IMPROVED REHABILITATION STRATEGIES FOR HIGHLY VULNERABLE AND SEVERELY ERODED AREA IN TUBORAN, MAWAB, COMPOSTELA VALLEY, REGION XI

by

Lyrae A. Casidsid, Florita E. Siapno, Evangeline T. Castillo

Abstract

The study was conducted in a severely eroded area in Tuboran, Mawab, Compostela Valley to come up with a successfully rehabilitated damaged areas out of verified technologies and research information to serve as model for large-scale rehabilitation.

Three technologies were tested such as: coco mat technology with falcata (Paraseriantes falcataria), mahogany (Swietenia macrophylla), narra (Pterocarpus indicus), African Tulip (Spathodea campanulata) and interplanted with forage peanut as cover crop ; vegetative technology with falcata (Paraseriantes falcataria), mahogany (Swietenia macrophylla), narra (Pterocarpus indicus), African tulip (Spathodea campanulata) and interplanted with forage peanut as cover crop and control (without intervention).

Results of the study showed that after 2 1/2 years, coco mat technology had highly significantly increased the survival of mahogany (95%), narra (99%) and African tulip (95%) and significantly increased the survival of falcata (81%) compared with the vegetative technology.

Further, coco mat technology had highly significantly increased the height growth of narra and significantly increased the height growths of falcata and mahogany.

Moreover, coco mat technology had highly significantly increased the diameter growth of falcata and significantly increased the diameter growth of mahogany.

Further, coco coir technology had a very significantly lower erosion rate compared with the vegetative technology and the control.

However, coco mat technology incurred higher cost of Php578, 850.00 inclusive of plantation establishment and maintenance.
Among the rehabilitation technologies tested, coco coir technology was effective in the rehabilitation of degraded areas in Tuboran, Mawab, Compostela Valley condition.

Keywords: rehabilitation, soil erosion, coco mat technology, vegetative technology, run-off and catchment approach.

Introduction

Soil erosion and degradation are serious problems in the Philippines where an estimated 8.3 Mha out of 30 Mha total area are severely eroded. (EMB,1990 as cited by Lasco and Pulhin 2006.) According to Briones (2009) grassland area in Region XI had an average erosion rate at 127.2 million tons/year.

Hence, rehabilitation of degraded and severely eroded areas are the primary concern of the government and other environmentalists.

However, the use of scientifically-based strategies has often been neglected and is not well-documented especially in rehabilitation efforts of the government, mining companies and other organization.

In this study, improved rehabilitation strategies were employed through the modification of existing technologies like geotextiles or the coco mat technology.

Through small but meaningful scientific investigations, effective ecological strategies can be formulated /developed to significantly minimize the level of environmental damage.

Standard methodological procedures of best technologies shall be generated / developed from verified technologies so that they may be employed for the large-scale rehabilitation of damaged ecosystems.

General Objective:

The general objective of this study is to come up with successfully rehabilitated damaged areas out of verified technologies and research information. This could serve as a model for large-scale rehabilitation of degraded, marginal ecosystems (i.e. critical watersheds, mining, damaged sites.)

The following are the specific objectives:
1. To determine the survival, height and diameter growth of trees under two rehabilitation technologies.
2. To determine the cost of the rehabilitation technologies tested.

Review of Literature

Description of Falcata, Mahogany, Narra and African Tulip

Falcata (Paraseriantes falcataria) is a fast growing tree that can reach a height of 7 m in one year and 16 m in 3 years under favorable conditions. It was also reported that mean diameter of falcata grown in East Java ranges from 3.4 to 16.7 cm (Krisnawati, H. 2011). It can grow better on slightly alkaline soils but tolerates wide range of soils from dry and damp soils; even to saline and acid soils up to pH 4.5 as long as the drainage is sufficient. (Arche et al. as cited by Varis 2011)

Mahogany (Swietenia macrophylla) is a tall tree that can reach a height of 30-40 m and has a circumference of 3-4 meters.

Narra (Pterocarpus indicus) is a large tree with an irregular fluted trunk; the crown is wide, spreading with drooping branches. (RISE, 1995) It can also grow fast since it is a nitrogen-fixing tree. Narra had high survival rate of 81.90% in flat area and 81.45% at mountainous area (Combalicer, 2010) In optimum conditions, narra could have a height growth of 2 m/year. (Thomson, 2006)

African Tulip (Spathodea campanulata) is a medium-sized tree that can grow to a 20 meters-30 meters in height. It has a diameter growth rate of 5 cm/year (Francis, 1990)

Soil Erosion

In a study conducted by Lasco and Pulhin (2006), et al. a SALT farm in Bansalan, Davao del

Sur had a soil erosion of 3.4 tons/ha and a Non-SALT farm at 194.3 tons/ha.

In a study conducted by Bugayong and Carandang (undated) that mean sheet erosion in fallow areas was 15.40 tons/ha.

Rehabilitation Technologies

Coco mat Technology is the use of coco mats that are made from 100% natural biodegradable cocnut fiber and are naturally resistant to to rots and molds. They are excellent in controlling soil erosion by holding the soil in place and dispersing the force of heavy rains and run-off water. Coco mats provide good support while allowing natural vegetation to become established. It also promotes growth of new vegetation by absorbing water and preventing the topsoil from drying out. (Terrafix Geosynthetics Inc. website as cited by ERDB)

Vegetative Technology is the use of trees and other vegetation in the rehabilitation of eroded areas. Trees are planting directly to the site at regular intervals on the slope. As they grow, they create a dense network of roots in the soil. The main engineering functions are to reinforce and , later, to anchor. (ERDB, 2013)

There is a need to expand pilot testing and verification of rehabilitation technologies and put up pilot demo in other strategic places in vulnerable areas to erosion, landslips and land slide.

Materials and Methods

The materials used in this study were: Manual Rain Gauge, Soil Auger, Erosion Gadget, Measuring Tape and Digital Caliper, coco mats, tree seedlings, and forage peanut.

Location of the study

Location of the study is Barangay Tuboran which is 14 kilometers away from Tagum City and 6 kilometers from the municipality of Mawab. It is bounded by Barangay Malinawon in the north, Barangay Pandapan of Tagum in the south, Barangay Sawangan in the east and Barangay Salvacion in the west.

Site Characteristics

Barangay Tuboran is characterized by hilly and rolling areas. Its climate is favorable and Type II characteristics with no dry season and with no prominent maximum and minimum rainfall. Thus, some parts of this barangay are prone to erosions and landslides.

The site selected for this project was a severely eroded area with an average slope of 37% affecting the infrastructure of Tuboran Elementary School ,Tuboran,Mawab, Compostela Valley. The soil is heavy-textured with a depth that ranges from 55-85 cm, bulk density from 0.94 to 1.57 g/cu.cm., water holding capacity from 56.30 to 71.05 % . Further, the soil is sandy clay loam to loam.

The dominant vegetation of the site is cogon (Cylindrica imperata) with centrosema, African tulip and other grasses.

Establishment of plots

Random plots were prepared for this project for the testing of different rehabilitation technologies such as coco coir technology, vegetative technology and control plot.

Plot 1 - Applied with Coco mat technology

A plot that measures 4 m x 40 m was prepared for coco mat installation. Staking and hole digging at the area were also done with a distance of 1 m x 1 m. Then, forest trees such as falcata, narra, mahogany and African tulip were outplanted. These trees were selected based from the Compendium released by ERDB. Further, forage peanut was also interplanted as cover to provide immediate cover to the site to reduce surface run-off due to the impact of rain and wind.

Plot 2 - Vegetative technology

Vegetative technology was applied to a plot with a size of 4m x 40 m and was also prepared for outplanting of four forest tree species such as falcata, narra, mahogany and tulip and interplanted also with forage peanut as cover crop.

Plot 3 - Control plot

This plot which has a size of 4m x 40 m was also prepared; however, no interventions were applied.

Collection of data

Data collection was conducted from January 2012 to June 2014. Height, diameter, survival of test plants, ground cover and soil fertility status were assessed and monitored quarterly. Soil loss were monitored every after a heavy rainfall. While rainfall was monitored daily using a manual rain gauge.

Establishment of erosion plots

Surface run-off gadgets which measured 2m x 5m were installed within the experimental plots to assess the effectiveness of the improved rehabilitation technologies. Run-off plots and Catchment Approach was used to measure the erosion rate as shown, below.

One liter sample of run-off was taken from the collecting bins every after a rainfall event. These samples were then weighed, filtered and oven–dried at the laboratory.

Soil sampling and analysis

Six samples were collected per plot once every quarter and a composite sample at one kilogram each per plot were submitted to the Regional Soils Laboratory for analysis for its acidity/basicity(pH), Percent Organic Matter, Phosphorus and Potassium content .

Seeding production

Seedlings of the selected tree species were raised in the nursery for four months using a standard soil medium mixture of processed topsoil and carbonized rice hull potted in a 4 inches X 6 inches x 0.02 mm polyethylene potting bags. Each pot shall be filled first to about 1/3 of its volume and five grams of mycorrhiza will be added and spread evenly on the top layer. The remaining 2/3 space shall be covered with the soil medium. Cuttings of forage peanut shall also be collected and propagated in the nursery.

Maintenance of the study site

Study site were cleared from weeds. Weeding around each plant was conducted regularly at 30 cm radius.

Analysis of Data

Data were analyzed using T-test (2-tailed) for height increment, diameter increment, survival of test plants and soil loss of test plots.

Results and Discussion

Survival and growth performance of test plants

Mean Survival

Figure 1. Quarterly survival (%) of trees under two rehabilitation technologies

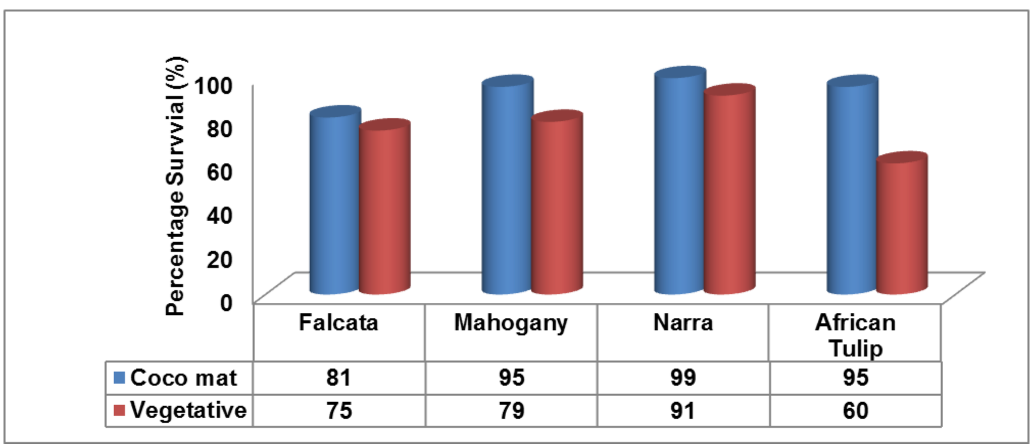

Table 1. Quarterly survival (%) of trees under two rehabilitation technologies

Species	Falcata	Mahogany	Narra	Tulip

Period	Coco mat	Vege-tative	Coco mat	Vege-tative	Coco mat	Vege-tative	Coco mat	Vege-tative
Q1	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Q2	100.00	100.00	100.00	100.00	100.00	93.00	100.00	100.00
Q3	100.00	100.00	100.00	93.00	100.00	93.00	100.00	67.00
Q4	73.00	87.00	93.00	80.00	98.00	93.00	93.00	47.00
Q5	73.00	60.00	93.00	73.00	98.00	93.00	93.00	47.00
Q6	73.00	60.00	93.00	73.00	98.00	87.00	93.00	47.00
Q7	73.00	60.00	93.00	73.00	98.00	87.00	93.00	47.00
Q8	73.00	60.00	93.00	67.00	98.00	87.00	93.00	47.00
Q9	73.00	60.00	93.00	67.00	98.00	87.00	93.00	47.00
Q10	73.00	60.00	93.00	67.00	98.00	87.00	93.00	47.00
Mean	**81**^{ns}	75	**95****	79	**99****	91	**95****	60
p-value	0.397		0.005		0.000		0.001	

Legend : **- highly/very significant; *-significant; ns-not significant

Results in Table 1 showed that survival of mahogany, narra and African tulip which were 95%, 99% and 95%, respectively in coco mat technology were significantly higher than their survival in vegetative technology with 75%, 79% and 60%, respectively with p value of 0.005 for mahogany, 0.000 for narra and 0.001 for African tulip. However, no significant difference was observed for falcata in both technologies.

It was also observed that although narra was attacked by a leaf miner in its early stage and caused perforations on its leaves, it still showed high survival. Clavejo, D.T. and E.D. de Guzman (1977), reported also that an unidentified leaf miner in Solomon Islands was the most serious insect pest that affected narra species.

The high significant results in terms of survival, height increment and diameter increment of test plants in coco mat technology could be attributed to the ability of the coco mat to hold the soil moisture and nutrients and served as mulch to the plants as it decays.

Mean Height increment

Figure2. Quarterly height increment (cm) of trees under two rehabilitation technologies

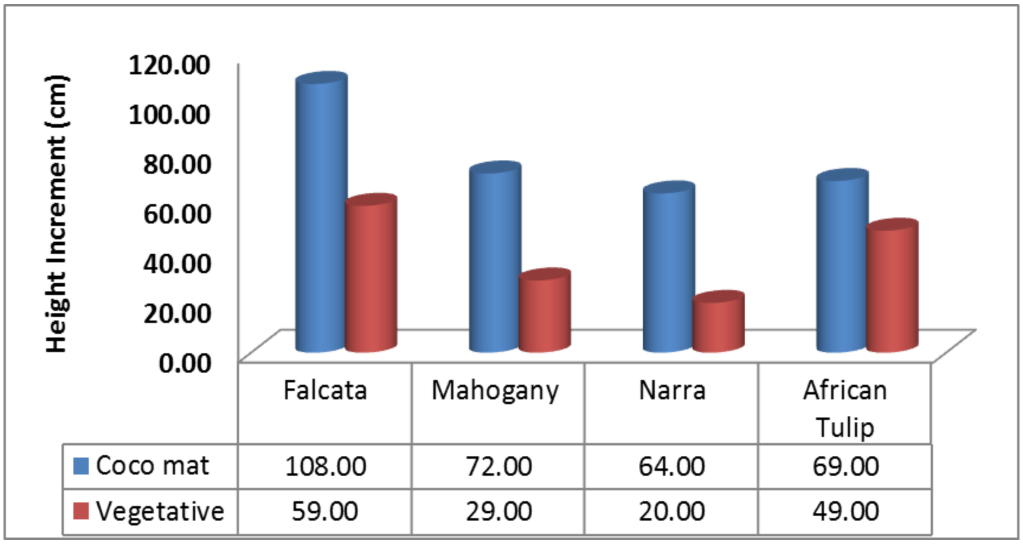

Table 2. Quarterly height increment (cm) of trees under two rehabilitation technologies

Species	Falcata		Mahogany		Narra		African Tulip	
Period	Coco mat	Vege-tative	Coco mat	Vege-tative	Coco mat	Vege-tative	Coco mat	Vege-tative
Q1	5.00	12.33	12.67	3.33	12.33	6.00	6.67	3.00
Q2	30.67	75.00	27.00	5.00	75.00	19.00	23.00	7.33
Q3	80.00	41.33	42.67	16.00	61.33	17.67	69.00	68.00
Q4	103.00	54.67	60.67	16.00	54.67	36.33	68.00	81.00
Q5	120.00	36.00	59.67	28.67	56.00	31.67	79.67	14.00
Q6	139.00	45.00	67.67	19.67	65.00	28.00	85.00	43.00
Q7	145.33	96.67	70.33	46.33	76.67	25.33	86.67	77.00
Q8	177.67	85.33	168.00	75.67	85.33	19.33	98.33	87.00
Q9	171.67	87.67	142.33	51.33	107.67	17.33	107.33	62.67
Total	972.33	534.00	651.00	262.00	594.00	200.67	623.67	443.00
Mean	**108***	59	**72***	29	**64****	20	**69ns**	49
p-value	0.043		0.035		0.000		0.221	

Legend: ** - highly/very significant, *-significant

Results in Table 2 showed that the mean height increment of narra (64 cm) in coco mat technology was very significantly higher compared with those planted at vegetative technology (20 cm) with p-value of 0.000. Results further showed that the height increment of falcata (108 cm) and mahogany (72 cm) under coco coir technology were significantly higher than those at vegetative technology with falcata at 59 cm and 29 cm for mahogany with p value of 0.043 and 0.035, respectively. However, no significant difference was observed for African tulip both technologies.

Mean Diameter Increment

Figure3. Quarterly diameter increment (cm) of trees under two rehabilitation technologies

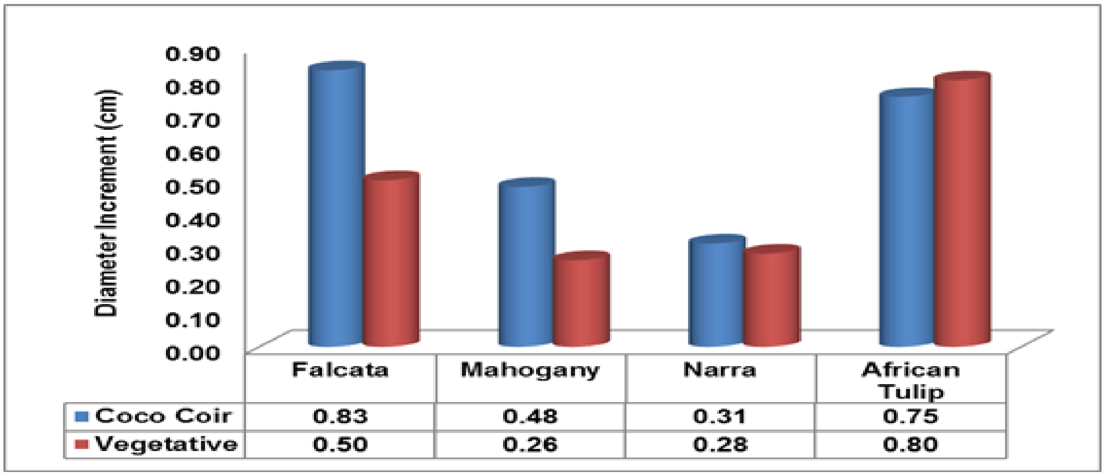

Table3. Quarterly diameter increment (cm) of trees under two rehabilitation technologies

Species	Falcata		Mahogany		Narra		African Tulip	
Period	**Coco mat**	**Vege tative**	**Coco mat**	**Vege-tative**	**Coco mat**	**Vege tative**	**Coco mat**	**Vege-tative**
Q1	0.26	0.16	0.27	0.12	0.24	0.22	0.22	0.39
Q2	0.74	0.37	0.23	0.11	0.28	0.27	0.69	0.54
Q3	1.04	0.68	0.61	0.21	0.27	0.25	1.25	1.15
Q4	0.62	0.43	0.45	0.34	0.25	0.21	0.65	0.84
Q5	0.97	0.72	0.34	0.15	0.28	0.27	0.87	1.13
Q6	0.97	0.72	0.34	0.15	0.28	0.26	0.87	1.13
Q7	1.00	0.38	0.73	0.35	0.31	0.27	0.70	0.80
Q8	1.00	0.38	0.73	0.35	0.32	0.28	0.70	0.80
Q9	0.91	0.66	0.61	0.54	0.57	0.46	0.79	0.42
Total	7.50	4.50	4.31	2.32	2.78	2.50	6.75	7.20
Mean	**0.83****	0.50	**0.48***	0.26	**0.31^{ns}**	0.28	**0.75^{ns}**	0.80
p-value	**0.007**		**0.015**		**0.417**		**0.709**	

Legend : **- highly/very significant; *-significant; ns-not significant

Results in Table 3 showed that the mean diameter increment of falcata (0.83 cm) in coco mat technology was very significantly higher compared to those in vegetative technology (0.50 cm) with p value of 0.007. Results also showed that mahogany (0.48 cm) in coco mat technology was significantly higher compared to those in vegetative technology. However, results also showed that narra (0.31 cm) and African tulip (0.75 cm) at coco mat technology had no significant difference with those at vegetative technology with 0.28 cm and 0.80 cm, respectively with p-value of 0.417 and 0.709, respectively.

Cost of Establishment

Table 4. Cost of establishment of the tested two technologies

Technology	Specification	Materials	Quantity	Unit Cost (Php)	Cost (Php)
Coco mat	1m x 20m dimension	coco mat	500	1000	500,000.00
	1m x 1m spacing	trees	10000	3	30,000.00
	0.5 x 0.5 spacing	forage peanut	40000	0.5	20,000.00
		abacca rope	100	5	500.00
	12 " length	bamboo pegs	1000	0.25	250.00
	1 m length	live post (kakawate)	100	1	100.00
			Sub-total		**550,850.00**
		Labor			
		Installation of coco mat			3,000.00
		establishment			5,000.00
		Maintenance & Protection (2.5 years @ P2,000/qtr)			20,000.00
			Sub-total		**28,000.00**
			Total		**578,850.00**
Technology	**Specification**	**Materials**	**Quantity**	**Unit Cost (Php)**	**Cost (Php)**
Vegetative	1m x 1m spacing	trees	10000	3	30,000.00
	0.5 x 0.5 spacing	forage peanut	40000	0.5	20,000.00
			Sub-total		**50,000.00**
		Labor			
		establishment			5,000.00
		Maintenance & Protection (2.5 years @ P2,000/qtr)			20,000.00
			Sub-total		**25,000.00**
			Total		**75,000.00**

Cost of establishment (Table 4) for coco mat technology was estimated at Php578,8500.00 per hectare at 1m x 1m spacing for trees and 0.5m x 0.5m for forage peanut as cover crop and Php75,000.00 for vegetative technology per hectare at 1m x 1m spacing for trees and 0.5m x 0.5m for forage peanut as cover crop. This was based on the activities undertaken, inclusive of cost of mycorrhizal-inoculated planting materials, transport (from nursery to planting site) and labor cost (nursery, site preparation, field planting).

Soil Erosion

Table 5. Mean Soil Erosion (tons/hectare/year) of test plots at year 1

Period_Tech	Cocomat	Control	Cocomat	Vegetative	Vegetative	Control
July_2012	0.484	1.359	0.484	1.095	1.095	1.359
Aug_2012	0.526	1.399	0.526	1.100	1.100	1.399
Sept_2012	0.537	1.416	0.537	1.099	1.099	1.416
Oct_2012	0.549	1.207	0.549	1.139	1.139	1.207
Nov_2012	0.239	0.823	0.239	0.807	0.807	0.823
Dec_2012	0.155	1.100	0.155	0.826	0.826	1.100
Jan_2013	0.097	0.807	0.097	0.607	0.607	0.807
Feb_2013	0.062	0.551	0.062	0.443	0.443	0.551
Mar_2013	0.021	0.449	0.021	0.429	0.429	0.449
Apr_2013	0.018	0.395	0.018	0.340	0.340	0.395
May_2013	0.014	0.221	0.014	0.204	0.204	0.221
June_2013	0.009	0.122	0.009	0.108	0.108	0.122
Total	**2.71**	**9.85**	**2.71**	**8.20**	**8.20**	**9.85**
Mean	**0.23**	**0.82**	**0.23**	**0.68**	**0.68**	**0.82**
mean	**0.23****	**0.82**	**0.23****	**0.68**	**0.68****	**0.82**
p-value	0.000		0.000		0.000	
Legend: ** highly significant/very significant						

Results in Table 5 showed that after the first year, the total soil erosion in coco mat technology which was 2.71 tons/ha/year was very significantly lower compared to the total soil erosion in control and vegetative technology which were 9.85 tons/ha/year and 8.20 tons/ha/year, respectively, with p-value at 0.000. Results further showed that total soil erosion in vegetative technology (8.20 tons/ha/year) was also very significantly lower compared to control (9.85 tons/ha/year) with p-value also of 0.000.

Moreover, the total soil erosion in coco mat technology (2.71 ton/ha/year) belongs to the very low category (0-7 tons/hectare/year) while soil erosion in control (9.85 tons/ha/year) and vegetative technology (8.20 tons/ha/year) belong to low category (7-12 tons/hectare/year) (Stone, 2006 as cited by Lanuza, 2014)

Table 6. Mean Soil Erosion (tons/hectare/year) of test plots at year 2

Period_Tech	Cocomat	Control	Cocomat	Vegetative	Vegetative	Control
July_2013	0.003	0.219	0.003	0.119	0.119	0.219
Aug_2013	0.003	0.215	0.003	0.104	0.104	0.215
Sept_2013	0.002	0.195	0.002	0.094	0.094	0.195
Oct_2013	0.002	0.168	0.002	0.043	0.043	0.168
Nov_2013	0.002	0.133	0.002	0.039	0.039	0.133
Dec_2013	0.001	0.100	0.001	0.036	0.036	0.100
Jan_2014	0.001	0.023	0.001	0.021	0.021	0.023
Feb_2014	0.001	0.016	0.001	0.008	0.008	0.016
Mar_2014	0.000	0.012	0.000	0.004	0.004	0.012
Apr_2014	0.000	0.011	0.000	0.002	0.002	0.011
May_2014	0.000	0.000	0.000	0.000	0.000	0.000
June_2014	0.000	0.000	0.000	0.000	0.000	0.000
Total	**0.014**	**1.091**	**0.014**	**0.470**	**0.470**	**1.091**
mean	**0.001****	0.091	**0.001****	0.039	**0.039****	0.091
p-value	0.0051		0.0100		0.0050	
Legend: ** highly significant/very significant						

Results in Table 6 showed that after the second year, the total soil erosion in coco mat technology which was 0.014 ton/ha/year was very significantly lower compared with the control at 1.091 ton/ha/year and vegetative at 0.470 tons/ha/year with p-value of 0.0051 and 0.0100, respectively. While the soil erosion in vegetative technology (0.470 ton/hectare/year) was also very significantly lower compared to control (1.091 ton/hectare/year) with p-value of 0.0050.

Results further showed that the severely eroded area was stabilized (zero erosion) 26 months after using the coco mat technology; and after 28 months for both vegetative technology and the control plot.

The soil erosion of the study for two years was summarized in Table 7, as shown below:

Table 7. Summary of soil erosion for two years

Technology	Soil Erosion (tons/ha/year)		
	Year 1	Year 2	Average
Coco mat	2.71	0.01	1.36
Vegetative	8.20	0.47	4.34
Control	9.85	1.09	5.47

The coco mat technology had the lowest mean soil erosion at 1.36 tons/ha/year, followed by vegetative technology at 4.34 tons/ha year and the highest were in control plot with 5.47 tons/ha/year.

Summary and Conclusions

The result of the study was expected to give information on the successful rehabilitation of damaged areas using a verified technology.

Rehabilitation of severely eroded area in Tuboran, Mawab, Comval using coco mat technology had a highly significant effects on the high survival of mahogany, narra and African tulip. It has also a highly significant effects on the higher height growth of narra and significant effects for falcata and mahogany.

Further, coco mat technology also significantly lowered the soil erosion of the project site.

It is concluded that coco mat technology was effective in the rehabilitation of a severely eroded area at Tuboran, Mawab, ComVal Province in combination with falcata, mahogany and narra, African tulip and forage peanut as ground cover.

Implication and Recommendations

Based from the significant results, the study implied that using coco mat technology in the rehabilitation of severely eroded site significantly decreased soil erosion of the school site of Tuboran Elementary School and succeeded to stabilize the slope.

It was also observed that there were highly significant and significant survival and growth of trees using the coco mat technology, thus, open and damaged site became productive for carbon sequestration and climate change mitigation.

Therefore, it is recommended that coco mat technology in combination with mahogany, narra and African tulip could be used in the rehabilitation of highly vulnerable and severely eroded areas of Tuboran, Mawab, Compostela Valley, Region XI.

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