considered in selecting lands for commercial rubber cultivation and a broad range of suitability indices for each parameter have been identified as shown in Table 15.

Table 15. Land suitability indices for commercial rubber cultivation

Character	Range suitable	Range suitable with correction measures	Range not suitable
Slope	0-20%	20%-45%	>45%
Rockiness	<50%	-	>50%
Soil depth	>100cm	-	<100cm
Depth of water table	>100cm	<100cm	
Stagnation of water	0 days	1-3 days	>3 days
Flooding	nil	after heavy rain	after light rain
Soil pH	4-6 (3.5-4.0 and 6.0-6.5)	<3.5 or >6.5	-
Organic carbon	2%-3%	<2%	