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Evaluation of bamboo based conservation measures for rehabilitation of degraded Yamuna ravines

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ABSTRACT

This vast tract of existing ravine lands in northwestern part of India poses potential threat to nearby productive lands due to over exploitation and mismanagement. There is an urgent need to manage these problematic lands and protect both the arable and non-arable land from further degradation. Keeping this in view, an experiment was undertaken to evaluate bamboo (*Dendrocalamus strictus)* based resource conservation techniques in the Yamuna ravines at Central Soil and Water Conservation Research and Training Institute, Research Centre at Agra (U.P). Four small micro watersheds were selected and four treatments *viz*., plantation of rows of bamboo in the upstream and downstream side of small earthen gully plugs (T_1), plantation of bamboo in staggered manner in the gully bed with trenches (T_2), two rows of bamboo planted in staggered manner as vegetative barrier (T_3) and control catchment having no intervention (T_4) were imposed in 2009 and gauging structures were constructed in all four watersheds. Among the four treatments, T-2 recorded highest growth in terms of average culm height (126.20 cm), average culm diameter (7.56 mm) and crown size (72.86 cm) were recorded in T_2 followed by T_1 than others. The soil physical and chemical properties were also considerably influenced by bamboo plants under treatment imposed lands. The soils under bamboo improved in terms of decreased pH and enhanced soil organic carbon. No soil loss and run off were observed in T_1 and T_2 after imposition of treatments as compared to average runoff (6.04 and 35.83 mm), average soil loss (0.66 and 4.40 t ha^{-1}) and average silt deposition (0.348 and 0.410 t ha^{-1}yr^{-1}) recorded in T_3 and control, respectively. In ravine lands, Bamboo acts as good soil binder owing to its dry hardy nature, peculiar dense clump formation and extensive interlocking fibrous root system, natural capacity to regenerate through its rhizomes which play important role in preventing erosion, water holding capacity and nutrient cycling under gully beds.

1. INTRODUCTION

Ravine lands are highly degraded dry lands and 3.97 million ha area is affected due to ravines in India. In Uttar Pradesh alone, 1.23m (14.5%) of land is under ravines which are mainly found along the banks of river Yamuna and its tributaries. The severity of water erosion is found at the peak along the banks of Yamuna and Chambal Rivers in the districts of Agra, Etawah, Kanpur and Fetehpur *etc*. where terrain has completely deformed into ravines. Rao *et al*. (2013) reported that stream bank erosion is a major cause of land degradation, leading to deteriorated drainage systems, which ultimately governs natural calamities in terms of floods, and non point source pollution in ravine lands of India. The problem of subsoil hardness is affecting physical and hydrological properties of the soil. High bulk density and low infiltration rate of these soils lead to low yields and water use efficiency of crops. Ravine lands of India have fluvial systems which are more sensitive to rainfall and important indicator of climate change. They respond to the variability in precipitation by alternating their plan form, channel geometry and sedimentation pattern which in turn influence floods and associated landscape evolutions (Rao *et al.,* 2013). Vegetation in these ravine regions suffers from a variety of unfavorable condition such as nutrient deficiency, moisture stress and biotic interference. The inclement weather conditions coupled with very high summer temperature further aggravate the problem and makes farming uneconomical. In such situations, less water and nutrient demanding technologies hold a good promise to sustain the productivity and provide alternative source of income to the farmers. This vast tract of existing ravine lands is poses potential threat to nearby productive lands because of over exploitation and poor management. Therefore, there is an urgent need to arrest degradation of these lands and protect both the arable and non-arable lands from further degradation. Since rain is a major source of water in the region, every drop of it must be conserved in the soil through *in situ* rainwater conservation.

Impacts of bamboo planting include raised groundwater level, increased land productivity, improved micro-climate and improved socio-economic conditions. It is also seen that bamboo based agroforestry models improve ecological parameters of a highly degraded basaltic tract of Jabalpur, Madhya Pradesh (Behari *et al* 2000). Similarly, Bahadur *et al*.(1980) reported that improved farm practices and land treatment by bamboo, grasses and legumes on bunds, sloppy lands and terraced lands have been found to be effective means of soil and water conservation. Rambabu *et al.* (1978) observed 40% reduction in peak rate of runoff on account of field bunding alone in agriculture lands of Doon valley watersheds. Plantation of *D.strictus* was quite successful in increasing the economic productivity of gullied beds. About 4000-5000 mature culms/ha^{-1} were harvested every year from the bamboo plantations on the gully beds (Anon., 2007). Several scholars (Lawler, 1993; Simon & Collison, 2002; Nath & Krishnamurthy, 2008, Kurothe *et al.,* 2012, Rao *et al.,* 2012a) have clearly established the importance of bamboo plant as effective means of resource conservation. In comparison to deciduous and coniferous plantations, bamboo plants, are hydrologically best suited plantation in degraded ravine lands (Rao *et al.,* 2012b). Pande *et al.* (2012) worked out the economics of bamboo plantation in ravines and suggested policy measures to development and finance institutions for large greening of ravines in the country. It is also seen that bamboo based agroforestry models improve ecological parameters of a highly degraded basaltic tract of Jabalpur, Madhya Pradesh (Behari *et al.* 2000). About 16 species were tried to identify species that could grow better on marginal soil. After a series of trials, it was found that the hardy *Dendracalamus strictus* and *Bambusa bambos* worked best and these were the two species that were initially given to the farmers to rehabilitate their land. *Dendraclamus strictus* is a deciduous densely tufted bamboo. This species occupies 53% of total bamboo area in India and predominant species of bamboo in Uttar Pradesh, Madhya Pradesh, Orissa, Eastern and Western Ghats regions. In India, it is widely distributed in semi arid and dry zone along plains and hilly tracts usually up to an altitude of 1000 m. It is widely adaptable to temperatures as low as 5ºC and as high as 45ºC. It is found suitable for reclamation of ravine land. It is used for construction, furniture, as well as raw material in paper mills and cottage industries. Improving vegetative cover in degraded land is of prime importance for control of erosion, reducing run-off, improving *in-situ* soil-moisture conservation, increasing water-table and improving productivity as well as profitability. Situation specific cost-effective viable technologies and dissemination of suitable technologies for reclamation and productive utilization of ravine lands in India are highly essential for arresting ravine extension, reclamation and improving production ravinous regions. This moisture conservation technique is substantially quite effective in recharging subsoil moisture through effect of vegetation which helps increase infiltration, reducing runoff volume and soil loss. Hence an investigation was carried out at Central Soil and Water Conservation Research and Training Institute, Research Centre, Agra, on hydrologic and economic evaluation of bamboo plantations in gullied lands under major ravine systems. This paper presents some salient findings of the experimental studies on bamboo plants with moisture conservation techniques in Yamuna ravines.

2. MATERIALS AND METHODS

The experiments were conducted at CSWCRTI, Research Centre, Agra, located at $23^{0}52'$ to $31^{0}28'$ N latitudes and 77^{0} 06' to 84^{0} 37' E longitudes and 168 m above mean sea level. The climate of the ravinous part of the state is tropical, continental and monsoonal with mild and dry winter and hot summer. During summer hot winds (Loo) blow from the west. At the study location, May is the hottest month with mean maximum temperature of 41^{0}C and January is the coldest month with mean minimum temperature ranges from 6.5^{0} to 10^{0}C. Relative humidity is least (21-27%) during summer, thus, making the summer dry and hot. It is high during June to September (70-85%) while it remains between 50-70% during the remaining parts of the year. Ravine lands typically fall under "Northern tropical thorn forest" according to Champion and Seth (1968) classification of forest types of India. The predominant vegetation comprises of Vilayati Babul (*Prosopis juliflora*) followed by Babul (*Acacia nilotica*) thorny legumes, Euphorbias and dwarf grass species. There are occasional occurrence of Neem plants (*Azadirachta indica*), Papdi (*Holoptela integrifolia*), Shisham (*Dalbergia sissoo*), Karanj (*Pongamia glabra*) and Chonkra (*Prosopis cineraria)*. For this study, four small micro watersheds of 3 to 6 ha size were selected and four treatments *viz*., plantation of closed spacing (2.0 m x 2.0 m) bamboo (*Dendrocalmus strictus*) in the upstream and downstream sides of small earthen gully plugs of cross section 1.05 sq m having top width 0.5 m, bottom width 2.10 m, height 0.80 m having side slope 1:1 (T_1), plantation of bamboo with staggered contour trenches in the gully bed of size 2 m length, 0.3 m width and 0.3 m depth (T_2), two rows of bamboo planted in staggered manner as vegetative barrier (T_3) and control catchment having no interventions (T_4). The selected gully beds were cleared of all vegetation except grasses. The average soil properties of experimental site were pH 8.3, Ec 0.24 dS/m, OC 0.65%, Available N 280 kg ha^{-1}, Available P 7.8 kg ha^{-1}, Available K 550 kg ha^{-1}. Each treated micro watershed was gauged separately using HS flume with automatic stage level recorders to measure runoff and soil loss. Runoff from each treated micro watershed was measured by HS flume gauging structure constructed at the outlet and sediment samples were collected manually to determine the soil loss. The plant growth parameters such as average culm height (cm), average culm diameter (mm), crown size (cm) and number of culms/clump were also recorded in all treated micro watersheds. The experiments were conducted during 2008-2011.

3. RESULTS AND DISCUSSION

Effect on Runoff and Soil Loss

The Runoff and soil loss behaviour of different treatments are presented in Table 1. It is evident that no runoff and soil loss were recorded in T_1 and T_2 treatments imposed catchments compare to T_4 (control). The higher soil loss was observed in T_4 followed by T_3. It was observed that the soil loss in 2010 is slightly higher than that of previous year in control due to a greater number of high intensity storms. Findings from other authors are also concomitant with this present study. Due to influence of vegetation on soil which increased permeability of the soil reduced surface run-off, evaporation loss, allowed better water penetration into the soil and increased drainage capacity of the soil. Sharma *et al.* (1992) have also reported that bamboo conserves soil moisture and mitigates the adverse drought effects on flora and fauna.

Soil loss decreased considerably and it has brought change in moisture and silt retention owing to the growth of a dense vegetative cover in upstream and downstream of the gully beds. The roots of Bamboo (*D.strictus*) plant play effective role to protect soil conservation structures like bunds and side slopes of gully beds. Similar study reported by Sharda *et al.* (1982) on the effect of contour trenching on runoff and soil loss in 0.2 ha watershed at Agra, was investigated. With a view to conserve 100% runoff, 346 trenches (average length 2.35 m) were dug in the watershed and planted with *Cenchrus ciliaris*. The runoff was brought down by contour trenching from 25% to almost nil. In the same way soil loss was also reduced. Further, the staggered contour trenches of variable length were effective in intercepting the incident rainfall, increasing phytomass production and in preventing gully head extension. The results of this treatment have been found quite promising in biomass productivity and enhancing the *in situ* moisture use efficiency. Through this finding, we could reclaim major ravine land ecosystem using *Dendrocalamus strictus* along with recommended moisture conservation measures. *D.strictus* has been identified for protective and productive use in ravine lands and this is a potential species for efficient resource utilization in non arable lands, livelihood support systems *etc*. This technology is applicable to light textured well drained soils including reclaimed ravine land where moisture and nutrient resources are scarce. The technology can suitably be adopted on the cultivable wastelands distributed in the north-western of India and in other areas having similar agro-climatic and soil conditions.

Table: 1
Runoff and soil loss under different treatments

Treatments	Year	Rainfall (mm)	Runoff (mm)	Average soil loss (t ha^{-1})
Plantation in the u/s and d/s side of small earthen gully plugs (T_1)	2008	342.2	0	0
	2009	265.6	0	0
	2010	456.0	0	0
	2011	226.2	0	0
Staggered plantation in the gully bed with trenches (T_2)	2008	342.2	0	0
	2009	265.6	0	0
	2010	456.0	12.27	0.77
	2011	226.2	0	0
Double row planting in staggered manner (T_3)	2008	342.2	0	0
	2009	265.6	0	0
	2010	456.0	44.0	4.27
	2011	226.2	6.04	0.66
No intervention (T_4)	2008	342.2	3.23	2.89
	2009	265.6	2.18	2.56
	2010	456.0	85.02	4.93

*Rainfall during runoff producing events has only been considered

Effect on Growth Performance

The growth performances of bamboo plants under different treatments are presented in Table 2. Among the treatments, T_1 (plantation of rows of bamboo in the upstream and downstream side of small earthen gully plugs) recorded significantly higher culm height (126.20 cm), culm diameter (7.56 mm), crown size (72.86 cm) and maximum of 12 culms/clump in comparison to other treatments. The superior performance of bamboo plants in T_1 was due to high *in situ* moisture availability in subsoil. The better *in situ* rain water harvesting and moisture conservation techniques might have helped the bamboo plants in sustaining its growth during hot and drought period. The results of the present study are in agreement with the findings of Srivastava (1975), who reported that soil working has an important component on plant establishment, moisture conservation and consequently on plant growth. At Agra, staggered contour trenches of 3 m x 45 cm x 45 cm spaced at 3 m apart with 5 m spacing between the rows were found to be the best for raising *Aacia arabica* by direct sowings and it is recommended for afforestation of Yamuna ravines. Yadav (1963) reported that higher level soil moisture content and soil accretion remained under bamboo (*D.strictus*) plantation than other species such as Sal, Teak and Chirpine. Similar findings were also reported by Mathur (1976) that the studies on the effect of land use such as natural fallow (grasses and shrubs) and grasses alone gave the least and negligible runoff from alluvial soils of semi arid regions.

Effect on Soil Properties

The data presented in Table 3 reveal that there was no significant difference observed in soil pH. EC increased in bamboo plantation treatments, however, the treatment effects were not significant in case of OC though it increased from average value of 0.65 to 0.86%. In case of soil fertility status, available N reduced drastically in three years duration, however available P increased in comparison to initial data. No visible difference in case of available K was recorded. Though it is known fact that plantation of bamboo increase the overall soil health in long term, in this case it will take minimum 6 to 7 years to establish relationship between soil health and growth of bamboo plantation under different treatments.

4. CONCLUSIONS

It has been concluded that planting of *Dendrocalamus strictus* with suitable moisture conservation practice proved as a viable alternative on ravine lands for gully

Table: 2
Comparative growth performances of bamboo plants under different treatments

Treatments	Av. Culm Height (cm)			Av. Culm Diameter (mm)			Av. Crown Size (cm)			No. of Culms /Clump		
	2010	2011	2012	2010	2011	2012	2010	2011	2012	2010	2011	2012
Plantation in the u/s and d/s side of small earthen gully plugs (T_1)	54.08	116.20	126.20	2.76	5.92	7.56	32.12	63.20	72.86	3.93	7.81	12.00
Staggered plantation in the gully bed with trenches (T_2)	66.24	99.45	108.75	3.25	5.60	7.96	36.72	57.93	66.82	2.65	5.77	9.67
Double row planting in staggered manner (T_3)	58.72	90.19	99.20	3.10	4.80	6.20	31.40	44.20	49.11	2.12	4.16	6.33
No intervention (T_4)	0	0	0	0	0	0	0	0	0	0	0	0

Table: 3
Effect of plantation methods on physio-chemical properties of soil

Treatments	pH		EC ($dS\,m^{-1}$)		Organic carbon (%)		Available N ($kg\,ha^{-1}$)		Available P ($kg\,ha^{-1}$)		Available K ($kg\,ha^{-1}$)	
	Initial	After 3 years	Initial	After 3 years	Initial	After 3 years	Initial	After 3 years	Initial	After 3 years	Initial	After 3 years
Plantation in the u/s and d/s side of small earthen gully plugs (T_1)	8.30	8.39	0.22	0.77	0.65	0.82	321	163	6.49	12.77	510	482
Staggered plantation in the gully bed with trenches (T_2)	8.32	8.55	0.22	0.77	0.70	0.86	301	213	8.51	10.75	551	448
Double row planting in staggered manner (T_3)	8.67	8.60	0.26	0.75	0.62	0.84	280	151	8.74	12.10	591	448
No intervention (T_4)	8.22	8.17	0.24	0.21	0.65	0.55	240	125	7.84	7.62	658	706

beds stabilization, control sloping land erosion through good soil binding effect and fast growing vegetative cover. The reduction of runoff volume, soil loss and established vegetative cover is effective in mitigating the ravine land extension, restoration of degraded lands and provide multiple benefits to local people through employment and income generation.This result proved that *D.strictus* is an ideal tropical hardy bamboo species for massive rehabilitation of degraded ravine lands. Therefore, the use of bamboo in watershed management, soil and water conservation, rehabilitation of degraded land could be possible and bamboo farming and material processing are well suited to this region due to twin concerns of livelihood enhancement and environmental protection-the key components for developing these resource poor lands. Hence, an effective organized massive cultivation of this species through community participation could be helpful to increase the green cover and establish industries that provide sustainable livelihood development to the local community.

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