IRRIGATION AND DRAINAGE
Irrig. and Drain. **60**: 694–702 (2011)
Published online 18 August 2011 in Wiley Online Library (wileyonlinelibrary.com) **DOI**: 10.1002/ird.643

MANAGING TERRACED LOWLAND AND MEDIUM SLOPING LAND FOR SUSTAINABLE AGRICULTURE: A STUDY FROM THE EASTERN GHAT REGION OF INDIA†

R. K. PANDA[1]*, C. P. ARORA[2], K. P. GORE[3], P. JAKHAR[3] AND B. K. DASH[3]

[1]*Directorate of Water Management (formerly WTCER), Chandrasekharpur, Bhubaneswar Orissa, India*
[2]*Central Soil & Water Conservation Research and Training Institute, Dehradun, Uttarakhand, India*
[3]*Central Soil & Water Conservation Research and Training Institute, Research Centre, Koraput, Orissa, India*

ABSTRACT

Judicious management of the terraced lowlands and adjacent medium-sloping lands of the Eastern Ghat Region in India was addressed through a case study, in order to develop a sustainable agriculture package as a resource for poor tribal farmers. Quantification of available water resources during the period 2004–2007 revealed that average base flow and surface flow (as percentage of total rainfall) at a level of 37.2 and 34.7% respectively, could be made available in the study area, and would otherwise go out of the system without proper utilization. Economic resource conservation options for farmers, such as the management of paddy field riser bunds through construction of semi-mechanical runoff disposal devices supplemented with a *Eulaliopsis binata* vegetative barrier, helped in reducing runoff and soil loss by 10.6% and 1.45 t ha^{-1}, respectively. Through paired *t*-tests at a 5% probability level, significant differences were observed in the reduction of the sediment yield, when comparing the proposed techniques with the farmers' practices. Introduction of a promising HYV paddy cultivar *(Oryza sativa* L. or Lalat) fortified with the application of *Gliricidia sepium* leaves (grown on the periphery of the terraced lowlands) resulted in a paddy yield of 4.2 t ha^{-1} as against 1.7 t ha^{-1} obtained through the local paddy cultivar. Further, based on the availability of runoff water through a perennial stream, it was found that provision for a diversion irrigation channel constructed to harvest water would be a promising option for irrigating the adjacent medium-sloping land for remunerative vegetable cultivation. Overall, the developed integrated package resulted in a cost–benefit ratio of 2.6:1 with a net present value of Rs. 116 000.00 (US$2900) at a 15% discount rate, increasing the scope for replicating this technology in other parts of the Eastern Ghat region. Copyright © 2011 John Wiley & Sons, Ltd.

KEY WORDS: low and medium land agriculture; Eastern Ghat; terraced paddy field bund management; diversion irrigation channel

Received 4 June 2009; Revised 9 April 2011; Accepted 6 May 2011

RÉSUMÉ

Une étude de cas est conduite ici sur le développement d'une agriculture durable pour les agriculteurs tribaux à faibles revenus et qui exploitent dans l'est du Ghat des terres basses aménagées en terrasses et des terrains adjacents à pente moyenne. La quantification de 2004 à 2007 des ressources en eau disponibles montre que le débit de base des cours d'eau et l'écoulement superficiel représentent respectivement 37,2 et 34,7% de la lame d'eau écoulée. Ces volumes, qui de toute façon quitteraient le système sans utilisation adéquate peuvent être réalloués sur la zone d'étude. La gestion des pipes d'amenée et des diguettes à travers des pièges à ruissellement semi-mécaniques, la création de barrières végétales plantées avec une espèce locale *Eulaliopsis binata*, et. l'introduction d'un cultivar de paddy prometteur (*Oryza sativa* L.*)*, encore appelé Lalat renforcé par l'application de feuilles de *Gliricidia sepium* (cultivée à la périphérie des champs de paddy) en tant que fertilisant ont permis un rendement de 4.2 t ha^{-1}, alors que le paddy traditionnel plafonne à 1.7 t ha^{-1}. De plus, l'eau de ruissellement étant devenue un écoulement pérenne, il a été possible de collecter cette eau dans des canaux d'irrigation qui desservent les terres intermédiaires en pente exploitées cultures légumières, par ailleurs rémunératrices. Le test t par séries appariées montre une réduction

* Correspondence to: R. K. Panda, Directorate of Water Management (formerly WTCER), P.O. Rail Vihar, Chandrasekharpur, Bhubaneswar – 751023, Orissa, India. E-mail: pandark1@rediffmail.com
†Gestion des terres en terrasses et des terres adjancentes à faible pente en vue d'une agriculture durable: Une étude de I'Est de I'Inde Région Ghat.

significative au seuil de probabilité de 5% des sédiments en comparant les techniques proposées aux techniques traditionnelles des agriculteurs.. Au total l'ensemble des améliorations a résulté en un ratio-bénéfice sur cout de 2,6 à 1, une valeur actualisée nette de 1 16 000.00 roupies ($2900) pour un taux d'intérêt de 15% et mettant en avantage toute réplique de la technologie dans la région est du Ghat.

MOTS CLÉS: MOTS CLÉS; l'agriculture des terres basses et de moyennes; Est du Ghat; gestion des rizières digue; canal d'irrigation de dérivation

INTRODUCTION

India is the largest paddy-growing country at 45 Mha (million ha), accounting for about one- third of the world acreage of the crop. It is grown in more than 30% of the total cultivated area. Rainfed lowland paddy in the country covers about 14.4 Mha, which accounts for 32.4% of the total area of paddy (National Bureau of Plant Genetic Resources, 2006). Although scientists have defined broad rainfed lowland sub-ecosystems, individual farmers in such areas usually manage lands distributed across local landscapes that include a diverse and dynamic range of rice environments (Fujisaka, 1990). All of the rainfed lowland paddy in South East Asia is grown in gently sloping areas along toposequences with differences in elevation of a few metres (Boling *et al*., 2008). The timing, frequency and amount of rainfall during the growing season determine the land productivity in this rainfed environment (Saleh and Bhuiyan, 1995).

The Eastern Ghats of India are discontinuous hill ranges lying on the eastern side of the Deccan plateau, located between $77^0\ 22'$ and $85^0\ 20'$ E and $11^0\ 30'$ and 22^0N and lie in a north-east–south-west direction in the Indian peninsula, covering an area of about 19.8 Mha with an average width varying between 100 and 200 km and a length of 1600 km. The area has a rich and diversified plant wealth due to undulating topography and availability of rich humus content. The altitude of hills ranges from 400 to 1600 m. The Eastern Ghat region is endowed with impressive biodiversity and is one of the primary centres of the origin of paddy (Dash, 2006). However, due to easy accessibility for encroachment, there has been a substantial increase in population and this has resulted in increased demands on natural resources. The forests of the Eastern Ghats are dense with different eco-climatic conditions and provide a natural habitat for local tribes. Nearly 54 tribal communities are present in the Eastern Ghats. The other problems and constraints encountered are deforestation, depleting fertility status of the soil, erosion of some river banks, degraded common and grasslands, inappropriate land use, fire resulting from shifting cultivation,[1] fragmentation of landholdings, frequent droughts and floods, uncontrolled mining activities, and a depleting groundwater levels system.

The average rainfall recorded is about 150 cm, mostly caused by south-west and north-east monsoons in the region. Even though the area receives the high rainfall, as a result of ignorance the tribal farmers could not develop the technology for storage and conservation of water resources. Each tribal settlement in the Eastern Ghats is usually situated near a hill stream or spring. Surface water like hill streams, tanks, ponds and reservoirs are the major sources of water supply for the tribal people. The other groundwater resources are the springs. Spring water is largely used for drinking and terrace cultivation purposes. Due to the rolling topography, it is very difficult for farmers to conserve water with the technology available locally. The lands in agricultural use in the region are classified into the following categories: (i) wet, (ii) dry, (iii) shifting cultivation and (iv) waste and forest lands. The waste and forest lands in a tribal habitat are commonly used by all the residents for grazing their cattle, collecting firewood, timber and other minor forest produce. The major portion of wetland cultivation in the tracts is seen by the sides of hill streams, where plain landscape is available. The majority of tribal farmers grow the paddy crop in wetlands during the wet season. The crops are mainly paddy (*Oryza sativa* L.), sorghum (*Sorghum vulgare*), pearl millet (*Pennisetum typhoides*) and finger millet (*Eleusine coracana*).

Analysis of the traditional agro-ecosystems of the Eastern Ghats of Orissa, an Eastern Ghat state (4.87 Mha), revealed that cultivated land occupies 66% of the total area (Dash and Misra, 2001). Lowland paddy ecosystems, which comprise approximately 5% of the landscape in the Eastern Ghat region, are located in gently sloping areas along broad-based terraced toposequences. Uninhibited surges of storm waters, through intense and short-spell rainfall occurrences and improper soil and water conservation measures, both upstream and on-site, result in unfavourable soil deposits, the breach of riser field bunds and the loss of topsoil nutrients. Attempts by researchers and developmental agencies to understand the phenomena of hydrology, sedimentation and management aspects in this crop ecosystem have been few and far between. Thus, the region suffers from depleted resources, mass poverty and socio-economic backwardness. Even though paddy cultivation has been in vogue since time immemorial in the region, productivity remains low at 1.2 and 1.3 t ha^{-1} during the wet and dry seasons, as against the national average of 1.81 and 2.9 t ha^{-1}, respectively. The medium-sloping land which comprises approximately 15% of the area is devoid of cultivation due to the lack of assured water.

Thus, attempts were made in the present study to address the management of the terraced lowlands and adjacent medium-sloping lands through a study of two hilly watersheds in the region. An integrated technological package was proposed for the judicious management of these lands for sustainable agricultural production through resource conservation options suitable for, and accepted by, the tribal farmers.

METHODOLOGY

Study area

The study area is situated between 82° 50′–82° 52′ 30″ E and 18° 40′–18° 42′ 30″ N (Figure 1). Physiographically, the area lies contiguous to the main land of the Eastern Ghats. Two hilly watersheds located in the Eastern Ghat region of Koraput district, Orissa, India, namely Kokriguda Jhola (WS-1) and Chullapari Jhola (WS-2), were considered for the present study. While quantification of water resources was made through collection of daily runoff data from both watersheds during the period 2004–2007 with the help of stage level recorder, the proposed technological interventions were considered only in WS-1. Topographically, both watersheds are typically representative of the Eastern Ghat region, having a wide range of land types comprising hill, hill slope, upland, medium-sloping land and terraced lowlands. The mean elevation of the location is 900 m above mean sea level. The process of denudation has advanced too far and the hills are covered with low scrub or disfigured with bare patches caused by shifting cultivation. Uplands and medium-sloping lands are generally cultivated with traditional paddy (*Oryza sativa* L.), ragi (*Eleucine corocana*) and niger (*Guizotia abyssinica*) during wet seasons only. However, due to the presence of perennial stream sources, the terraced lowlands are cultivated with paddy throughout the year (Figure 2). The average annual rainfall is around 1500 mm (no. of rainy days = 78). During the wet season (June–September), the area experiences maximum and minimum cardinal temperatures of 25–30 and 15–20 °C, respectively; soil temperature of 21–27 °C (in depths of 5–20 cm); relative humidity of 85–95%; sunshine hours of 2–6 h; and wind velocities of 2–8 km h^{-1} (Panda *et al.*, 2007a, 2007b).

Experimental set-up

Streamflow and sediment load collection. Daily runoff passing through the terraced lowland paddy fields (Figure 2) was gauged at the outlet in the two watersheds. A rectangular weir with stage level recorder provision was constructed in order to quantify the daily runoff water. The sediment deposition rate was monitored during wet seasons by fixing graduated pegs in 5 × 5 m grid spacing in the terraced paddy fields.

Management of terraced lowlands and medium lands. Loose boulder runoff disposal semi-mechanical systems were constructed on the riser bunds in the terraced lowland paddy fields for generating non-erosive runoff water. After several field experiments conducted in the region, *Eulaliopsis binata*, a non-grazing local grass species, was found to be a suitable vegetative barrier for controlling

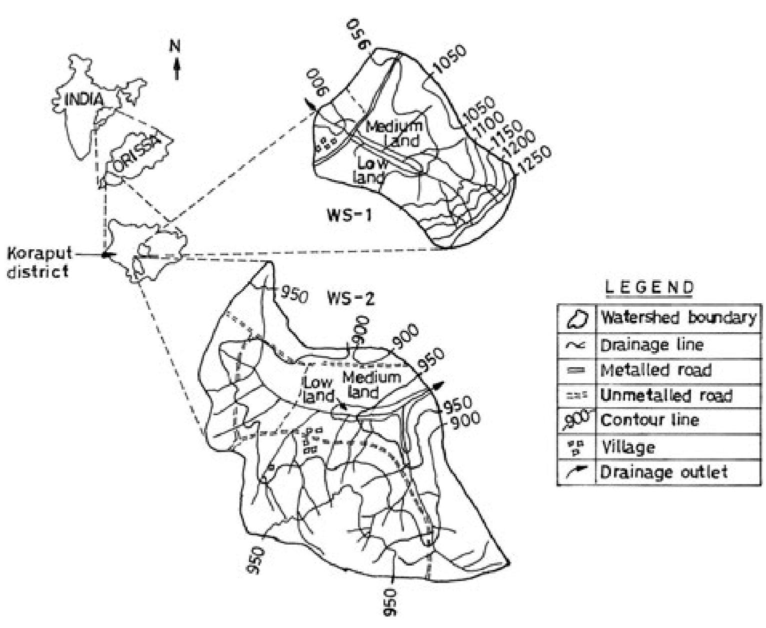

Figure 1. Location map of the study area

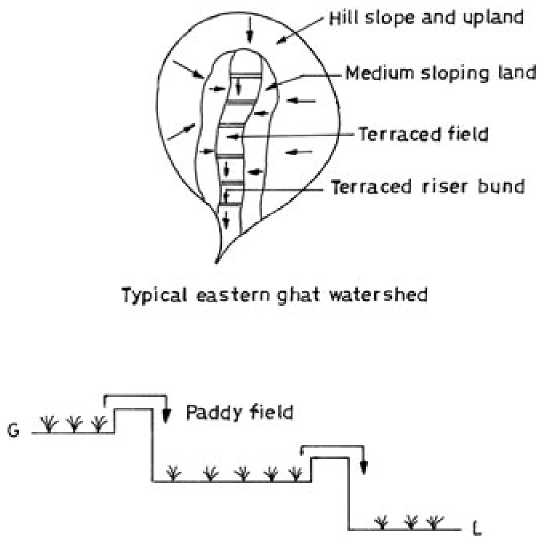

Figure 2. Farmers' practiced terraced paddy fields.

runoff and soil erosion from agricultural fields (Sudhishri *et al.*, 2008). Thus, in the present study, this grass species was considered as the vegetative barrier and put on the riser bunds in two rows (Figure 3). In order to enhance the productivity of the water-rich lowlands, two hybrid (Pro-agro-6444 and Pro-agro-6111), four high-yielding varieties (HYVs, namely Lalat, Puja, Durga and Khandagiri) and one local variety of paddy cultivar were evaluated for growth and yield attributes. These paddy varieties were planted in a 2-ha area in contiguous terrace beds. To meet fertilizer requirements, *Gliricidia sepium* hedges were planted on both sides of the terraced beds at 0.5 m intervals (plant to plant), and their leaves were incorporated in the paddy fields. In order to make lowland water available for crop production in the adjacent medium-sloping lands, which are located on both sides of the terraced fields (with 1–1.5 m higher elevation difference from the terrace fields), a diversion channel was provided to divert lowland perennial water. Based on the quantification of lowland water and its temporal availability, a diversion channel with dimensions of $1.0 \times 0.50 \times 0.50$ m (top width × depth × base width) was found sufficient for diverting water for remunerative vegetable cultivation.

RESULTS AND DISCUSSION

Characteristics of terraced lowlands

The tribal farmers in the two study watersheds reclaimed the gullies and converted these lands into levelled paddy fields. They took advantage of the perennial streams (generally these lands have the resource of perennial streams) to irrigate these narrow terrace paddy fields. The area of terraced lowland systems in WS-1 and WS-2 watersheds was found to be 7.5 and 18.3 ha, out of a watershed area of 169.5 and 384.4 ha, respectively, which comes to about 5% (Central Soil and Water Conservation Research and Training Institute, 2004–2005). Similarly, the medium-sloping lands constitute 12.3 and 17.1%, respectively (Table I). These two terraced lowland systems were narrowly stretched to a length of 0.8–1.3 km, with a width varying between 60 and 140 m. Cross-sections taken at various locations revealed that the depths of terraced lowland systems at the outlet

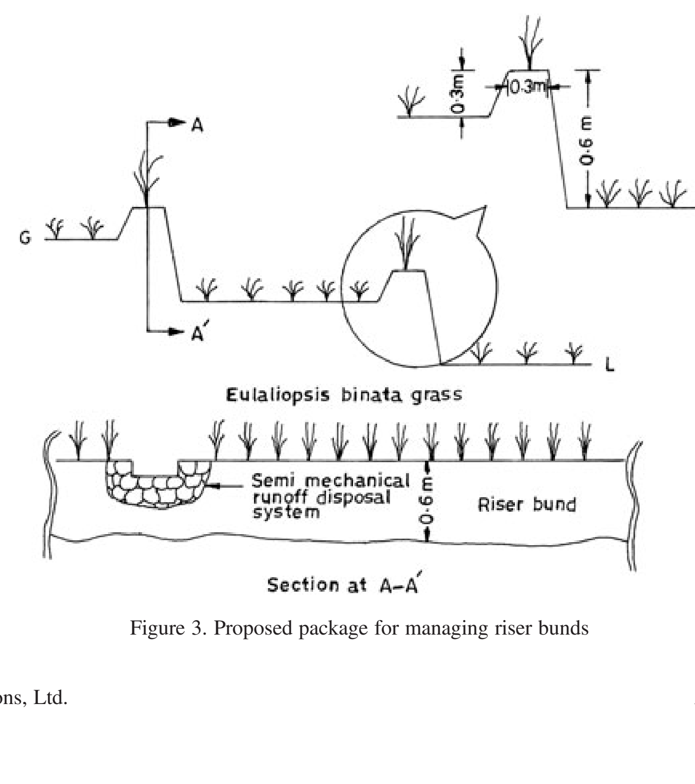

Figure 3. Proposed package for managing riser bunds

Table I. The study area

Watersheds	Total area (ha)	Average slope (%)	Terraced lowland (ha)	Medium-sloping area (ha)
WS-1	169.5	2.9	7.5 (4.4)	20.8 (12.3)
WS-2	384.4	1.2	18.3 (4.8)	65.7 (17.1)

Figures in parentheses indicate percentage of total watershed area.

position vary between 1.5 and 1.75 m (while measuring the elevation difference between the bottom of the lowland and medium-sloping land). Average slope of these systems along the flow direction varied between 1.2 and 2.9%.

Physico-chemical properties of soil

Surface soil (at 0–15 cm depth) of these lowland systems is predominantly clay loam in texture and moderate in organic carbon (average 0.22%). Available N, P and K are computed as 120.4, 24.1 and 183.0 kg ha^{-1}, respectively. Similarly, subsurface soil (at 15–30 cm depth) has an average organic carbon content of 0.10% with available N, P and K at 57.4, 33.4 and 125.2 kg ha^{-1}, respectively (Table II). Permeability is slow to moderate (1.53–3.45 cm h^{-1}) in the upper zone and very slow (0.37–1.38 cm h^{-1}) in the lower zone. Medium land soils are sandy loam in texture, having an organic carbon content of 0.51% and available N, P and K at 256.0, 6.0 and 302.0 kg ha^{-1}, respectively (Patnaik *et al.*, 2004).

Table II. Physico-chemical properties of terraced lowlands

Distance downstream	Bulk density	O.C.	Available nutrients		
			N	P	K
(m)	(gm cc^{-1})	(%)	(kg ha^{-1})		
Surface at depth 0–15 cm					
35	1.13	0.35	196.0	38.6	254.0
160	1.23	0.26	145.6	16.0	232.0
250	1.34	0.17	95.2	27.0	136.0
625	1.43	0.08	44.8	14.8	108.0
Average	1.28	0.22120.4	24.1	183.0	
Subsurface at depth 15–30 cm					
35	1.18	0.13	72.8	30.8	136.0
160	1.23	0.12	67.2	38.4	200.0
250	1.28	0.07	39.2	27.2	102.0
625	1.40	0.09	50.4	37.3	63.0
Average	1.27	0.10	57.4	33.4	125.2

Socio-economic study

The socio-economic study revealed that large landholding tribal farmers (> 2 ha) owned a greater portion of the terraced lowlands (Table III). Terraced lowlands constitute 13.2% of the total land possessed by large farmers (Central Soil and Water Conservation Research and Training Institute, 2005–2006), which is 42 and 76% higher than that of medium land holders (1–2 ha) and small category farmers (< 1 ha). The contribution of lowlands to the total income of small category farmers is 17.3 and 40.2% higher than that of large category farmers (17.1%). Thus there is a need to develop a suitable technological package for managing terraced lowlands, which can help to increase the socio-economic conditions of the small and medium landholding farmers.

Hydrology

The temporal and spatial availability of water resources were quantified during the period 2004–2007. Daily base flow and a surface flow hydrograph from a representative year, 2004 (wet season), is presented in Figure 4. The base flow component was segregated from the total runoff ordinates by the procedure of drawing tangent lines from the rising limbs and falling limbs of the runoff hydrograph (Panda *et al.*, 2007a, 2007b). Average base flow and surface flow (as a percentage of total rainfall) were found to be 37.2 and 34.7%, respectively, amounting to a total runoff of 72% (Table IV). These findings revealed that this abundant quantum of total flow needed to be judiciously conserved for use in the medium lands for remunerative agriculture during the post-monsoon season.

Resource conservation measures

Management of riser bunds in terraced paddy fields. The lowlands in the Eastern Ghat region are stabilized level terrace beds. The dimensions of the riser bunds separating two adjacent terrace rice fields are approximately 0.3 × 0.3 × 0.6 m (upstream height × top width × downstream height). Being made out of stone-stacked/earthen materials, and as the entire length of the bunds acts as a crest during peak rain events, the riser bunds are vulnerable to frequent

Table III. Contribution of lowlands in agricultural income of farmers

Category	Average land-holding (ha)	Lowlands (%)	Contribution to total income (%)
Large (> 2 ha)	10.3	13.2	17.9
Medium (1–2 ha)	5.0	9.3	21.0
Small (< 1 ha)	2.2	7.5	25.1

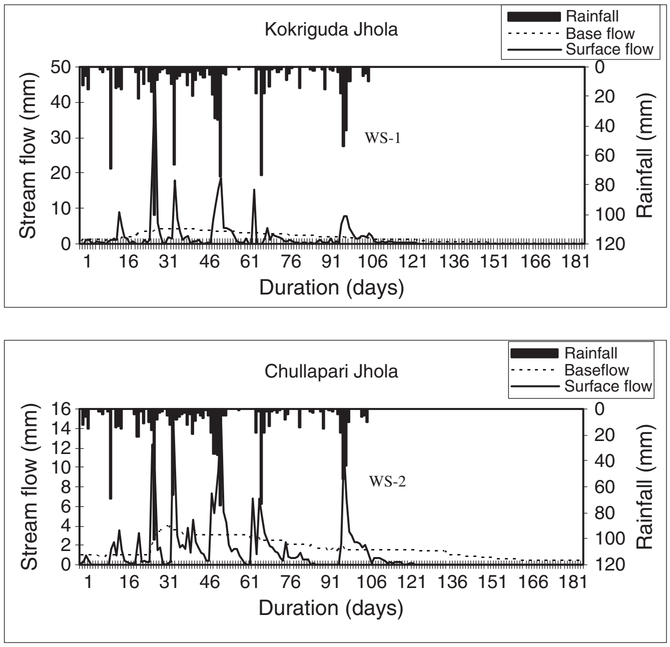

Figure 4. Daily rainfall, base flow and surface flow during representative year 2004 (1 July – 31 December) in watersheds.

Table IV. Spatial and temporal flow (as percentage of total rainfall)

Watershed	2004		2005		2006		2007		Average	
	BF	SF	BF	SF	BF	SF	BF	SF	BF	SF
WS-1	34	31	48	23	44	43	29	32	41.3	32.3
WS-2	33	22	23	39	39	46	37	41	33	37
Average	33.5	26.5	35.5	31.0	41.5	44.5	33.0	36.5	37.2	34.7
Average rainfall (mm)	1332	1274	2174	1616	1682					

BF=base flow and SF=surface flow.

damage. To ward off the problem, a permanent solution can be found by constructing permanent masonry riser bunds for the safe disposal of runoff water. However, this being an expensive proposition and one which would occupy a greater crop area, the resource-poor tribal farmers cannot afford to construct these structures. Thus, in order to suit the resources of poor tribal farmers, a semi-mechanical stone-packed runoff disposal system with vegetative barriers on the remaining portion of the riser bunds was found to be a promising proposition (Figure 3). The runoff water could flow past the riser bunds through the disposal system without causing damage to the bunds. *Eulaliopsis binata*—a local grass species abundantly available in the vicinity—was considered as the suitable vegetative barrier for the riser bunds. With its wide-ranging tolerance of adverse climatic and edaphic conditions, and a non-grazing species, the *Eulaliopsis binata* grass barrier was proven to be an effective, low-cost system for soil and water conservation measures in the Eastern Ghat region of India. The dimensions of the crest opening of the devices were put at 0.3×0.6 m (depth × width) based on the design runoff discharge of $0.17\,m^3 s^{-1}$. The approximate cost of each semi-mechanical runoff disposal system was Rs. 1375.00 (US$34). A *Eulaliopsis binata* barrier was provided on the top of the bunds in two rows with an interval of 0.3 m. The root system of one *Eulaliopsis binata* plant gave binding effects to the soil of up to 40 and 22 cm, laterally and vertically down, respectively. Normally 1–1½ years are required to stabilize the grass barrier on the riser bunds. As the *Eulaliopsis binata* grass is a hardy species, survival percentage was found to be more than 80%.

Under different crop environments, similar results have been established by various researchers. While using grass as a

Table V. Sediment load deposition depth (cm) and sediment yield ($t ha^{-1}$) compared between treated and untreated terraced paddy fields

Years	Treated terraced paddy fields		Untreated terraced paddy fields (farmers' practices)	
	Sediment deposition depth	Sediment yield	Sediment deposition depth	Sediment yield
	(cm)	($t ha^{-1}$)	(cm)	($t ha^{-1}$)
2004	2.1	2.1	3.6	18.7
2005	2.0	1.8	2.8	17.5
2006	1.7	1.4	2.4	21.1
2007	2.4	0.5	3.1	15.7
Average	2.1	1.45	3.0	18.3
paired *t*-test SD[a]				

[a]Significant difference at 5% level.

suitable vegetative barrier for controlling runoff and soil erosion, Sudhishri *et al*. (2008) reported that on an 11% slope in the Eastern Ghat region, *Eulaliopsis binata* and *Vetiveria zizanoides* barriers reduced runoff and soil loss by 63.4 and 68.5% respectively. The hydrological performance of vegetative barriers versus farmers' practices on 11% slopes in the Eastern Ghat region of Orissa state has been tested (Prakash *et al*., 1999). Planted on a miniature bund of $0.1 m^2$ cross-section, *Eulaliopsis binata* grass produced the lowest runoff of 26.9%, followed by farmers' practices (43.3%), and an increase in yield of grain over farmers' practices of 25.6%. A similar result was reported by Sharma *et al*. (1999). While studying contour vegetative barriers of adapted perennial grasses in an arid region of India, they found that runoff volume and specific peak discharge were reduced by 28–97% and 22–96% respectively, with negligible soil loss.

Sediment deposit pattern

The average sediment deposit pattern was observed by fixing graduated pegs during four consecutive years (2004–2007) in the proposed WS-1 watershed. Pegs were fixed at an interval of 5 m along and across the field slopes in a staggered fashion in the terraced paddy fields, with the provision of a semi-mechanical runoff disposal device, *Eulaliopsis binata* plantations, and with the terraced fields under farmers' practices having earthen bunds. The combined technology package was proven to be viable with 10.6% runoff and $1.45 t ha^{-1}$ soil loss, against that of the farmers' practice of earthen riser bunds, which resulted in 32% runoff and $18.3 t ha^{-1}$ soil loss (Table V). A significant difference was observed between the sediment loss with the proposed technology and that of the farmers' practice, at a 5% probability level. This system helped save 45 man-days $ha^{-1} yr^{-1}$ towards maintenance of the farmers' earthen bunds. Sediment deposit patterns were monitored at a level of 2.1 cm ($210 m^3 ha^{-1}$) and 3.0 cm ($300 m^3 ha^{-1}$), respectively (Table V), which found a significant difference at a 5% probability level when analysed through paired *t*-tests.

HYV paddy in terraced lowlands fortified with Gliricidia sepium *leaves*

Average biomass yield of *Gliricidia sepium* hedges was found to be $12\,438 kg ha^{-1}$ at the end of the third year. Better paddy yield from *Gliricidia sepium*-applied fields convinced

Table VI. Yield and yield attributes in the terraced lowlands

Variety	Biomass ($g m^{-2}$)	Test weight (g)	Grain yield ($q ha^{-1}$)	Straw yield ($q ha^{-1}$)	Harvest index (%)
Hybrid 6444	537.2	83.0	51.5	54.0	48.8
Hybrid 6111	622.6	80.8	48.5	51.0	48.7
HYV (Durga)	521.2	74.3	26.0	31.0	45.6
HYV (Puja)	422.3	79.5	32.5	33.0	49.6
HYV (Lalat)	530.4	81.4	42.0	45.0	48.3
HYV (Khandagiri)	379.7	77.8	21.0	22.0	48.8
Local	445.7	77.5	17.5	26.0	40.2
Average	494.2	79.2	34.1	37.4	47.1

Table VII. Cost involved for the proposed interventions and revenue generated

Details	Cost (Rs ha^{-1})
A. Cost involved	
Capital cost of semi-mechanical devices (8 nos.)	
@ Rs. 1375.00 per no.	11 000.00 (US$75)
Diversion channel 400m @ Rs. 17.55 per running metre (rm)	7 020.00 (US$176)
Eulaliopsis binata plantation @Rs. 4.00 per rm, 1000 rm ha^{-1}	4 000.00 (US$100)
Gliricidia sepium planting @Rs. 3.00 per rm, 320 rm ha^{-1} 960.00 (US$24)	
Cost of inputs	200.00 (US$380)
B. Revenue generated	
Revenue from farm outputs	53 400.00 (US$1335)
Man-days saved (45 nos.) for maintenance of bunds 3 150.00 (US$79)	

tribal farmers of the merits of using *Gliricidia sepium* as a source of nutrients (1t of dry *Gliricidia sepium* leaves was found to be equivalent to 27kg of nitrogen). This periphery plantation of *Gliricidia sepium* hedges also helped stabilize the terraced bed banks. Similar results from *Gliricidia sepium* were also obtained elsewhere. While studying in an area of 20–30% slope in the Philippines, contour hedge row systems of *Gliricidia sepium*, a native pasture grass (*Paspalum conjugatum*) and a productive fodder grass (*Penisetum purpureum*) in oxisols (Ferralsols), Agus *et al.* (1999) reported availability of 20kgha^{-1} each of P and K and 60kgha^{-1} of N while growing cereal crops like rice and corn (*Zea mays* L.).

Hybrid paddy (*Pro–agro-6444*) and HYV paddy variety (Lalat) yielded accumulation of more biomass. With respect to test weight, the Lalat cultivar registered the maximum weight. Even though *Pro–agro-6444* hybrid paddy outperformed it in respect of grain yield and straw yield, the HYV Lalat variety, which is found to be easily available in the nearby seed depots, was accepted by the tribal farmers (Annual Report, 2005–2006). The Lalat variety showed a promising yield of 42 q ha^{-1} with a harvest index of 48.3% (Table VI).

Diversion channel for irrigating medium-sloping lands

In order to make lowland water available in the adjacent medium-sloping lands, provision of a diversion channel was made in order to divert perennial stream water. Based on the temporal availability of runoff water, diversion channels of ½ km length of $1.0 \times 0.5 \times 0.5$m (top width × depth × base width) with a side slope of ½: 1 (H: V) were constructed in WS-1 (laid on both sides of the lowland terraced beds) and stream water was diverted from the upper reach (Central Soil & Water Conservation Research and Training Institute, 2006–2007). By irrigating an area of 5 ha in the medium-sloping lands it was found feasible to grow a number of remunerative and easy marketable vegetables during the post-monsoon season. The preferred vegetables were cabbage (*Brassica oleracea capitata*), cauliflower (*Brassica oleracea botrytis*), beans (*Phaseolus vulgaris*), tomato (*Lycopersicon lycopersicum*) and brinjal (*Solanum melongena*). Excluding the cost of growing the vegetables, a net profit of approx. Rs. 20 000.00 (US$500) ha^{-1} was gained by the tribal farmers through introduction of this system.

Table VIII. Economics of the proposed intervention in terraced lowland and medium-sloping land

Indicators	Farmers' practices	Proposed technology packages
BCR	1:1	2.6:1
NPV (at 15% discount rate)	0	116 000.00 (US$2900)

Economics of the proposed system

The proposed integrated technique for managing the lowlands and the adjacent medium lands established a benefit cost ratio (BCR) of 2.6: 1 and net present value (NPV) at a 15% discount rate of Rs. 116 000.00 (US$2900) (Tables VII and VIII).

CONCLUSION

Tribal farmers in the Eastern Ghat region of India are poor, with a lack of scientific know-how in agriculture. Thus, implementation of high-cost agricultural packages will not be sustainable in the long run. Therefore, a friendly, location-specific and easy to adopt technology package for farmers, like a semi-mechanical runoff disposal system along with *Eulaliopsis binata* plantations on the paddy field riser bunds, introduction of HYV paddy (with *Gliricidia sepium* as a source of easily available nutrients) and the provision of diversion channels for growing vegetables in medium-sloping lands were found to be a promising technology package. Being a low-cost approach, the package was found to be acceptable by the tribal farming community. Even if only 20% of the land in the Eastern Ghat region constitutes terraced lowland and medium-sloping land, there is tremendous scope for increasing crop production through adoption of this resource conservation option.

ACKNOWLEDGEMENTS

The authors are grateful to Dr V. N. Sharda, Director, CSWCRTI, Dehradun (India), for his constant support and encouragement with conducting this research as an Institute project. The authors also wish to thank S/Sh. A. Dass, Scientist SS (Agronomy) and S. Kindal, T-2 (draughtsman) for their continued help with carrying out the research work.

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