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CULTURAL PRACTISES FOR MANAGING SOIL EROSION IN FOREST PLANTATIONS: A STATE-OF-KNOWLEDGE REPORT

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ABSTRACT

Soil erosion is a phenomenon that has existed throughout geological time, but lately human activities have accelerated it. It continues at slow rate in natural forests, but soil disturbances by several operations promote erosion in forest plantations. Though mechanical and cultural methods are available for erosion control, current view is that low-cost cultural conservation practices are appropriate in forest plantations. This project was launched for preparation of a state-of-knowledge report oncultural practices suitable for managing soil erosion in forest plantations with special reference to Kerala.

Soil loss in a region is the function of climate, soil erodibility, topography, vegetation cover and anti-erosion measures. While mechanical and cultural methods are accessible for erosion control, effects of the former are short-lived unless measures are taken to reduce exposure of soil to raindrops. Further, under tropical conditions a vegetation or mulch cover is the key factor in erosion management. An overview reveals that use of grass-legume mixtures, cover and under crops, mulches, minimum and zero tillage, contour cropping, gully control by vegetation and afforestation are the major cultural practices.

In low-input forest plantations prevention is better than cure approach is apt and here erosion management requires proper action at the proper time. As the time of worst vulnerability to erosion is during establishment period, maintenance of cover by taungya crops, undergrowth, tinder crops or mulches is crucial. Contour planting of seedlings and use of ridge and furrow system for tapioca planting can minimize erosion in forest plantations. Also, inrercrops which provide good caver namely Leucaena leucocephala, ***Calliandra colothyrsus*** and Acacia auriculiformis may be tried during the post-taungya period to alleviate harmful effects of erosion.

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Key words: Cultural practices, soil erosion, forest plantations, erosion management.

INTRODUCTION

Soil erosion is the detachment and transport of soil constituents by water, wind and gravity It is a natural process that has existed throughout geological time, but lately human activities have accelerated this. Water erosion proceeds at slow pace in natural forests, but soil disturbances by road alignment, site preparation, taungya operations and logging promote splash, rill and gully erosion in forest plantations. A previous study by Kerala Forest Research Institute revealed that soil erosion is a problem in the initial years of teak and eucalypt plantations raised under taungya and suggested adoption of soil conservstion measures in case of rigorous taungya practices (Alexander *et* a/ 1980). Though mechanical and cultural methods are available for erosion control, the present feeling is that low-cost cultural conservation practices are appropriate rather than expensive mechanical ones.

There is scant information on any specific cultural practice for managing soil erosion in forest plantations. In contrast to rubber, coffee, tea and cardamom plantations, less expensive cultural practices must be employed in forest plantations instead of costly terracing and contour bunding. The cultural practices can minimize soil. particle detachment and transport through soil cover, increased soil aggregation, maximum storage of water and stability of soil structure. Thus, many of the cultural practices followed in agriculture and horticulture are also applicable in forest plantations with adaptations to match site.

it is with this background that the present project was launched for prepaiation of state-of-knowledge report on cultural practices suitable for managing soil erosion in forest plantations, with particular reference to Kerala.

AN OVERVIEW OF CULTURAL PRACTICES FOR MANAGING SOIL EROSION

Grass–Legume Mixtures

Sod-based rotation is a sequence of crops which includes legume or grass–legume crops at least once in five years to improve the soil depleted by other crops in the rotation. The grass–legume crops reduce erosion, improve soil structure and build up soil nitrogen. Stable soil aggregates are formed by the action of plant roots, tillage, wetting and drying and activity of microorganisms and small animals like earthworms. Also, actively decomposing organic matter stabilisss the aggregates which resist breakdown and loosening by rainfall. Orr (1970) concluded from an experiment on a slopy catchment area that sowing a grass-legume mixture could decrease runoff and erosion and the soil could be stabilised within four years.

Cover and Under Crops

A cover crop is grown to protect soil when there are no regular crops on it. In addition to protecting soil from erosion, cover crops add organic matter to the soil and conserve plant nutrients by taking up soluble nutrients which might otherwise be lost by leaching. These crops can be raised as part of the regular farming operations or as the need arises. They are beneficial only if moisture conditions are favourable, if not the soil moisture may get exhausted thus adversely affecting next crop. Green manure crops such as Crotalaria, Sesbania, Cowpea and Horsegram, which are raised and ploughed under, are grown as cover crops. Under crops are also cover crops, the difference being that these are grown with regular crops to protect and improve the soil. Under crops decrease soil temperature and maintain soil structure, organic matter content and soil fertility. however, there are disadvantages like damaging of permanent crops by twining plants and increase of fire, pest and disease hazards. Some of the under crops are ***Calopogonium mucunoides, Centrosema pubescens, Indigofera spicata (I. endecaphylla)*** and ***Pueraria phaseoloides.***

Mulches

Mulches dissipate the force of falling raindrops reducing splash erosion and surface sealing. Not only does mulches physically protect soil, they also provide a continuous supply of structurally stabilising organic matter to it. Further mulches tend to retard surface flow thus permitting more time for infiltration. Osborn (1 954) found that the rate of intake of water by soil is determined more by the amount of ground cover than the permanent characteristics of soil such as soil texture. The residues absorb and hold considerable water, retard evaporation from soil surface and dampen heat gains during the day and heat losses during the night Generally, mulches are of greater value when soil-depleting and row-crops are grown. Sometimes, these are incorporated into the surface soil partly. Thus the combination of

some residues on the surface giving top cover and some close to the surface improving drainage is a desirable practice which would keep erosion at minimum levels. The growing crop provides cover by the time residues decay and lose their effectiveness.

Minimum and Zero Tillage

Minimum tillage denotes tillage done in less time and with less work than is required in conventional methods. Strip cultivation, shallow surface cultivation and similar operations provide proper environment for seediings in the row areas and simultaneously conserve moisture and reduce erosion in the interrow areas. Zero tillage has the advantage of moisture conservation in the soil in addition to decreasing run off and soil erosion. In this system, weed control can be effected through herbicides and residue mulches. Generally, chemicals that kill the weeds on contact or retard further growth are used. In zero-tilled fields organic matter content of the surface horizon is better maintained and so is water-holding capacity of the soil. As zero-tilled land tends to have lower infiltration rate than well-managed traditionally cultivated land, more water is likely to run off during storms in the former. However, the soil surface is more resistant to erosion and soil loss is usually less in spite of the extra runoff. Although there are aaronomic problems associated with zero tilliage, the erosion control without recourse to expensive mechanical methods is a great advantage (Lal and Greenland 1979).

Contour and Contour Strip Cropping

Contour cropping is the practica of planting in rows and operating tillage implements across slope or along contour. Each row acts as a barrier to the flow of water, thus reducing soil and water losses. Contouring should also be supported by other good farming practices. Runoff from contour cultivated fields should be directed through grassed waterways to prevent gullying. On gentle slopes, contouring along with proper rotations controls erosion on lengths upto 90m. On steeper slopes, the maximum lengths on which contouring is considered effective are 60 30, **20** and 18m on 8, 10, 12 and > 12% slopes respectively. Suarez De Castro (1951) recommended formation of natural terraces by contour planting of densely growing perennials on ridges in plantations. The most suitable barrief plants were khus-khus ***(Vetiveria*** zizanioides), lemongrass ***(Cymbopogon citrata)*** and Paspalum ***(Paspalum conjugatum).***

Planting alternate strips of close-growing grass and grain crops on the contour is known as contour strip cropping. The **soil** loss from a strip-cropped field is **25-30%** of what it would be; if cultivation is up and down the slope. Strip cropping is generally practised on steep slopes. The sod strips reduce erosion by both raindrop and surface flow, but the crop strips provide least protection. The sod strip absorbs water flowing from the crop strip above during ordinary showers; but, when rainfall is heavy or of long duration, large quantities of water may flow from the sod to the clean-tilled strip below. In such cases, soil losses may be considerable. Roose and Bertrand (1971) tested the effectiveness of 2-4m wide anti-erosion

strips of permanent grassland along the contour under forest and savanna conditions. The strips were very effective in controlling erosion in regions where grass grew abundantly in the rainy season.

Gully Control by Vegetation

Vegetation once established in the gullies, slows down flow and reduces scouring and abrading by water. As a result, some of the sediments get deposited and thus plant growth is encouraged This in turn leads to further deposition of sediments and the cycle goes on till the gully is filled. Suitable planting techniques have to be devised to match local requirements, Regarding gully sides, pockets of soil can be filled into these and plants can be grown. Surface mulches of straw, crop residues and cut grass accelerate the establishment of vegetation and anchoring materials like woven nets of jute or coir fibre fastened with spikes keep the soil and plants from getting washed away.

Afforestation

Generally soil erosion is less severe in forested than in arable lands. The canopy cover provided by the trees and extensive tree roots are the stabilising forces in forest plantations which keep erosion checked. Fine roots serve as cohesive binders for topsoil and where larger roots penetrate surface layers, they anchor the topsoil to the subsoil. This is the reason why poor or other sites with limitations are put under trees to fulfil a protective function like erosion control,

The literature is replete with references on the role of trees in preventing soil erosion. A study in Ivory Coast found negligible soil loss (0.03 t/ha/yr) from land with secondary forest, 90t/ha/yr when annual crops were cultivated and 138 t/ha/yr when ground was left bare (Grainger 1980). Based on Kenyan experience, Pereira (1979) concluded that planting 6% of the area of an agricultural watershed by contoured strips of trees was sufficient to reduce runoff by 50%. In China, under tropical monsoon climate, establishment of forests on eroded slopes decreased annual soil loss from 15 000 to 3 000 m^3/km^2 over a period of 20 years (Lal 1979) In astudy from Dehra Dun. 28 and 73% rsduction in runoff and peak rate of flow was attributed to changes brought about by reforestation of the watershea by ***Eucalyptus grandis*** and ***E. camaldulensis*** (Mathur *et a/* 1976). Similar observations were also reported from studies on mixed plantations of ***E. globulus*** and ***Acacia mearnsii*** in Nilgiri (Agrawal *et a/* 1961, Samrai *et a/* 1977). In this connection, soil conserving nature of bamboos and reeds should not be overlooked. On account of extensive root systems and accumulation of leaf mulch, bamboos and reeds are efficient in preventing erosion (Pillai 1966, Yadav 1963),

DISCUSSION ON CULTURAL PRACTICES FOR MANAGING SOIL EROSION IN FOREST PLANTATIONS

Maintenanace of Vegetation Cover

Soil loss is the function of climate, soil erodibility, topography, vegetation cover arid anti-erosion measures. Among these, vegetatioc cover of the soil dominates all factors in erosion control (FA0 1965, Greenland and Lal 1977, Harcharikand Xunkle 1978, SCSA 1977, UNESCO 1978), Under natural conditions, rate of erosion is controlled by the presence of vegetation cover. However, when this cover is removed, the rate is accelerated to a dangerous degree. The dramatic increase in soil loss from a bare land compared to well-covered one was demonstrated in an experiment reported by Hudson (1971). He compared two plots, one covered with double layer of fine wire gauze and the other uncovered. Ten-year average losses were 0.9 and 129t/ha/yr from wire gauze-covered and uncovered plots.

That forest ecosystem plays a clear role in providing soil cover to keep soil erosion at bay is seen from the following soil-loss figures (t/ha/yr):2.55 in Trinidad, 0.41 in French Guyana and South East Asia and < 1 at Bandung (Java). Soil loss was neglible under secondary forest in Madagascar, but it increased to 9 t/ha/yr after clearing and cultivation. A low level of erosion beneath a forest was increased to only 0.025 t/ha/yr under eucalypt plantations, but reached more than 59 t/ha/yr under various agricultural crops (UNESCO 1978). From a 14-year investigation on forested, deforested and bare plots, Marston (1952) concluded that ground cover decreased runoff at all intensities of rainfall. Rain at 40mm/hr caused nearly 20% runoff on bare soil, but <5% where ground cover reached 5%.

Thus under tropical conditions, where erosion can occur on very gentle slopes due to high intensity of rainfall, a vegetation or mulch cover is the key factor in soil erosion management. In a site without cover, both soil particle detachment and transport are speeded up and these processesare accelerated when there is considerable soil working. If the forest plantation is established through taungya, choice of taungya crop is important. The crop selected should not compete with tree seedlings for light, water or nutrients and simultaneously it should provide good cover. Also, the raising of taungya crop should involve minimum soil disturbances. A detailed discussion on taungya in relation to soil erosion and soil management was presented in a previous publication (Alexander *et a/* 1980). When taungya is not practised, cover can be provided by undergrowth, under crops or mulches.

Undergrowth

During the initial years of plantation, maintenance of an undergrowth is essential to keep intertree spaces from exposure. If clean weeding is not practised, there will always be an undergrowth in forest plantations. Champion (1932), Laurie (1941 and Ghani (1951) pointed out the importance of undergrowth for decelerating erosion in teak plantations. Maintenance of undergrowth has also been recommended in

some of the Working Plans (Adiyodi 1974, Chandrasekharan *et al* 1969, Vasudevan. 1967). In a way, Eupatorium *(Chromolaena odorata)* , an exotic weed in Kerala is. serving as an undergrowth in many plantations. Even after thorough weeding, it comes up profusely within few weeks and soil erosion can be kept at bay by periodiccutting and retention of this plant. Eupatorium can contribute about 25 t/ha green matter (5 t/ha dry matter) in an year (Moni and George 1959). However, if not properly managed, it can suppress the trees.

Under Crops

Under crops, in addition to protecting soil from erosion, decrease soil temperature, add organic matter to soil and conserve plant nutrients As early as 1928, Bunting. and Milsum recommendedthe use of under crops in rubber and oil palm plantations in Malaysia. Though maintenance of under crops in these plantations is easy as. there are frequent cultural operations in them, such crops can become climbers in forest plantations, if not attended. Some of the under crops which can be tried in forest plantations are *Crotalaria* spp., *Sesbania* spp., *Vigna* spp., *Calopogonium mucunoides. Centrosema pubescens* and *Pueraria phaseoloides* (Anon 1951).

Mulches

Leaf litter serves as a mulch in forest plantations and it dissipates the force of falling rain drops. Further, it tends to retard surface flow thus permitting more time for infiltration. In this connection, rainfall interception in 35-year old plantations at Dehra Dun indicated that 6, 73 and 21% of rainfall were accounted by stemflow, through fall and interception respectively and litter contributed 9% to the interception (Dabral *et al* 1963). In another study at Dehra Dun, the litter interception was approximately 29% (Pradhan 1973). Thus, retention of leaf litter in plantations is advisable as it can contribute the rnuch-needed organic matter.

Musat (1970) used stones as mulch in *Ligustrum vulgare, Prunus mahaleb* and *Pinus nigra* plantations. The mulch with stones up to 12-10 cm maximum diameter! had very beneficial effects in conserving soil moisture during growing season and in preventing runoff and erosion. The weeded material from taungya plantations can also be used as muich. Such plant debris should be arranged in small bunds along, contours and covered with soil to deter runoff and erosion (Akkara, 1974).

Intercropping in the Post-taungya Period

Leucaena /eucocephala (L. glauca) intercropping in teak plantations of Java is a classic example (Coster and Hardjowasono 1936, Roosendael 1928). Preliminary studies in sal plantations of Uttar Pradesh indicated that *Albizia procera, Bauhinia variegata, Cassia fistula* and *Ougeinia oojeinensis* can be grown in the taungya lines without harmful effects on tree crop (Tiwari *1970).* These species of multipurpose value provide cover, add organic matter to soil and also supply fuelwood and fodder Though trials have not been done on intercropping in forest plantations. of Kerala, intercrops which provide good cover may be tried during the post-taungya* period, Some of the species which may be tried as intercrops are *Calliandra calo-*

thyrsus, Leucaena leucocephala and *Acacia auriculiformis.* Calliandra grows very quickly, its dense foliage provides good Cover and its extensive and deep root system binds soil, thereby making it suitable for erosion control. Leucaena's aggressive root system breaks up impervious subsoil layers, improving water penetration and decreasing runoff. Densely packed plantations of Acacia have proved effective in 'preventing erosion even on hillsides of upto 50% slope in Sri Lanka, Indonesia and Zaire (Anon 1980).

Additional Practices

As forest plantations have close intertree spacing, generally 2 x 2m or less, planting along contours can minimize erosion to some extent. In plantations raised under taungya, simple cultural practice like ridge and furrow system may be useful as an erosion-control measure. This system is widely practised and it has a dual purpose of drainage and erosion control (Greenland 1981). In some parts of Kerala, farmers follow this system for raising legumes with tapioca. In forest plantations, instead of mounds for tapioca planting, ridge and furrow system may be tried to minimize erosion. It is crucial that ridges and furrows are taken along contour for preventing gully formation.

CONCLUSION

Prevention is better than cure approach is apt in low-input forest plantations and here erosion management requires proper action at the proper time. Less expensive cultural practices are appropriate instead of costly mechanical ones such as terracing and contour bunding. As the time of worst vulnerability to erosion is during establishment stage when soil loss can be serious due to intensification of taungya operations, maintenance of cover by taungya crops, undergrowth, under crops or mulches is important. Contour planting of seedlings as well as ridge and furrow system for tapio-a planting can minimize erosion in forest plantations. Also, intercrops which provide good cover namely *Leucaena leucocephala, Calliandra calothyrsus* and *Acacia auriculiformis* may be tried during the post-taungya period to mitigate deleterious effects of soil erosion.

LITERATURE CITED

ADIYODI, P. N. **1974.** Working Plan of Wynad Forest Division for **1974–1983. 150** p.

AGRAWAL, **S. S ,** CHINNAMANI, S. and REGE, N. D, **1961.** Mixed plantation **for** effective soil conservation in the Nilgiris. Indian Forester **87: 26–33.**

AKKARA, K. **1974.** Working Plan of Malayattur Forest Division for **1974–1983' 115** p.

ALEXANDER, T. G., SOBHANA, K., BALAGOPALAN, M. and MARY, M. V. **1980.** Taungya in relation to soil properties, soil erosion and soil management. KFRI Research Report **4,** Kerala Forest Research Institute, Peechi, Kerala. **24** p.

ANONYMOUS. **1951.** Leguminous creepers in younger teak plantations. in Forest Research in India **1951–52,** Part 2: Reports from Burma and Indian States. FRI, Dehra Dun. p. **38.**

ANONYMOUS. **1980** Firewood crops: Shrub and tree species for energy production. National Academy of Sciences, Washington, DC **237** p.

BUNTING, B. and MILSUM, J. N. **1928.** Cover crops and green manures. Malayan Agric. J. **16: 256.**

CHAMPION, H. G. **1932.** The problem of the pure teak plantation. Forest Bulletin **78,** FRI, Dehra Dun, **38** p.

CHANDRASEKHARAN, K.P., MOOSA, M. and ANANTHASUBRAMONIAN, A. S. **1969.** Working Plan of Nemmara Forest Division for **1969-1983. 98** p.

COSTER, C. and HARDJOWASONO, M. S. **1936.** The influence of agricultural crops in taungya plantations on the growth of teak. Indian Forester **62: 461–462.**

DABRAL, **B. G.,** PREMNATH and RAMSWARUP. **1963.** Some preliminary investigations on the rainfall interception by leaf litter. Indian Forester **89: 112–116.**

FAO. **1965.** Soil erosion by water: Some measures for its control **on** cultivated lands. FAO, Rome **276** p.

GHANI, Q. **1951.** Effect of teak plantations on the soils of the evergreen and semievergreen forests of East Bengal. Pakistan J. Forestry 3: **342–347.**

GRAINGER, A **1980.** The state of the world's tropical forests. Ecologist **10: 6–54.**

GREENLAND, D.J. (ed). **1981.** Characterisation of soils in relation to their classification and management for crop production: Examples from the tropics. Clarendon Press, Oxford. **446**

GREENLAND, D.J. and LAL, R. (ed). **1977.** Soil conservation and management in the humid tropics, Wiley, Chichester. **279** p.

HARCHARIK, D.A. and KUNKLE, **S.** H. **1978.** Forest plantation for rehabilitating eroded lands. in Special Readings in Conservation. FA0 Conservation Guide 4. FAO, Rome. p. **83–101.**

HUDSON, N.W. **1971.** Soil Conservation. Batsford, London. **315** p.

LAL, R. **1979.** Effects of cultural and harvesting practices on soil physical conditions. ***in*** Soils Research in Agroforestrv. Proceedings of an Expert Consultation ICRAF, Nairobi. p. **327–351.**

LAL, R. and GREENLAND, D.J. **1979.** Soil physical properties and crop production in the tropics. John Wiley, Chichester. **551** p.

LAURIE, M.V. **1941.** The problem **of** the pure teak plantation. Proceedings of the 5th Silvicultural Conference. FRI, Dehra Dun. p. **123.**

MARSTON, R.B. **1952.** Ground cover requirements for summer storm runoff controt on aspen sites in northern Utah. J. Forestry **50: 303–307.**

MATHUR, H. N., RAM BABU, JOSHIE, P. and SINGH, BAKHSHISH, **1976.** Effect of clearfelling and reforestation on runoff and peak rates in small< watersheds. Indian Forester **102: 219–226.**

MONI, N=S. and GEORGE, M.P. **1959.** ***Eupatorium odoratum*** - a common weed found in the teak plantations of Kerala State. Indian Forester **85: 728–730.**

MUSAT, l. **1970.** The influence of different mulching materials on soil moisture and seedling development. Rev. Padurilor **85: 310–313. in** Forestry Abstract **32: 304.**

ORR, H.K. **1970.** Runoff and erosion control by seeded and native vegetation on-a forest burn: Black Hills, South Dakota. US For. Serv. Res. Paper, Rocky Mt. For. Range Exp. Station No. RM–60. **12** p.

OSBORN, 6. **1954.** Effectiveness of cover in reducing soil splash by raindrop impact. J. Soil ***&*** Water Conservation **9: 70–76.**

PEREIRA, C. **1979.** Hydrological and soil conservation aspects of agroforestry. ***in*** Soils Research in Agroforestry. Proceedings of an Expert Consultation. ICRAF, Nairobi. p. **315–326.**

PILLAI, N. K. **1966.** Working Plan of Konni Forest Division for **1966-1980. 138 p.**

PRADHAN, l. P. **1973.** Preliminary study on rainfall interception through leaf litter. Indian Forester **99:** 440–445.

ROOSE, E. J. and BERTRAND, R. **1971.** A study of the antierosion strip method for controlling water erosion in Western Africa. Experimental results and observations. Agronomie Tropicale 26: **1270–1283.** ***In*** Soils Fertili–zers **35: 317.**

ROOSENDAEL, J, van. 1928. Experiments of undsrplanting of teak plantations. Tectona 21: 316–333.

SAMRAJ, P. CHINNAMANI, S. and HALDORAI, B. 1977. Natural versus man-made forest in Nilgiris with special reference to runoff, soil loss and productivity. Indian Forester 103: 460–465.

SOIL CONSERVATION SOCIETY OF AMERICA, 1977. Soil erosion - prediction and control. SCSA, Ankeny. 391 p.

SUAREZ DE CASTRO, F. 1951. Living barriers in soil conservation. Agric. Trop. Bogota 7 (8): 45 – 48 in Soils & Fertilizers 15:. 40.

TIWARI, K.M. 1970. Interim results of intercropping of miscellaneous tree species with main crop of taungya plantations to increase the productivity, Indian Forester 96: 650 - 653.

UNESCO. 1978. Tropical forest ecosystems: A state - of – knowledge report by UNESCO/UNEP/FAO. UNESCO, Paris. 683 p.

VASUDEVAN, K. G. 1967. Working plan of Nilambur Forest Division for 1967 - 1976. 236

YADAV, J. S. P. 1963. Site and soil characteristics of Bamboo forests. Indian Forester 89: 177 - 193.