

Present Status and Strategies for Ecorestoration of Degraded Ecosystem at Cherrapunjee

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Introduction

The existence of extremely degraded grassland ecosystems in the highest rainfall area of Meghalaya is an unresolved ecological problem. Some ecologists believe that the grassy landscape at Cherrapunjee has emerged as a consequence of deforestation due to age-old practice of slash-and-burn agriculture locally called as 'Jhum'. They believe that a floristically rich broad leaved evergreen forest existed in the past over gentle slopping hills which today support vast stretches of grasslands on highly degraded and nutrient depleted soil substratum. Some of the earlier records of rainfall, vegetation and soil, however, suggest that the graminacious vegetation at Cherrapunjee has not developed during recent past, rather climate, topography and geology of the area are responsible for the development of this type of vegetation. Dr. T. Oldham (c.f. Allen 1905) has described the

effects of these factors on the vegetation in the following words:

'To the denuding force of these heavy and sudden falls of rain is also due the almost total absence of any soil in the flats of the hills near the Southern escarpment. All has, in fact, been washed away, and a thin crop of coarse grass alone finds sustenance on the rocky surface. The marked absence of trees, the growth of which is cut off as with the axe along the edges of every flat, is largely due to the same causes but also largely to the blighting storms which sweep over these hills. On the sloping sides of these valleys trees grow abundantly, and at many places luxuriantly: there they are sheltered, and abundantly supplied with moisture'.

The present day landscape of Cherrapunjee does not differ markedly from the above description and is characterised by vast tracts of grasslands on highly drained flats and slopes of hills with small isolated patches of crooked forests occurring frequently in lowlying areas such as along the streams and rivulets, and gullies and dykes of hillocks. Because sufficient water and nutrients are available throughout the year and the effect of winter storm is less, tree growth is possible on these places. Besides these natural environmental factors, cutting of trees and frequent burning of grasslands by the local people during late winters, before the onset of monsoon, have also contributed substantially to the degradation of land and vegetation at Cherrapunjee. On account of these activities and hilly terrain major part of rain water is channelised through over land flow causing heavy sediment and nutrient losses. Coal and limestone mining and change in land use pattern due to unprecedented rise in population have also accelerated the pace of degradation of natural resources of the entire Southern parts of Shillong plateau including Cherrapunjee.

In this article, we should examine the present status of vegetation and soil of Cherrapunjee and discuss the strategies for eco-restoration of the area.

Geographical Location and Climate

Cherrapunjee (25° 15' N latitudes and 91° 45'E longitudes with 1313 m altitudes from mean sea level) is located 50 kms Southwest of Shillong and is the headquarters of Sohra Civil Sub-division. The total area of this sub-division is about 488 sq. kms (2.18 per cent of the total area of the state) and the population according to 1981 census is 44,500 persons only (i.e., 3.8 per cent of the total population of the state). The rise in the population during 1981-91 is estimated as 31.8 per cent (Census of India 1991). The climate of Cherrapunjee is monsoonal subtropical with distinct wet and dry periods. The year can be divided into a long rainy season (May to October), and a dry winter (November to February) with a short spell of spring during March and April. The annual rainfall at Cherrapunjee ranges between 6689 and 16487 mm with an average of 11276 mm (from 1977 to 1988) (Fig.-4.1). Cherrapunjee is known as the world's number one inhabited place which receives highest amount of rainfall. The rainfall was as high as 22987 mm in 1961 and 24600 mm in 1974. A major portion (95 per cent) of annual rain falls during May to October and rest 5 per cent is received during November to March. The mean monthly maximum and minimum temperatures in the coldest month (January) are 16.2 and 7.7°C and in the hottest month (August) are 23.1 and 18.4°C respectively. The atmosphere is almost saturated with water vapour (relative humidity >90 per cent) during rainy season, but air is relatively dry (relative humidity 60-70 per cent) during the winters. Strong wind (locally known as *Pythaw*) lashes out the area during spring season.

Soil Fertility

The physico-chemical conditions of soil at Cherrapunjee are at sub-optimal level to support healthy plant growth (Table-4.1). The substrata supporting grasslands are stony or gravely. The soil is highly drained and the proportion of clay particles which serve as the repository of plant nutrients is

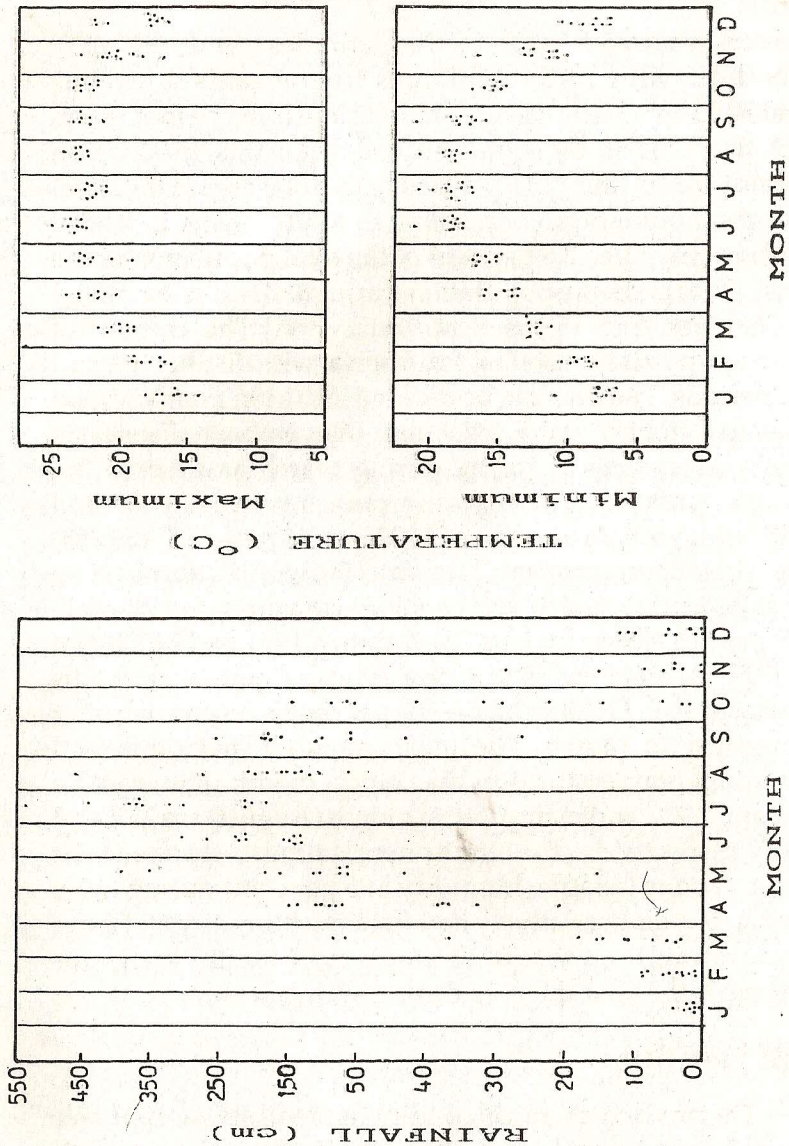


Fig. - 4.1: Variability in Monthly Rainfall and Mean Monthly Minimum and Maximum Temperature during 1977 to 1988.

very low. Nitrogen and Phosphorus, which play a pivotal role in the plant growth, are in extremely low quantities in available nutrient pool in the soils. Approximately 3.8 kg. N/ha and 1.8 kg. P/ha occur in available forms in soil down to 30 cm depth, if the soil is weighted for <2 mm size fraction. A comparison between forest and grassland soils indicates a great deal of similarity between the two. Excessive run off and leaching are the principal factors responsible for this state of soil.

Vegetation

The vegetation of Cherrapunjee can be classified into three categories : (i) broad-leaved evergreen forests, (ii) degraded forest with pine, and (iii) grasslands. The forest is preserved in the form of two small patches, viz., the Sacred Grove and the Reserve Forest. The sacred grove is located around limestone cave in Mausmai village near Cherrapunjee. It occupies about 6 sq. km area and is preserved by the local 'Khasis' due to traditional religious beliefs. The Khasi tribe believes that the sacred grove is the abode of gods/deities and removal of any plant or plant part is against god's will. The reserve forests spread over an area of about 4 sq. kms. This patch of forest is protected by the Village Council. Selective felling of old dying trees is often permitted in this forest. Besides these two protected forests, some broad-leaved and pine trees also grow in isolated pockets on the low lands where the soil and other micro-climatic conditions are conducive for tree growth.

The major species in tree layer of the sacred grove are *Engelhardtia spicata*, *Syzygium macrocarpa*, *Echinocarpus dasycarpus*, *Drimycarpus eacemosus* and *Elaeodendron lanceaefolius*. The major shrub species include *Clerodendron nutans*, *Phlogocanthus curviflorus* and *Camellia caudata*. The important species which grow in the herb layers along with grasses and ferns are *Boehmeria platyphylla* and *Rubus*

moluccanus. Orchids, mosses and climbers are abundant in the forest. The reserve forest is dominated with trees like *Lingustrum robustum*, *Quercus spicata*, *Lithocarpus dealbata*, *Quercus dealbata* and *Wendlandia tinctoria*. The major shrub elements are *Camellia caudata*, *Eurya japonica* and *Syzygium macrocarpa*. The herb layer is composed of *Strobilanthes coloratus*, *Carex baccans*, *Adiantum sp.*, *Panicum maximum*, *Urena lobata* and saplings of *Gomphostemma parviflora*, *Camellia caudata*, *Eurya japonica* and *Clerodendron bracteatum*. Species like *Englehardtia spicata* and *Drimycarpus racemosus*, *Clerodendron nutans* and *Symplocos glomerata* which are dominant in the sacred grove, occur occasionally in the reserve forest. However, in both the forests evergreen species are dominant. The number of deciduous species is much smaller in the sacred grove compared to the reserve forest. Understorey has relatively more evergreen species compared to overstorey in both the forests (Table - 4.2).

Broadly speaking, grasslands of Cherrapunjee come under Themeda-Arundinella type (Dabadghao & Shankar-narayan 1973). At local level, five grassland types, namely, *Osbeckia* type, *Arundinella benghalensis* type, *Ischaemum* type, *Eragrostiella* type and *Arundinella khaseana* type have been recognised by Ram (1986) and Uma Shankar (1991), depending on frequency of burning, soil characteristics and species composition. *Osbeckia* type community generally occurs where the soil is relatively thick and burning is infrequent (once in six years). In this community, dominant species are *Osbeckia crinita*, *Arundinella benghalensis*, *Chrysopogon gryllus* and *Fimbristylis thomsonii*. The *A. benghalensis* type community is similar to the *Osbeckia* type, but has *Arundinella benghalensis*, *Chrysopogon gryllus* and *Carex cruciata* and *Eulalia trispicata* as dominant species. The *Ischaemum* type community developed on sites subjected to burning at two year interval is dominated by *Ischaemum goeblii* and *Fimbristylis complanata*. The *Eragrostiella* type community found on unburned sites with ill weathered, shallow (<30 cms) and

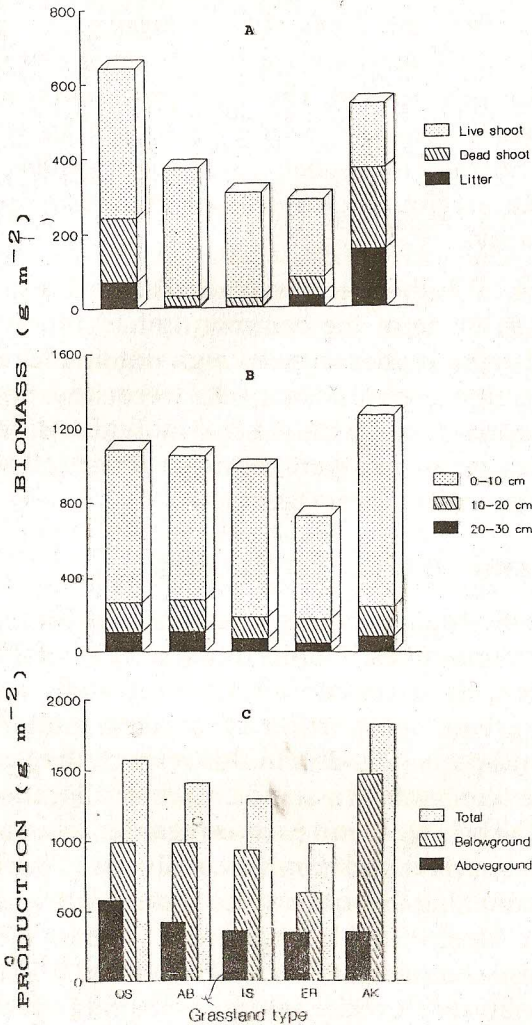
nutrient deficient soils is composed of *Eragrostiella leioptera*, *Borreria articularis* and *Fimbristylis complanata*. *A. khaseana* type community is developed on hilly coarsed-textured and nutrient impoverished soil. The site is protected from burning and regular livestock grazing for about four years. On this site, *Arundinella khaseana*, *Chrysopogon gryllus*, *Eulalia trispicata* and *Eragrostiella leioptera* are important species in the community.

Table-4.3 lists the species recorded in the five grassland communities. None of the community had more than 21 species. All communities showed high dominance and low species diversity. Leguminous species were either noticeably absent or represented by only a few individuals. In all the communities, perennials were the major structural elements and annuals were under represented.

Biomass and Organic Production

Productivity and biomass data are available only for the grassland communities. Despite differences in total biomass accumulation, these communities are markedly similar in allocating greater proportion of organic matter to the belowground parts (Fig.-2b). In this respect, they are more close to the temperate grasslands. Greater allocation of resources to the belowground parts is regarded as an adaptive strategy for survival under stress conditions (Chapin 1980) and for maximizing the root surface area for nutrient uptake (Nye 1977). Most of the belowground biomass (73-80 per cent) in these communities is concentrated in 0-10 cms soil layer, probably due to rocky nature of substrata which do not allow the roots to penetrate to deeper layer.

Fire is one of the most important factors which determine the growth and vigor of plants and control the overall functioning of ecosystem. The *Osbeckia* community which was not subjected to burning for last six years had maximum aboveground biomass followed by *A. khaseana* community which was not burned for four years (Fig.-4.2a). In *A.*



N.B. : OS= *Osbeckia* type, AB=*Arundinella benghalensis* type, IS=*Ischaemum* type, ER=*Eragrostiella* type, AK=*Arundinella khaseana* type.

Fig - 4.2: Average Dry-matter Standing State in Aboveground Compartments (A) and in three Soil Layers (B), and Net Primary Productivity (C) in Five Grassland Communities of Cherrapunjee

benghalensis community where burning took place just one month prior to the beginning of the study, biomass was substantially low. The *Ischaemum* type community which was exposed to regular burning at two years interval and where last burning was done one month before the start of study had about one-half biomass of the *Osbeckia* type community. The *Osbeckia* type and *A. khaseana* type communities had a fairly good amount of standing dead and litter mass on the ground surface, while in *A. benghalensis* and *Ischaemum* types, the amount of standing dead and litter mass was much lower. Besides fire, soil conditions also influence biomass accumulation in the community. This is clearly evident in case of *Eragrostiella* community which had the lowest amount of biomass even without burning.

Belowground Net Primary Production (BNP) was more than the Aboveground Net Primary Production (ANP) in all the communities (Fig.-4.2c). This was particularly true where *Arundinella khaseana* and *Chrysopogon gryllus* were abundant. The ANP was maximum in *Osbeckia* community which was not burned for six years. ANP declined following fire. Ramakrishnan and Ram (1988) reported that biomass and productivity declined in the subsequent year of burn and it took about two years to reach pre-burn levels. This time lag in the recovery process is ascribed to the loss of nutrients from the system through ash and sediment due to heavy rainfall.

Nutrient Accumulation and Dynamics

Nutrient dynamics, which involves complex and continuous interactions between biotic and abiotic components of the ecosystem, plays a key role in the growth and development of plant community on degraded sites. Nutrient cycling in an ecosystem is primarily controlled by its static and dynamic properties (Burke 1989). Species composition, nutrient content in soil and soil texture etc. are static properties at time scale of decades, whereas dynamic properties include

soil available nutrient pools, soil moisture and temperature and population of microbes in the soil which vary widely over shorter time scales, i.e., daily, monthly, seasonally and/or annually and across the altitudinal gradient. Other factors which influence cycling of nutrients in grassland ecosystems include fertilizer application, burning and climatic conditions of the area.

Our understanding of nutrient accumulation and dynamics in degraded ecosystem at Cherrapunjee is based on the data recently collected from *A. khaseana* community by Uma Shankar (1991). The results of the study reveal that nitrogen, phosphorus and cations in the shoots of the dominant grass species are below the dietary requirements of the livestock (Table-4.4). *C. gryllus* showed greater of N, P, Na, and Ca, whereas *A. khaseana* stored more K and Mg. Such a preferential requirement of dominant species for mineral elements could be one of the important reasons for their co-existence on nutrient poor soil of Cherrapunjee. Because when a community is dominated by the one or a few species, there might be a greater nutrient limitation to the individuals growing on less fertile soils, due to continued demand of the same resource (Chapin *et. al.* 1986).

Annual uptake of nutrients and their distribution in above and below ground parts of the community varied from one element to another. A major portion of N, P and Na uptake was reflected in the below ground parts, whereas Ca, Mg and K were largely translocated to the shoot system (Table-4.5). In an annual cycle a major portion of nutrients which are absorbed by the vegetation is returned to the soil through litter and dead root (N 98, P 77, K 49, Na 109, Ca 87 and Mg 65 per cents). In this process of nutrient release belowground parts play a more important role than the shoot system because of their fast turnover rate. Rain water which serves as an important source of N and P input into the system is also responsible for loss of nutrients, especially cations, through run-off and leaching (Table-4.7).

Role of Fire

At Cherrapunjee burning of the dried vegetation during dry winter months (January-February) is an integral component of socio-cultural milieu of the people. The impact of fire on ecosystem is profound and its consequences are dependent on intensity and frequency of fire, proportion of biomass that is burned, the time of monsoon setting and total annual precipitation.

The direct influence of fire on vegetation is the conversion of dried shoot and dead remains on the ground surface into ash and other combustion products. The extent to which organic matter is transformed into ash depends on a number of factors, such as, intensity and duration of fire, fuel load, moisture content in the fuel, weather and topography (Boerner 1982). After fire, the nutrients locked in organic matter may be:

- deposited as ash on the soil surface,
- held up in charred but not completely burned material,
- lost to atmosphere through volatilization.

Nitrogen and sulfure which are volatilized at relatively low temperatures (Ca. 200°C) are readily freed into atmosphere in proportion of the amount of fuel burned (White *et. al.* 1973). Phosphorus and cations, viz., potassium, calcium, sodium and magnesium are generally lost in low quantities because their volatilization temperatures are relatively higher (>500°C) (White *et. al.* 1973). Nonetheless, large amounts of cations may be lost during fire by convection of ash (Harwood and Jackson 1975). At Cherrapunjee, study of soil properties immediately after burning of aboveground vegetation showed an increase in pH and cations and a decrease in carbon and nitrogen contents in the surface soil (Table - 4.6) (Ram and Ramakrishnan 1988). Quick release of nutrients, especially cations, soon after the fire has been reported by other workers as well (Kellman *et. al.* 1985).

Rainfall that follows fire, is of particular importance because it causes heavy loss of nutrients. At Cherrapunjee a major portion of rainwater is lost from the system by way of run off and the loss by percolation though soil profile is relatively less important (Ram and Ramakrishnan 1988). This implies that a major portion of nutrients released after burning of phytomass is lost through run off water and relatively less amount enters into the soil profile (Table-4.7). At many places, dissolved nutrients in soil solution move upward by capillary action during the dry winter period, but this sort of nutrient movement is not possible at Cherrapunjee due to hilly topography and coarse texture of soil.

Thus, combustion of dried phytomass which forms an effective covering on the soil surface and serves as the energy and nutrient source to soil micro-organisms alters the physico-chemical and biological properties of soil and strongly influences the hydrology and nutrient cycling by accelerating losses through various channels. Besides these effects, fire seems to be responsible for bringing about change in the species composition of the community by causing death of those species which propagate mainly through seeds. This might be one of the reasons for poor representation of dicot species including legumes in the Cherrapunjee grasslands.

Strategies for Eco-Restoration

The need for eco-restoration of Cherrapunjee is now widely accepted, and due emphasis is being laid on this task by government as well as non-governmental organisations and agencies. The task of restoring degraded land is not an easy one, because it requires much clearer understanding of soil, plants and climate and their interactions with each other. It also involves understanding of how land is degraded and disturbed and which factors are of critical importance (Bradshaw and Chadwick 1980).

While formulating strategies for ecological restoration

for any area, the first step is to decide the priorities based on the culturable potential of the land in question. The foremost priority must be given to the essential needs of the people inhabiting the area. The necessary requirements of the people who would essentially include the basics of livelihood foodgrains and fruits, fiber, fuelwood and timber, and fodder for livestock. To meet the foodgrain requirements, agricultural use of the land should be preferred.

Areas where sustained agriculture is possible should be marked and brought under cultivation. Where it is not practicable, possibility of plantation forestry could be explored. In plantation, forestry emphasis is most often laid on the fast growing tree species with a view to obtain high economic returns in the form of timber, fibre, fodder or fruits within a short duration; and what is ignored is the carrying capacity of the soil. However, if it is realised that the soil is not able to support healthy growth of plantation forestry, the landscape must be converted into grasslands or it can even be restored for amenity purposes such as recreational lands - playing fields, parks, running tracks etc.

At Cherrapunjee presence of small pockets of crooked forests and growth of grasses, sedges and of members of melastomaceae on exposed surfaces indicate that the micro-level differences in edaphic conditions are very wide. And probably this is the main reason why both forests and grasslands are existing as stable communities under the same climatic conditions. The former representing the climatic climax and the latter exhibiting the bio-edaphic climax community in the area. Since these two types of communities differ markedly from each other in their structure and function, any uniform method of their ecorestoration will not yield desired results. Therefore, it is essential to adopt different strategies for different eco-system. The sacred forest requires protection from all types of human interventions for its growth and as a repository of rich gene-pool. In the grassland areas efforts should be directed mainly to

minimize sediment loss and conserve moisture and nutrients in thin soil so that quality and quantity of grassland produce could be gradually improved by encouraging growth of better graminaceous and leguminous species in the community. Some of the strategies which could be taken into consideration for the eco-restoration of Cherrapunjee are as follows :

1. Conservation of Gene-pool and Bio-diversity : The origin and the extinction of species are the two continuously occurring processes in nature. The human interference with nature has, however, accelerated the latter process to such an extent that, if unabated, it would cause a massive loss of gene pool even before we realize the economic importance of several taxa and derive benefits from them. It is, therefore, necessary to preserve them because of the following reasons :

- we don't know at present which species would be of importance and to what extent in future,
- if the gene-pool is once lost, it cannot be retrieved again,
- the posterity must not be deprived of the nature's gift, and
- biological diversity is the basis of all bio-productivity.

The most simple, cost-effective and appropriate effort for the conservation of biodiversity is to provide protection. A number of temple forests (sacred groves) and scattered patches of crooked pocket forests are the potential repositories of biodiversity at Cherrapunjee. Such areas must be protected and preserved. Removal of any plant part should be completely avoided and care must be taken that the litter and detritus is not destroyed by fire.

2. Conservation of Grass Cover : Conservation of the existing grass cover at Cherrapunjee is necessary because :

- the dominant perennial grasses in the community have been found to apportion a major portion of their

annual net primary productivity to the belowground parts, which form a stout mat of roots and rootstocks and help bind greater amount of soil,

- the perennial species have the advantage of regenerating through rhizome and don't depend on seeds which may be washed away due to exceptionally high rainfall,
- quick growth of these species in the beginning of rainy season is responsible for the transfer of a major quantity of available nutrients from the soil to phytomass, thus contributing to their conservation against run off and leaching losses,
- dead shoot and litter of the grasses form a protective shield on the ground surface, which prevents slashing of soil particles,
- the dead shoot and root mass also help in soil formation process and create favorable micro-environmental conditions for greater microbial growth (Fig.-4.3 A and B), and
- the nutrient poor coarse-textured soil is incapable of sustaining healthy tree growth.

3. Restoration of Degraded Forests : The idea of forest development by planting trees on open upland sites doesn't seem tenable at Cherrapunjee because of poor quality of soil, and unfavorable micro-environmental conditions. In recently initiated restoration through social forestry plantation at Cherrapunjee what has been ignored is the tenet of succession theory which predicts that late successional species will tend to fail when introduced into a disturbed or open site due to unfavorable water and nutrient relations. During normal succession process, the growth of the vegetation is favoured by the ameliorated site conditions as a consequence of subtle adaptations and interactions within the antecedent vegetation. The ecorestoration of such areas can be best initiated by

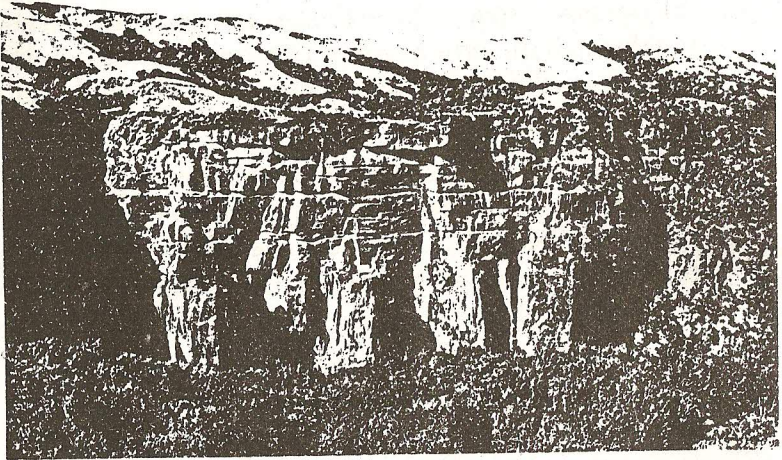


Fig. -4.3 A : Soil Profile (foreground) and Pocket Forest Growth amidst Grassland Matrix (background) at Cherrapunjee.

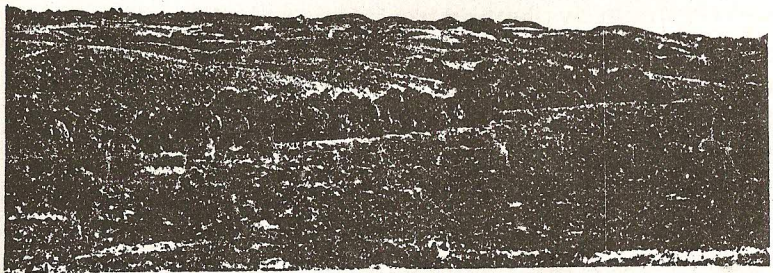


Fig. -4.3 B : Vast Extension of Grassland and Scattered Trees Growing along the Streams.

growing early successional species which are suited to the local conditions. It is, therefore, essential to have a thorough understanding of ecological requirements of the individual species and their subtle adaptations and interactions within a community before selecting them for plantation.

Presence of patches of degraded forests in the area provides clue that these degraded forest sites could be ideal for the forest restoration work, since the site quality is relatively better for the success of plantation forestry. In order to understand the requirements of the tree plantings and their influence on soil conditions, a good deal of research is required through carefully designed experiments under the field conditions.

4. Exclusion of Fire and Control of Grazing : Natural ecosystems exhibit considerable resistance and resilience to periodic disturbance. But persistent or continued disturbance may have pronounced and prolonged ill effects on ecosystem (Odum 1983). Ground fire introduced almost every year during dry winter period in the grasslands at Cherrapunjee is the chief disturbing force causing major nutrient losses from the system. Therefore, there is an urgent need for controlling fire in the area. Grazing is also prevalent despite the poor forage quality. It not only adversely affects grassland communities, but also damages the planted as well as naturally recruited tree seedlings. Prevention of grazing is not possible because of scarcity of fodder in the area, but it could possibly be regulated by adopting scientific methods of pasture management.

5. Increasing Awareness among the Local People : Full support of the local people is a pre-requisite for the success of any ecorestoration work. The people inhabiting the degraded area are the worst sufferers and they fully realize the adverse consequences of degradation of vegetation and soil, even then they are often compelled to cause further damage under pressing need of fuel and fodder. In spite of this, it is imperative to explain them the causes and consequences of

land degradation and the underlying principles of eco restoration. By organising frequent meetings and by using audio-visual aids and other means, ecological awareness could be generated among the local people and they could be actively involved in the eco restoration activities.

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Table-4.1 : Physical and Chemical Characteristics of the Soil (down to 30 cm. depth) of the Sacred Grove, Reserve Forest and Five Grassland Communities at Cherrapunjee.

Character	Sacred Grove **	Reserve Forest **	Grassland Communities*				
			Osbeckia	A.bengh-lensis	Isch-aemum	Eragro-stiella	A #. khaseana
(a) Soil Substratum Composition (%)							
Stone (>5 mm)	-	-	-	-	-	-	40.0
Gravel (5 to 2 mm)	-	-	-	-	-	-	28.1
Mineral Particles (<2 mm)	-	-	-	-	-	-	23.9
(b) Texture (% of Mineral Particles)							
Sand	-	-	-	-	-	-	80.7
Silt	-	-	-	-	-	-	10.3
Clay	-	-	-	-	-	-	9.0
Water Holding Capacity (%)	-	-	-	-	-	-	41.9
pH	4.4	4.2	5.5	5.5	5.4	5.2	5.5
Organic							
Carbon (%)	2.4	2.3	2.6	2.4	1.8	1.0	1.5
Total Nitrogen (%)	0.30	0.26	0.29	0.28	0.23	0.14	0.15
C/N Ratio	8.8	9.1	8.9	8.4	8.0	7.1	9.7
NH ₄ -N (mg 100g ⁻¹)	-	-	-	-	-	-	0.12
NO ₃ -N (mg 100g ⁻¹)	0.16	0.15	0.29	0.28	0.23	0.20	0.41
PO ₄ -P (mg 100g ⁻¹)	0.13	0.11	0.18	0.16	0.13	0.12	0.56
CEC (mg 100g ⁻¹)	-	-	-	-	-	-	8.1
Exchangeable							
Potassium (mg 100g ⁻¹)	0.27	0.26	0.18	0.17	0.17	0.14	0.07
Exchangeable							
Sodium (mg 100g ⁻¹)	-	-	-	-	-	-	0.06
Exchangeable							
Calcium (mg 100g ⁻¹)	1.26	0.54	1.38	1.28	1.10	0.73	1.13
Exchangeable							
Magnesium (mg 100g ⁻¹)	4.24	1.21	1.93	1.69	1.51	1.31	0.21

Sources : ** after Khiewtam (1986); * after Ram & Ramakrishnan (1988); # after Uma Shankar (1991)

Table-4.2 : Important Species of Sacred Grove and Reserve Forest at Cherrapunjee.

Species	Sacred Grove	Reserve Forest
Tree layer		
<i>Ardisia florinunda</i> Wall	-	+
<i>Camellia caudata</i> Wall	+	+
<i>Castanopsis kurzii</i> (Hance.) S.N. Biswas	+	+
<i>Cinnamomum tamala</i> Fr. Nees	+	+
<i>Clerodendron bracteatum</i> Wall	-	+
<i>Clerodendron nutans</i> Wall	+	+
<i>Daphne cannabina</i> Wall	+	+
<i>Debregeasia wallichiana</i> Wedd	-	+
<i>Drimycarpus racemosus</i> Hk.f.	+	+
<i>Echinocarpus dasycarpus</i> Benth	+	-
<i>Elaeocarpus lanceaefolius</i> Roxb	+	-
<i>Englhardtia spicata</i> Bl.	+	+
<i>Eurya japonica</i> Thunb	-	+
<i>Glochidion multiloculare</i> Muell	+	+
<i>Glochidion thomsoni</i> Hk.f.	+	-
<i>Lingustrum robustum</i> Bl.	+	+
<i>Lindera melastomacea</i> Benth	-	+
<i>Lithocarpus dealbata</i> (Miq.) Reh.	+	+
<i>Ltsea elongata</i> Benth. & Hk.f.	+	+
<i>Myrica esculenta</i> Buch. -Ham. ex D.Don	-	+
<i>Phlogocanthus curviflorus</i> Nees	+	-
<i>Quercus dealbata</i> Hk.f. & T.	+	+
<i>Quercus spicata</i> Sm.	+	+
<i>Strobilanthes coloratus</i> T. Anders.	+	-
<i>Symplocos glomerata</i> King ex Gamble	+	-
<i>Symplocos racemosa</i> Roxb.	-	+
<i>Syzygium macrocarpa</i> Roxb.	+	+
<i>Syzygium tetragonum</i> Kurz.	+	+
<i>Wendlandia tinctoria</i> DC.	-	+

Contd. ...

Species	Sacred Grove	Reserve Forest
Herb layer		
<i>Arisaema echinatum</i> Schott.	+	-
<i>Boehmeria platyphylla</i> D.Don.	+	-
<i>Carex baccans</i> Nees	-	+
<i>Fragaria indica</i> Andr.	-	+
<i>Hedyotis scandens</i> Roxb.	+	-
<i>Inula cappa</i> DC.	-	+
<i>Osbeckia crinita</i> Benth.	-	+
<i>Panicum maximum</i> Wall.	+	+
<i>Paspalum orbiculare</i> Forst.	+	-
<i>Poa khasiana</i> Stapf.	+	+
<i>Pogostemon</i> sp.	-	+
<i>Robus moluccanus</i> L.	+	-
<i>Selaginella</i> sp.	+	+
<i>Setaria glauca</i> Beauv.	-	+
<i>Utrica parviflora</i> Roxb.	+	-
<i>Viburnum foetidum</i> Wall.	-	+
Ferns		
<i>Adiantum</i> sp.	+	+
<i>Microsorium</i> sp.	+	-
<i>Pteris</i> sp.	+	-
<i>Thelypteris</i> sp.	+	-

Source : Khiewtam (1986).

Table-4.3 : Floristic Composition of Five Grassland Communities at Cherrapunjee.

Species	Grassland Communities				
	Osbeckia	A.benghalensis	Ischaemum	Eragrostiella	A. khaseana
Grasses					
Arundinella					
benghalensis (Spreng.) Druce	+	+	+	+	+
A. khaseana Nees	-	+	+	+	+
A. nepalensis Trin	+	+	+	-	-
Axonopus compressus (SW.) P. Beauv.	-	-	+	-	-
Capillipedium assimile (Steud.)	+	-	+	-	-
A. Camus					
Chrysopogon					
gryllus (L.) Trin	+	+	+	+	+
Dimeria fuscescens Trin.	-	-	+	+	-
Eragrostiella					
Teioptera (Stapf.) Bor	-	-	+	+	+
Eulalia trispicata (Schult.) Henr.	+	+	+	-	+
Eulalia quadrinervis (Hack.) O. Ktze	+	+	-	-	-
Hetropogon contortus P. Beauv	+	-	-	-	-
Ischaemum goeblii Hack.	-	+	+	+	-
Paspalum orbiculare Forst.	+	+	+	+	+
Pogostemon					
quricularis (L.) Hoak	+	+	+	+	-
Setaria glauca P. Beauv.	+	+	+	-	-
Sedge					
Carex cruciata Wahlenb.	+	+	+	+	-
Fimbristylis complanata L.	-	+	+	+	-
Fimbristylis dichotoma (L.) Vahl	-	-	-	-	+

Species	Grassland Community				
	Osbeckia	A.bengh- lensis	Isch- aemum	Eragro- stiella	A. khaseana
Fimbristylis					
thomsonii Beeck	+	-	+	+	-
Legume					
Eriosema chinense Vogel.	-	-	-	-	+
Forb					
Anotis oxyphylla Hk.f.	-	-	-	+	-
Anotis wightiana Hk.f.	-	-	-	-	+
Borreria articularis (L.f.) N.F. William	-	-	-	+	-
Centella asiatica (L.) Urb.	-	-	-	-	+
Cyanotis vaga (Lour.) Schult Eriocaulon	-	-	-	-	+
cristatum Mart.	-	-	-	-	+
Gentiana quadrifaria					
Clark non Bl.	-	+	+	+	+
Leucas ciliata Benth.	+	-	-	-	-
Melastoma malaba- thricum L.	+	+	-	-	-
Osbeckia capitata Benth.	+	+	+	+	+
Osbeckia crinita Benth.	+	+	+	+	-
Phyllanthus simplex Roxb.	+	+	+	+	-
Plactranthus japonicus (Burn f.) Koidz.	+	+	+	-	-
Polygonum bistorta L.	-	-	-	-	+
Total Species (34)	18	18	21	17	15

Source : ** after Ramakrishnan & Ram (1988); and Uma Shankar (1991).

Table-4.4: Nutrient Concentration (mg g^{-1}) in Shoots of Dominant Grasses in A. Khaseana Community at Cherrapunjee, and Dietary Requirement of Six Mineral Elements.

Species	Nitrogen	Phosphorus	Potassium	Sodium	Calcium	Magnesium
A.khascana	4.80+0.24	0.72+0.04	5.72+0.60	0.24+0.02	1.02+0.04	3.39+0.23
Chrysopogon gryllus	5.97+0.30	0.79+0.05	3.80+0.38	0.25+0.01	1.66+0.10	1.00+0.17
Eulalia trispicata	8.19+0.46	0.80+0.05	3.06+0.30	0.27+0.02	2.66+0.18	1.31+0.10
Eragrostie leioptera	6.65+0.31	0.48+0.03	2.43+0.30	0.18+0.01	1.85+0.14	0.68+0.08
Other Species	8.47+0.55	1.01+0.06	3.12+0.22	0.24+0.01	3.64+0.44	2.19+0.35
Dietary requirements	11.7-18.0 ^a	1.5-3.0 ^b	5.0-8.0 ^c	0.9-2.0 ^a	3.5 ^c	2.0 ^d

Source : a - CAB (1980); b - Wordon *et al.* (1963); c - National Research Council (1971); d - Kemp (1960)

Table - 4.5 : Annual Uptake and Release (Kg/ha) and Recycling Coefficient (release/uptake) of Six Mineral Elements in A. Khaseana Community at Cherrapunjee.

	N	P	K	Na	Ca	Mg
Uptake						
Aboveground	24.6	3.7	25.7	1.1	6.6	10.0
Belowground	112.7	6.8	25.4	4.4	2.1	8.2
Total	137.3	10.5	51.1	5.5	8.7	18.2
Release						
Through litter	18.2	0.9	3.6	0.5	3.8	1.7
Through root	116.1	7.1	21.6	5.5	3.8	10.0
Total	134.3	8.0	25.2	6.0	7.6	11.7
Recycling coefficient						
Above ground	0.74	0.24	0.14	0.45	0.57	0.17
Below ground	1.03	1.05	0.85	1.26	1.81	1.22
Total	0.98	0.77	0.49	1.09	0.87	0.65

Table-4.6 : Changes in the Chemical Properties of Surface Soil (0-5 cm.) after Fire in Two Grassland Communities at Cherrapunjee.

Character	A. benghalensis		Ischaemum	
	Before fire	After fire	Before fire	After fire
pH	5.80	6.20	5.60	5.90
Organic Carbon (%)	2.35	2.13	1.84	1.78
Nitrogen (%)	0.28	0.25	0.23	0.22
C/N ratio	8.40	8.50	8.00	8.10
NO ₃ -N (mg 100g ⁻¹)	0.28	0.29	0.23	0.24
PO ₄ -P (mg 100g ⁻¹)	0.16	0.18	0.13	0.14
K (mg 100g ⁻¹)	0.17	0.47	0.17	0.35
Ca (mg 100g ⁻¹)	1.28	2.10	1.10	1.34
Mg (mg 100g ⁻¹)	1.69	2.35	1.51	1.75

Source : Ram & Ramakrishnan (1988).

Table -4. 7 : Annual Input of Nutrients (gm²) through Rainfall and their Losses through Run-off (R) And Percolation (P) in Three Grassland Communities at Cherrapunjee.

Character	Input through rain water	Output					
		Osbeckia		Ischaemum		Eragrostiella	
		R	P	R	P	R	P
Water	1038	719.70	136.40	818.20	126.60	856.50	130.70
NO ₃ -N	4.67	1.86	0.70	4.28	0.58	1.25	0.36
PO ₄ -P	4.15	0.18	0.03	0.22	0.03	0.17	0.03
K	24.92	4.14	0.83	7.53	0.44	3.38	0.30
Ca	58.14	11.40	1.73	8.41	1.63	7.44	1.42
Mg	22.87	3.92	0.44	3.76	0.64	2.46	0.26

Source : Ram & Ramakrishnan (1988).