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Effectiveness of bioengineering methods of water erosion control in Tarka Valley Versant, Niger Republic

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ABSTRACT
Erosion problem is recognized as a serious threat to human beings, forestry and agricultural activities in the rural areas of Niger Republic. The effectiveness of three Bio-engineering methods of water erosion control in the degraded land of two villages in Bouza local government area, of the Niger Republic was assessed. These two villages are highly susceptible to water erosion. The three methods of erosion control used were wall of stone, Trench and Demi-Lune. Trees and herbaceous plants were then introduced to the reclaimed land to green up the environment. After regeneration, data collected include rate of soil cover by herbaceous vegetation, inventory of woody and herbaceous vegetation, stand density and the survival rate of planted trees. Results showed high biomass production and great density of herbaceous species of different families with the highest species frequency being Gramineae. The total biomass production for the two sites was estimated at about 413.15 and 461.12 tons for Babarangua and Kougouptache respectively. Statistical analysis showed that the site has no significant influence on biomass production while the technique adopted exhibit significant influence on production at the same level of probability. The wall of stone technique gave the best result in herbaceous production while the trench and Demi-lune technique ensure good rate of tree survival for the planted trees. The three methods were effective in erosion control in the two sites.

Key words: *Bioengineering, water erosion control, Tarka Valley, Babarangua and Kougouptache communities*

INTRODUCTION

A very large scale of water erosion control techniques exist and their use depends largely on the type of soil, the degree of erosion, the slope and climatic conditions. The general classification of the erosion control technique has be broadly grouped under two categories which are biological and mechanical (engineering) methods. The preferred method is usually the biological method because of its flexibility, adaptability and cheapness. The planting of a combination of trees, shrubs and grasses for the purpose of erosion control had been effectively used to control surface-run off thereby reducing soil losses (Allen and Leech 1997, Stiles 1988, Lewis 2000 and Yang et al 2002). The environmental beneficial effect of protection of the soil surface area with adequate vegetation cover has been research into and the findings are documented in the work of Wang *et al* (1998). The presence of vegetation improves soil physical and chemical properties and therefore increases it resistance to erosion. Tree and vegetation maintain and improve soil status.

Many other ecological benefits resulting from keeping a soil under vegetation have been detailed in the work of Allen and Leech (1999) and Sterk (2002). In some situation, the use of vegetation alone through direct planting may not be an immediate solution in water erosion control. It needs to be supplemented by mechanical techniques of water and soil conservation and this technique of checking erosion and water runoff is called bioengineering. Bioengineering is the combination of biological, mechanical and ecological concept to control, and stabilize soil through the sole use of vegetation or in combination of non living materials (Mannering 1981, Stocking 1986, Hudson 1991, Li and Eddleman 2002). In Niger Republic, techniques such as wall stone, trench and Demi-lune have been developed in the various erosion control projects (Keita project, Bada guichin project and soil plannification project etc.) to solve sheet and reel erosion problems (SAE 1999). However the impact and effectiveness of such projects using the aforementioned techniques have not been quantified and qualified. This study is therefore carried out to assess the effectiveness of these three bio-engineering erosion control methods in Tarka Varsant Valley of Niger Republic.

Material and Methods

Study Site:

Tarka Valley lies between Damergou in Zinder State in the Southern zone of Niger Republic and Goulbi of Sokoto State in Nigeria. The Valley and its tributary cover an area of about 2800km^2. Tarka Valley climate is south Sahelian type with long dry season of seven months (November-May) and raining season of less than five months (June-October) the mean annual rainfall of over 30 years was 413mm and the peak of rain in the year is July. The sunshine is estimated at 3000hours/year (SAE 1999).

Three geomorphologic areas constitute Tarka Valley which is the Plateau, the varsant and the lower valley and five different types of soil, identified are Fadama, Gandari, Baringo, Dabagi and Jigawa. The total land area covered by erosion control project was 342.2km in Kongoupthe. Wall of stone was used to treat the upper versant while trench and demi-dune were used on lower versant. The resource assessment was carried out five years after the treatment for erosion control of the selected areas.

Data Collection

Before actual data collection, a reconnaissance survey was carried out to obtain information about the prevailing environmental conditions in the two sites. This was to assist in taking adequate decision on the type of sampling procedure and the equipment required for the study.

With sampling intensity on vegetation cover of 10 percent. Data were collected on following parameter, the rate of soil cover by herbaceous vegetation, the list of woody and herbaceous vegetation, stand density and the survival rate of the trees planter. Data on herbaceous biomass production were collected in accordance with SAE (1999) recommendation procedure for sahelian regions of plot size 0.25ha (50m X 50m).

Data analysis

Data collected were analyzed using a combination of simple percentages, students T-test and analyses of variance (*ANOVA*). Where there are significant differences Fischer's least significance difference (LSD) was employed for post mortem analyses.

Results and Discussions

The results on herbaceous biomass production for the two sites are presented on Table 1. The analysis of variance result is presented on Table 2 while the LSD result is presented on Table 3. The total biomass production of herbaceous vegetation for the two sites was estimated at about 413.15tons and 461.12tons for Babarangua and Kougouptche respectively. This production varies depending on the techniques. In the two sites, the biomass production is higher in wall of stone than Demi-lune, while demi-lune also produces more biomass than trench.

The result of statistical analysis carried out to compare the three techniques in the two sites as presented on Table 2 showed that the effect of the site in biomass production was not significant when tested at 5% level of significance. This shows that the site has significant effect on the volume of biomass production in the two sites. On the other hand, the technique exhibited significant differences at the same level of probability. Post mortem analysis carried out as revealed on Table 3 shows that the wall of stone gave the best result.

Table 1: Herbaceous Vegetation Biomass production for the Two Sites

Technique	Babarangua			Kougouptache		
	Wall of stone	Trench	Demi-lune	Wall of stone	Trench	Demi-lune
Production (ton/ha)	2.281	0.887	1.014	2.016	0.819	0.973
Total production (ton)	247.75	103.38	62.02	270.22	98.8	92.1
Percentage	60%	25%	15%	59%	21%	20%
Total site production (ton)	413.15			461.12		

Table 2: Anova Result for the Treatment and Site on Biomass Production

SV	DF	SS	SS	F	P. Level
Site	1	0.023313	0.023313	3.1183	0.21946
Techniques (treatment)	2	2.02139	1.010695*	135.1889*	0.007343*
Error	2	0.014952	0.007476		
Total	5				

*Significant at $p<0.05$

Table 3: LSD Result

Technique	Wall of stone	Trench	Demi-lune
Wall of stone		0.004425*	0.005558*
Trench	0.004425*		0.245676
Demi-lune	0.005558*	0.245676	

*Significant at $p<0.05$

Table 4 shows the different herbaceous species on the two sites and their frequency of apparition and ecological preference. The Table revealed a great dominance of *Gramineae* with *Cyboyogon schoenanthus* having the highest frequency of 44 followed by *Cenchrus biflorus* and *Pennisetum pecticellatum* with frequencies of 31 and 29 respectively. The rate of soil cover by herbaceous vegetation as reported in Table 5 showed a highest value of 68.57% for Babarangua and 52.50% for Kougouptache sites in wall of stone as against the least 42.50% and 31.66% recorded in Trench for the two sites respectively. Statistical analysis carried out to compare the three techniques in the two sites as presented in Table 6 showed that site effect on rate of soil cover by herbaceous vegetation was not significant when tested at 5% level of significant. On the other hand, the techniques exhibited significant difference at the same level of probability. Post mortem analysis carried out compare difference among the mean of the three techniques showed that, the wall of stone gave the best result as shown on Table 7.

Table 4: List of Herbaceous Species identified in the Two Sites

Species	Family	Frequ %	Site Bab	Koug	Ecology TV-LV
Cyboyogon schoenantus	Poaceae	44	+	+	TV-LV
Andropogon gayanus	Graminnae	13	+	+	TV-LV
Cenchrus biflorus	"	31	+	+	TV-LV
Pennisetum pecticellatum	"	29	+	+	TV-LV
Schenefeldia gracilis	"	13	+	+	TV-LV
Eragrotis pilosa	"	02	+	+	TV-LV
Aristida metabilis	"	08	+	+	TV-LV
Brachiar distiphylla	"	01	+	-	TV-LV
Tetrapogon cenchriformis	"	02	+	+	TV-LV
Zormia glochidiata	Papilionodeae	02	+	+	TV-LV
Indigofera senegalensis	"	01	-	+	LV
Alysicarpus Ovalifolius	"	29	+	+	LV
Crotalaria podocarpa	"	02	+	+	TV-LV
Leptadenia hastate	Asdepiadaceae	01	+	+	LV
Cleome scaposa	Capparidaceae	01	-	+	TV
Geratotheca sesamoides	Peadaliaceae	01	-	+	TV
Leucas martinisensis	Lamiaceae	01	+	+	LV-TV
Amaranthus graecizans	Amaranthaceae	03	+	+	LV
Eragrotis tremula	Gramineae	01	+	+	LV
Physalis angulata	Solanaceae	01	-	+	LV
Sida cordifolia	--	05	+	+	LV

Note: Koug. = Kougouptache Bab. = Babarangua
TV = Top Versant LV = Lower Versant

Table 5: Percentage of Soil Cover by Herbaceous Vegetation.

Site	Wall of stone	Trench	Demi-lune
Babarangua	68.57%	42.5%	46%
Kougouptache	52.5%	31.66%	40%

Table 6: ANOVA on rate of soil cover by herbaceous vegetation after treatment

Source of variation	Df	SS	Ms	F	P. Level
Site	1	180.5114	180.5114	14.23372	0.63624
Techniques	2	595.1064	297.5532**	23.46273*	0.40579*
Error	2	25.3639	12.68195		
Total	5	800.9817	490.74655		

* Significant at p<0.05

Table 7: LDS test variables on the rate of soil cover by herbaceous vegetation

Technique	Wall of stone	Trench	Demi-lune
		37.08000	43.00000
Wall of stone	-	0.022285*	0.038857*
Trench	0.038857*	-	0.0238331
Demi-lune	0.038857*	0.238331	-

*Significant at p<0.05

Woody vegetation

The result of the stand density per site for the three bioengineering control methods is presented in table 8, while the analysis of variance result is presented in table 9. Survival rate of the planted trees is reported on table 10 and the result of the statistical analyses are presented on tables 11 and 12. Table 8 shows the mean density of naturally regenerated bole per block and per site. The highest number of 994 bole per hectare was recorded in the trench for Babarangua while the least of 394 boles per hectare was recorded in wall of stone for Kougouptache. Statistical analysis carried out to compare the three techniques in the two sites as reported in Table 9 showed that there is significant difference among the techniques in density of trees naturally regenerated at 5% level of significance. However, the difference was not significant between the two sites at the same level of probability.

From Table 10 it was discovered that the rate of survival of planted trees on each technique and the global rate of survival on each site is highest in trench with value of 72.80% for Babarangua site. The least value of 31.10% was however recorded in wall of stone at Kougouptache. Statistical analysis showed that site effect in tree survival was not significant at 5% level of significance. This observation is in line with the findings and reports of Allen and Leech 1997, Sharma 2000, Oumarou 2001, and Yang et al 2002. On the other hand, technique effect is significant at the same level of probability. Post mortem analysis carried out to compare the different among the three techniques using LSD showed that trench and demi-lune gave the best result.

Table 8: Density of naturally regenerated Trees per Treatment

Technique	Wall of stone (bole per ha)	Trench (bole per ha)	Demi-lune (bole per ha)	Global mean (bole per ha)
Babarangua	490	994	923	791
Kougouptache	394	759	584	572

Table 9: Anova on Density of Naturally Regenerated tree

Source of variance	Df	SS	MS	F	P. Level
Site	1	75264.00	75264.00	10.11001	0.86300
Techniques	2	199892.23	99946.16	13.42550	0.069322*
Error	2	14889	7444.500	-	-
Total	5	290045.32	182654.66		

*Significant at p<0.05

Table 10: Rate of survival of planted tree

Technique	Wall of stone (%)	Trench	Demi-lune (%)	Mean survival rate
Babarangua	43.30%	72.80%	63.00%	59.70%
Kougouptache	30.10%	60.09%	53.88%	47.83%

Table 11: Anova on Rate of Survival Plantation

Source of variance	D.F	SS	MS	F	P. Level
Site	1	113.7091	113.7091	10.23570	0.085372
Techniques	2	1198.3462	599.1731	53.93550*	0.018203*
Error	2	22.21814	11.10907		0
Total	5				

*Significant at p<0.05

Table 12: LSD for rate of Survival Plantation

Technique	Wall of stone	Trench	Demi-lune
	36.70000	70.90000	58.44000
Wall of stone	-	0.009365*	0.0022707*
Trench	0.009365	-	0.064689
Demi-lune	0.022707	0.06489	-

Table 13 shows that the woody species that has the highest survival rate on the two sites is *Acacia raddiana* with frequency of 58%. This is followed by *Combretum micrantum* and *Acacia senegalensis* which have frequencies of 39% and 31% respectively. The species with least survival rate of 4% was recorded in *Calotropis prolera*. Also low survival rate of 6% and 8% were equally recorded for *Acacia albida* and *Commiphora africana* respectively.

The total area treated through erosion control work was 642ha which represent 46.1% of the total versant in the two villages. For the bioengineering methods to have more impact in erosion prevention and control the treatment should be extended to the remaining versant land covering an area of about 755 hectares as shown in Table 14. The know-how acquired in erosion control work through the first phase of the project will be an advantage that can be utilized. The forest service should assist the future local organization to sensitize people for a free participation in protecting an environment from which depend for their basic need. From technical point of view, it is proposed that wall of stone should be combined with trend on the main versant because of the slope steepness.

Table 13: List and Frequency of Woody Species after Treatment

Species	Location	Frequency (%)
Acacia raddiana	TV + DV	58%
Combretum micrantum	TV + DV	39%
Boscia senegalensis	TV	21%
Leptadenia hastate	TV + DV	11%
Piliostigma reticulatum	T.V	15%
Combretum aculeatum	T.V	24%
Acacia nilotica	D.V	16%
Acacia senegal	D.V	31%
Commiphora africana	D.V	8%
Calotropis prolera	D.V	4%
Ziziphus manritiana	TV	16%
Acacia albida	D.V	6%
Prosopis juliflora	TV + DV	11%
Guera senegalensis	D.V	24%
Other species	TV + DW	

TV = Top Versant, DV = Down Versant
"other species" include combretum glutinon Hyphaene thebaica, Acacia laeta, and Parkinsonsa aculeate.

Table 14: Remaining Versant Land to be treated Through Erosion Control work and Techniques to be used

Village	Plateau (ha)	Main versant (ha)	Eroded glacis' (ha)	Total (ha)
Babarangua	O	228	113	431
Kougouptache	48.8	194	80.9	323.7
Total (ha)	138.8	193.9	193.9	754.7
%	18%	26%	26%	-
Technique	Wall of stone	Wall of stone + trench	Demi-lune	

Conclusion

Within the scope of this study, the three methods of bioengineering methods assessed are relatively effective in the reduction of rate of water erosion in the two sites. But due to the lower rate of survival of trees planted on wall of stone (43% for Babarangua and 30% for Kougouptche) compared to other two methods and considering the high density of naturally regenerated trees observed after treatment, trench and demi-lune basin should be give priority in the choice of bio-engineering methods to be adopted for erosion control for trees.

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