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HARIT DHARA

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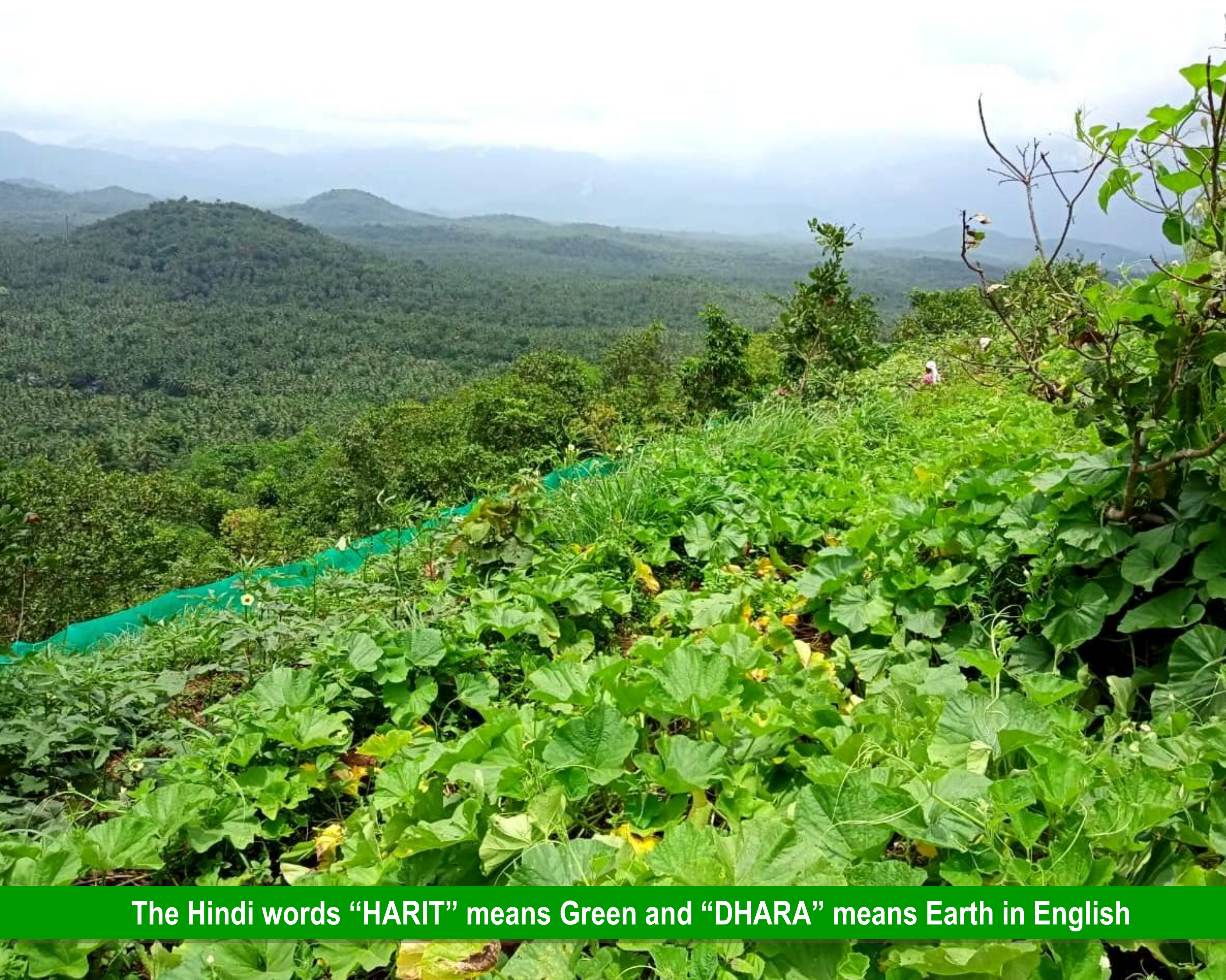

The Hindi words “HARIT” means Green and “DHARA” means Earth in English

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Vegetable fields of tribal farmers in hill slopes of Narikkuni village located in the Kozhikode district of Kerala (Photo: Thejas M.R.)

Water harvesting pond near the tribal farm fields of Kulpa village located inside the south Balaghat Forest Range (Photo: Sanjay S.)

CONTENTS

KUTTANAD SOILS: THE POTENTIAL ACID SULPHATE SOILS OF KERALA

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Kuttanad, a globally important agricultural heritage system, is a low lying deltaic region 0.6-2.2 m below Mean Sea Level (MSL) extended over an area of 854 km^2 in three southern districts of Kerala state viz., Kottayam, Pathanamthitta and Alappuzha. It is a deltaic region formed through natural reclamation of four rivers viz., Pampa, Achancovil, Manimala and Meenachil that drain into Vembanadu Lake, a Ramsar site. Kuttanad consists of fragmented landscapes and different ecosystems like paddy fields, rivers, coastal backwaters, ponds, garden lands, marshes etc. Soils of this region are generally acid saline in nature. To a great extent, this area remains flooded with water throughout the year and is exposed to saltwater intrusion through from adjoining lakes/rivers in summer.

Kuttanad region is subdivided into six agronomic zones viz., Upper Kuttanad, Lower Kuttanad, North Kuttanad, Kayal lands, Vaikkom Kari, and Purakkad Kari based on geomorphology, soils and salinity intrusion. The soil type in Kuttanad is further divided into three distinct zones such as *Karappadam*, *Kari lands* and *Kayal lands* based on texture, acidity, salinity, electrochemical properties etc. Paddy is the main crop in Kuttanad (Figure 1) and the traditional paddy crop grown here is known as *Punja* (November - March).

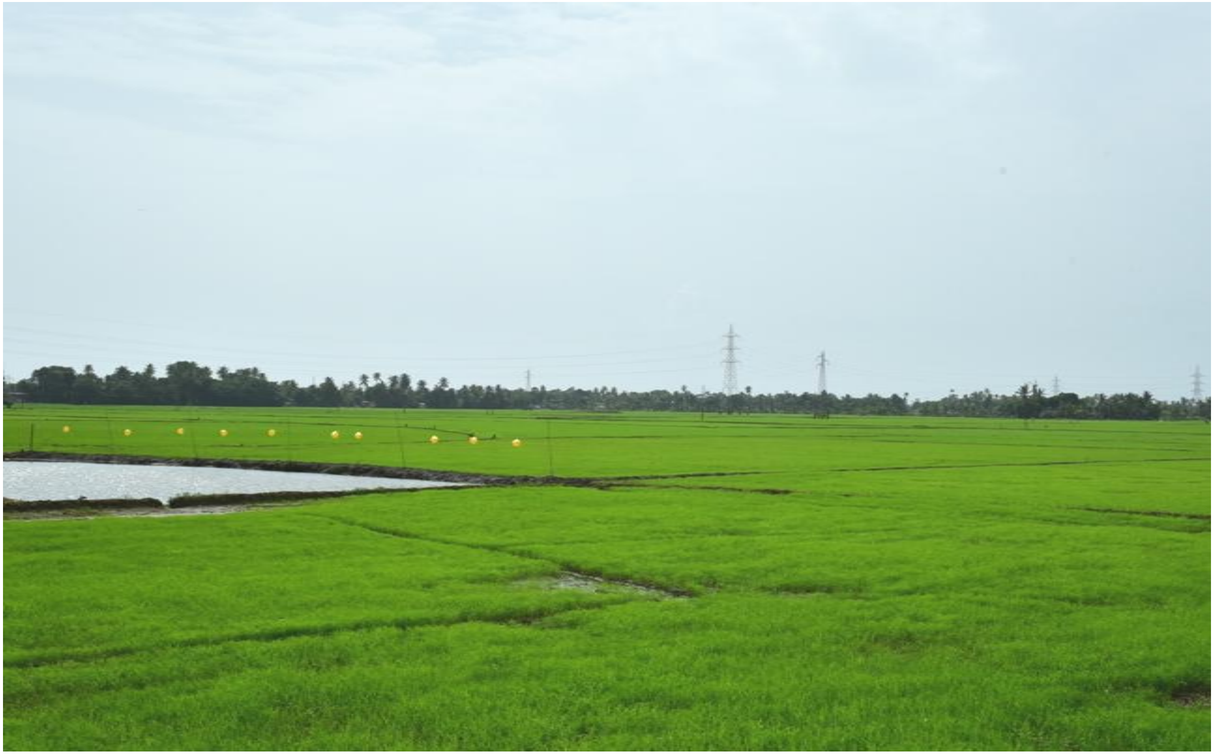

Figure 1: A view of paddy cultivation in the reclaimed wetlands of *Kuttanad* region in Kerala (Source: https://www.mssrf.org)

Depending upon the flood and saline water intrusion two paddy crops are grown in Upper Kuttanad (Karappadam lands) lies 1-2 m below MSL along the upper area of the river delta; one or two crops are grown in Lower Kuttanad (Kari lands) that lie about 2-2.5 m below MSL as middle basin of the river delta; and single crop is cultivated in Kayal lands (lower basin) locate 2-3 m below MSL.

KUTTANAD SOILS

Kuttanad soil is a mixture of sand and clay in different proportions. It contains decayed organic matter including decayed logs of wooden materials in many parts. Low lying areas of Kuttanad soils are highly acidic in nature with high level of toxic salts. These poorly drained potential acid sulphate soils contain high level of pyrites too. Based on soil morphology, soils of Kuttanad are classified into Karappadam, Kari and Kayal lands (Chattopadhyay and Sidharthan, 1985). Though the classification is quite traditional and realistic their boundaries are not clearly demarcated and fairly overlapping each other in nature.

Karappadam lands covers an area of about 42,505 ha and soils of this region are largely riverine (river born) alluvium rich in organic clay. Kari lands extend in an area of around 6075 ha and mainly have deep black soils. 'Kari' literally means 'Charcoal' and these soils are abnormally black colour and rich in organic carbon, often spotted with deeply buried, partly burned out big pieces of timber specimens of ancient periods most likely in the Pleistocene period. These specific structures are very rarely seen in Karappadam and Kayal lands. Microbial sulphur cycle is also one of the characteristic features of Kari lands. Kayal lands, a delta region of Vembanad Lake, occupy an area of about 8100 ha, are often reclaimed for rice cultivation (Fig 2).

Figure 2: Soil profile of Kuttanad Kayal (Acid sulphate soils): Salidic Sulfaquepts (Source: NBSSLUP Archives)

In an estimated area of 50,000 ha rice cultivation, the acid sulphate soils (classified as Typic Sulfaquents according to the soil taxonomy) covers an area of 14227 ha. Kallara, Ambalappuzha, Purakkad, Thakazhi, Thottappally and Thuravur are documented as acid sulphate soil series of Kuttanad. These soils are classified under the order Entisols, suborder Aquents, great group Sulfaquents and sub group Typic Sulfaquents (Beena, 2005). Karappadam soils (Typic Tropaquepts) are mainly seen in inland water ways and rivers. Kari soils contain high amount of organic matter and these soils are black in colour. Acid sulphate soils, mainly seen in Kari lands are confined to a small number of pockets in a discontinuous manner along the coastal plains adjoining the Vembanad Lake. Kayal soils are reclaimed from Vembanadu Lake. Kuttanad soils are saline in nature. The EC values vary between 0.1-43.6 dSm^{-1}.

Kari soils are affected by severe acidity and periodic saline water inundation with constant accumulation of salts. Kuttanad soils on submergence showed a small increase in pH and on no occasion it exceeded 5.

CHARACTERISTICS OF ACID SULPHATE SOILS

The lower pH of the Kari soils of Kuttanad is due to the acid sulphate nature of the soil and the presence of undecomposed organic matter in the form of wood fossils. These soils are dark brown to black in colour, rich in organic carbon, sandy to clayey in texture, with random deposits of lime shells and humus (Figure 3).

Figure 3: Soil profile of Kuttanad Kari (Acid saline soils): Typic Sulfohemists (Source: NBSSLUP Archives)

These soils serve as a carbon sink due to its specific wetland characteristics. The organic matter in Kari soils of Kerala is predominantly ligno-protein complex comprising large quantities of lignin, ether and alcohol soluble substances and some cellulose and polyceronoides. Kari soils and the wood fossils associated with them are found to contain different forms of sulphur such as free, organically combined sulphide and sulphate forms.

Acid sulphate soils are naturally formed under anaerobic conditions. These soils either comprise sulphuric acid or have the potential to form it in an amount that can have significant impact on other soil characteristics (Dent and Pons, 1995). The pH of these soils is below 4.0 due to the formation of sulphuric acid by the oxidation of pyrites. The presence of 'sulphur oxidising' and sulphur reducing bacteria in acid sulphate soils proved the existence of a bacterial sulphur cycle, which involves the conversion of organic form of sulphur to sulphuric acid form through the inorganic sulphides and sulphates. The production of sulphuric acid by this way is responsible for the low pH in Kari soils. Also soils contain iron sulphides similar to marcasite and pyrrotite on exposure sulfuric acid and ferrous sulphate.

Acid sulphate soils present in Kuttanad regions are very low in pH ranging from 3.0-5.2. Here, compared to exchangeable acidity, potential acidity is very high and hence special management practices such as liming, leaching with water, providing sub-surface drainage etc. are required to ameliorate the acidic conditions. Toxic quantities of iron, aluminium, manganese and sulphides are present in the soil. Toxicity becomes severe at the top soil as a result of toxic salts coming out by capillary action to the surface as and when the fields are dry during summer months or when the water outside the field rises high. Kayal lands are more seriously affected by salinity. The presence of labile organic carbon and dissolved sulphate under anaerobic conditions provide an ideal environment for sulphate reducing bacteria. Along with this the dissolved iron coming from ferruginous parent material lead to the formation of pyrite (FeS_2).

When pyrites exposed, oxidation occurs and presence of microbes like *Acidithiobacillus ferroxidants* under low pH (less than 4.0) further enhances this and produces sulphuric acid and Fe^{2+}. Acid sulphate soils remained safe to the environment until exposed to oxygen. Once it gets exposed, it leads to the production of sulphuric acid and seeps out into flood water and drainages. The runoff from acid sulphate soils is extremely acidic in nature. Fe^{2+}, Al^{3+} and SO_4^{2-} are the dominant ions in the runoff water. Presence of sulphuric acid lowers the soil pH and reduces the availability of other nutrients to plants. The low pH dissolves iron and aluminium in the soil and develops toxicity symptoms in plants.

GENESIS OF ACID SULPHATE SOILS

The acid sulphate soils are formed through the formation and oxidation of pyrites (FeS_2). For formation of pyrites, Fe^{2+} must be available, which usually is resulted from the weathering of iron containing parent material under anaerobic condition. Sulphates present in organic matter and sea water will react with the Fe^{2+} under anaerobic condition results in the formation of pyrite in the coastal low lands.

Raw acid sulphate soils generated by drainage will become extremely acidic within weeks or months, which can be identified by the presence of straw yellow coloured mottles of jarosites ($KFe_3(SO_4)2(OH)_6$) that develop around the pores and on ped faces and by acid, red in drainage water. As long as the pyrite continues to generate acid, plant root growth is inhibited and hence the soil remains physically unripe (raw acid sulphate soil). Acid sulphates have passed through the raw stage to the ripe stage with the profile sequence as, at depth, where the soil remains water logged and reduced, a gray layer still containing pyrite and above this a physically ripe layer with jarosite and goethite mottles, then a ripe horizon with visible red haematite and goethite mottles, still very acidic with pH about 4 and with high exchangeable aluminium and finally a very dark coloured top soil.

Non-Biological

The overall reactions include reduction of all sulphate to sulphide, followed by oxidation of sulphide to disulphide (S_2^{2-}).

$$Fe_2O_3 + 4\,SO_4^{2-} + 8\,CH_2O + 1/2\,O_2 \longrightarrow 2\,FeS_2 + 8\,HCO_3^- + 4\,H_2O$$

The fine grained pyrite is readily oxidized upon exposure to air, giving Fe (II) sulphate and sulphuric acid:

$$FeS_2 + 7/2\,O_2 + H_2O \longrightarrow Fe^{2+} + 2SO_4^{2-} + 2\,H^+$$

The entire oxidation and hydrolysis process of iron to Fe (III) oxide yields 2 moles of sulphuric acid per mole of pyrite:

$$FeS_2 + 15/4\,O_2 + 7/2\,H_2O \longrightarrow Fe(OH)_3 + 2\,SO_4^{2-} + 4H^+$$

Pyrite is oxidized more rapidly by dissolved Fe (III) than by oxygen:

$$Fe\,S_2 + 14\,Fe^{3+} + 8\,H_2O \longrightarrow 15\,Fe^{2+} + 16\,H^+ + 2\,SO_4$$ (Dent and Pons, 1995)

Biological

$$2S + 3O_2 + 2H_2O \xrightarrow{\text{Microbial oxidation}} H_2SO_4$$

$$H_2S + 2O_2 \xrightarrow{\text{Microbial oxidation}} H_2SO_4$$

MANAGEMENT OF ACID SULPHATE SOILS:

There are different practices for the successful management of acid sulphate soils. But no single method could be useful for reclamation and management of acid sulphate soils. One of the most important practices is the application of liming materials. Lime should be applied at the rate of 6.0 to 12.5 ton ha^{-1}. Liming and leaching can reduce soil acidity to a great extent. Adequate drainage is essential for leaching in order to reduce acidity. Management of water table during dry season helps to prevent the penetration of oxygen into iron pyrite layer. This could be achieved by allowing flooding, or controlled irrigation, or formation of sub-soil hard pan etc. (Cho *et al*., 2002). Another technique for managing acid sulphate soil is to keep away from disturbing or draining the iron pyrite layer.

CONCLUSION:

The severe acidity as observed by the very low pH hinders the potential of acres of Kuttanad soils leaving it unsuitable for cultivation. Along with that the low lying areas are affected by flood and salinity, which also create problems to utilize the land for cultivation. The already made constructions like Thanneermukkam bund helps to prevent the entry of salt water from sea and the Thottappally spillway helps to spill the excess water from the field improving its availability for cultivation. However, these structures alone cannot be a remedy to solve the problem. Hence, adoption of suitable soil and crop management practices along with the use of suitable varieties to tolerate or resist the extreme pH situations also required by these soils to become more productive.

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