THE DEMONSTRATIVE STUDY ON THE APPLICATION OF ECO-TECHNOLOGY TO THE TREATMENT OF MUD-AND-ROCK- CAUSED BROKEN STRUCTURES IN THE HIGH-ALTITUDE DRY-HOT VALLEYS AND THE CONSEQUENT PRODUCTION OF BIOMASS FUEL

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SUMMARY: How to survive plants rapidly and control water loss and soil erosion effectively on the extremely barren and arid mud-and-rock-caused broken structures is always the problem which is in the field of study of the ecological treatment of mud-and-rock-caused rocky desertification.

Selecting the appropriate high-quality pioneer species to conserve water and soil and construct the biodiversity-based platform of the degraded ecosystem, and ameliorating the ecological structure of the soil, is the key technology that decides whether the vegetation can be recovered successfully. It's one of the most important and the most basic steps of application of ecological project to the treatment of rocky desertification. This study is to applying vetiver as the pioneer plant to promote the plants to root rapidly in the extremely poor mud-and-rock mudstones, enhance plants resistance, and improve the ecological structure quickly and effectively and control the progress of erosion by reforming the plant roots, integrating the technology of ecological drought resistance and water maintenance, and planting exclusive rhizosphere microorganism of promoting root growth and improver. After five-year laboratory and field tests, the study has proved that this intergraded technology has effective recovering influence for mud-and-rock-caused hillside fields and rocky desertification field. Simultaneously, the by-products of vetiver have also been transformed to the biomass fuel in this process.

Key words: Mud-and-rock flow, Biomass fuel, Broken structure, Rocky desertification

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A Brief Introduce to the First Author

Bo Huang, the senior ecological environmental engineer of Yunnan Institute of Environmental Science and the CTO of Deep Far Yunnan Environmental Technology Co.Ltd, is now responsible for research on biological resources protection and sustainable utilization, and biological technology application of ecological restoration and reclamation of degraded systems in Mud-and-rock flow region of Yunnan Province. Graduated from Shanghai Ocean University, which majored in fresh water biology, he has worked at Yunnan Institute of Environmental Science since 1987 till now, mainly engaged in research on lake ecology, ecological restoration, environmental influence evaluation and environmental science, In the period of 1991 -2007, he moved to Yunnan Introduction and Breed Center of Rare and Endangered Plant Species, leading the work of ecological restoration and reconstruction.

1. BACKGROUND OF THE STUDY

Dongchuan, a district of Kunming, Yunnan, China, which is located in Xiao Jiang fault zone that has frequency crust activities and mud-and-rock disasters, is called the" World mud-and-rock natural museum". In this district, the typical mud-and-rock disasters are in the Xiao Jiang drainage area. Xiao Jiang River, which is length of 14 kilometers, drainage area of 3043 square kilometers, is a tributary of Jin Sha River. Since West Han Dynasty, the human mining activities has caused the low vegetation coverage, severe water loss and soil erosion, large area of exposed bedrock, barren land, ecosystem degradation, productive forces declining and gradually decreasing biodiversity and biomass. According to statistics, the forest coverage of Dongchuan district had only 13% in last century, and basin altitude of 2000 meters below the hillsides were basically no forests. Xiao Jiang basin, which is as the representative of mud-and-rock flow and soil erosion in Dong Chuan District, the average annual sediment discharge is nearly 3016t/km^2, the maximum annual amount of sediment is up to 5314t/km^2, which is the several times of the same areas.

The question of how to plan plants in rather barren, dry debris flow and gravel (broken structure) and control the soil erosion effectively is always the biggest difficulty in this field. The main reasons are: 1the gravel, ayic and sloping land, made by debris flow, is mainly consist of broken suspension load kernel. The land is low in soil (the percentage of gravel on the soil surface is over 60%). Ordinary plants can barely grow for the rather barren, lacking stroma and nutrition for growing. 2. The broken structures can let water pass through easily, so they are not good at keeping water. The plants must have the ability of not afraid of inundating so that they can survive. 3. Dong Chuan is the dry and hot valley climate, in which the distribution of water is not even, the hot and dry summer is very long and the rainy seasons fall on July to September. Under these circumstances, hardly has the common plants can bear.

In June, 2006, with the financial aids from the local government, the experiment was carried out about applying the techniques to improve the roots of plants and biotic drought resistance and maintaining water to improving the skills of growing the Vetiveria Zizanioids. After operating experiments in laboratory and the gravel grounds beside mud river Da Bai, Dong Chuan, we could conclude that the techniques of improving had a rather good performance in the environment of drought resistance, inundating, and barren resistance. In 2009, the place was truck with the great drought, without raining 330 days, but the plants grew well. The strong roots consolidated the broken structure effectively, preventing locomotion of the shallow surface. Those roots demonstrated characteristics of administrating the soil erosion and controlling the move of mud and sand; and restrain broken structure from erosion. All could prove that the integrated technique would affect well operating debris flow to improve the inhesion of the earth and the resistance to shear, which was to enhance the consolidation of the soil as the function of the techniques of barnacle.

The by-products of vetiver, a kind of granular newly fuel, which the diameter is 6-8mm; the length is 4-5 times of its diameter; the broken rate is less than 1.5%-2.0%; dry basis moisture content is under 10%; ash content is under 3%; the sulfuric content and the chlorine content are all under 0.07%; the nitrogen content is less than 0.5%, is made by blending additive and other material. The calorific value of this biomass fuel normally is more than 4000 Kcal, achieving the transformation of forestry products to biomass energy.

2. ENVIRONMENTAL CONDITIONS

2.1 Geologic and Geomorphic Conditions of Mud-and-Rock-Caused Slope of Da Baini River Area in Dongchuan District of Kunming

The experimental hillside, which is combined with three parts of dry-hot mud-and-rck-caused broken structure, is located in the Xiao Baini valley near the highway that is in Dongchuan District of Kunming. The total area of mud-and-rock-caused crushed-stone slope is around 4000m^2 which the slope angle is 40°-45°. The slope, composed of loose Paleozoic shale and mudstone, is averagely 50°.It was defined as the active disintegrating slope after the site investigation and analysis. The surface was mainly made of strongly weathered mudstone, crushed rock and moderately mudstone, accounting for 90% of the total substrate. The total flood washed area is nearly 20000m^2, which the mainly rock body is composed of mixture rock such as mudstone, sandstone and crushed rock. The entire slope was weathered and became fragmental structure with poor shear strength.

2.2 Climate Condition of Experiment Spot

The annual average temperature is 20.6℃. The extreme low temperature is -7.2℃, and the highest is 38℃. The annual rainfall is about 1200 mm, but the drought disaster in 2009, the annual rainfall is only 432mm, and the dry season is in winter and spring, while rainstorms concentrate in summer and autumn. The highest daily precipitation is up to 72.4 mm. Such high intensity of rainfall caused soil erosion, even landslide. The extremely continuing drought happened from April 2009 to June 2010. The experimental field is a very precipitous trapezoidal slope which is formed by cutting the hills; and the slop angle is 40-45°. Before the experiment, the slope was a totally bare crushed-rock slop without any vegetation.

2.3 Soil Characteristics of the Slope

The soil of the slope is typical mudstone, shale, and crushed mother rock, washed and accumulated by mud-and-rock flow and building highways. The surface soil did not exist because of excavating mountain; only mudstone and weathered detritus of mother rock were on the slope. Among these, crushed mother rock had a very high proportion, accounting for 2/3 of total soil weight (Table1). The soil is alkaline and extremely infertile, lacking of nutrition.


Table 1. Basic Composition of Soil in the Experimental Slopes

Locale	pH	Organic ingredient	Total N	Total P	Total K	Available K	Alkali N	Available P	Available Ca	Available Me	Gravel in Soil
		%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	647	(%)
A rock slope	8.46	0.28	0.07	0.07	3.08	0.85	12.04	3.46	2633	647	90
B	8.31	0.78	0.09	0.09	3.28	0.96	13.28	3.69	1437	554	60
C	8.27	1.38	0.09	0.10	3.33	0.78	12.29	3.28	1974	463	47

3. THE DEMONSTRATIVE STUDY

3.1. Laboratory Studies:

the process and material of drought-resistant technology is mainly used in the poor retention of sand gravel layer and the dry condition to provide nutrients, retain moisture, and improve soil ecological structure, centralizing and embedding Acetobacter, Zymomonas, Actinobacillus, Bacillus subtilis, Bacillus cereus, Bacillus megateriam, and Bacillus licheniformis on the large proportion of surface area of nonmaterial and hydrofphilic carrier such as OH-polyacrylate-polyacrylamide trimeric soil conditioner so that it can slowly release the water from the biological material to offer the roots growth in the drought condition.

3.2. Field Experimental Studies:

Project site: Mud-and-rock-caused hillsides of Da Baini of Dongchuan District of Kunming

The vetivers , which is used in this study , are three-year selected and improved varieties which are by three-year wild cultivation. In 2006, the project was subsidized by the People's Government of Kunming Dongchuan District. Since now, it has built a demonstrative field of recovering degenerate eco-system of mud-and-rock-caused broken structure of hillsides which has 4000m^2 in the 60°slope of 2000m^2 flood-washed fields. Go through by vetiver's rhizosphere improving and biological dry-resistant and water retaining, the project achieved an effective treatment consequence. On the one hand, the experimental field formed the obviously contrast to the surrounding mud-and-rock-caused hillsides; vetiver rooted rapidly in the extraordinarily infertility mud-and-rock-caused broken structure, controlling erosion and preventing the mud-and-rock-caused landslide. One the other hand, compared with the drought disaster in Dongchuan District this year, through biological dry-resistant and water retaining technology, obviously improved the soil fertility in the infertile mudstone and sandstone broken structure, simultaneously enhanced the dry-resistant and high-temporary-resistant biological response of vetiver, speedily and efficiently developing planting matrix and eco-structure.

4. EXPERIMENTAL OBSERVATION

This study improved vetiver 150 slips per square meter. The experimental hillsides were the bare mudstone structure without any vegetation. The principle of treatment is that as vetiver to be the pioneer plant, building a biodiversity basic platform and deploying landscape plants which have different functions according to the requirement of steadying the slopes, so that to build a compatibly complementary plant circulation system. The goal of treatment is to covering the barren hillsides by vegetation as quickly as possible so that to steady the hillsides. From May 24 to June 7, 2008, we divided the experimental field into A, B, C three sites, planting vetiver in the same height. The method which we used is to build a 30-meter to 40-meter width, contour platform and a

15-centimeter deep planting valley according to 80-centimeter spacing along the slope, planting vetiver in line with 10cm-15cm spacing on the platform. Before planting, all vetiver should be handled by biological treatment. Observe the reviving rate, survival rate, growth height and tillers regularly. Simultaneously, as the contrast hillside in the same section, it should be totally kept the natural condition, testing the differences of plant diversity between the experimental slope and the natural slope so that to reflecting the effect of fixing the hillside on the experimental hillside.

All the testing plants had been planted during May 24 to June 7, 2008. After planting, we observed and recorded the survival rates, the growth and development condition of plants, the condition of invasive species and the soil and water conservation of ecological engineering of vetiver in June 16, August 28, October 10, November 20, 2008 and March 20, May 24, July 28 and October 28, 2009. We randomly selected 12 slips, observing the height of the plants, length of the roots and the number of the tillers, the covering rates and the compatible condition with other plants.

5. RESULT OF THE EXPERIMENT

5.1 The survival rates of the pioneer plant

The investigation results of the three sites, A, B, C showed that vetiver did not turn green 40 days after planting; the seedlings in non-fertilized area first became green till July 6 and the reviving rates were up to 91%. Vetiver began to produce new tillers, tiller number per slip was up to 1-6 slips from 0, the maximum tiller number was 6, which means the technology of dry-resistant and water retaining has affecting effectively. After entering the rapid growing stage, the growing speed of fertilized treatment were much rapider than those of non-fertilized ones, and the tiller number of the former was far more than that of the latter(Table3), showing that fertilization still had positive effect to vetiver after turning green.

Table 2 Effects of fertilization and non-fertilization on survival rate and initial growth of vetiver(Investigated on July 6)

Site	Add bacterium agent			Non-Add bacterium agent		
	Survival rate (%)	Height (cm)	Tillers per slip	Height (cm)	Tillers per slip	Tiller number of the largest slip
A	89	3	1	5	2	3
B	92	3	2	5	3-4	5
C	91	5	2-3	6	3-4	5

Table3 Effects of fertilization and non-fertilization on early growth of vetiver (investigated on August 28)

Site	Survival Rate (%)	Add bacterium agent		Non-Add bacterium agent		Add bacterium
		Height (cm)	Tillers per slip	Height (cm)	Tillers per slip	Tillers number of the largest slip
A	91	66	4-8	55	3-4	7
B	92	68	4-6	51	3-4	7
C	97	62	4	49	3	6

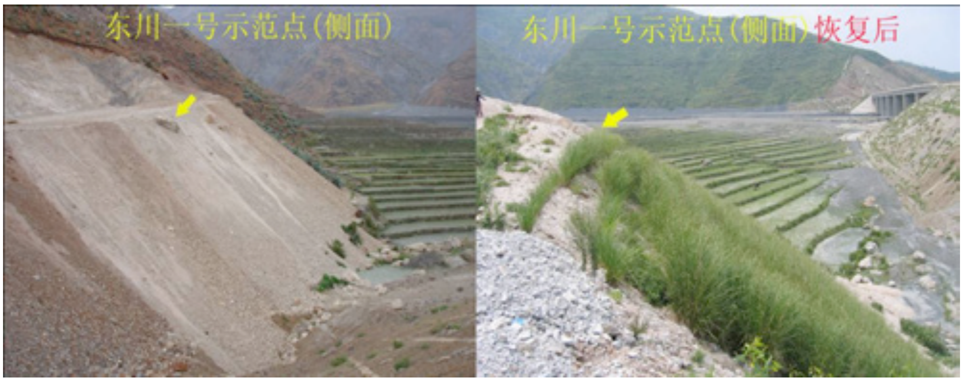
5.2 The growth condition of tillers and the effect of the slope fixing in the experimental hillside

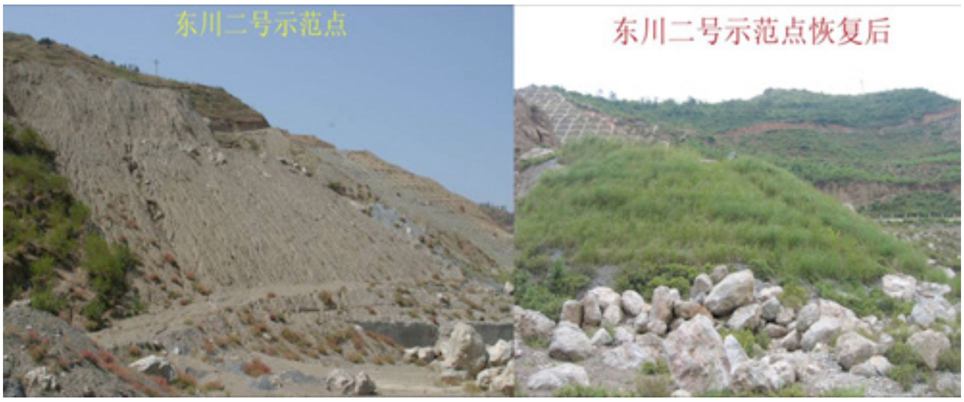
Five investigations in 2008 showed that vetiver planted along contour could form hedgerows, but the growing speed was different in different stages. The faster growing season was from July to October (Table 4 and 5). At the fifth investigation (November 2009), dense hedgerows of vetiver had formed. The average tillers were up to 18.6 each slip, average height to 110.6 cm and average root depth to 98.6 cm; The gradient of site A and B was about 50°averagely, and their soil was mainly composed of mudstone, accounting for 40%, while the gradient of site C was up to 70°and its soil was chiefly composed of crushed-stone structure, accounting for 90%. As a result, vetiver planted in site A and B formed a thick covering layer and the coverage reached 96%, which took auxiliary effects on stabilizing slope and preventing soil from washing away. On the contrary, due to the site C had a high proportion of large scale of crushed-stone structure; other plants were difficult to root on the slope and form the vegetation layer. However, vetiver formed a thick covering layer at site C which was accounted for 95%. In July the rainfall was 30% more than the same period of previous years, and rainstorms were more frequent, there were 3-4 days which rainfall came to 72.4 mm so that the control under completely natural situation formed serious landslip and the cannel of the power station was scoured to collapse, while there were no damage on the slope fixed by vetiver hedgerows. More importantly, the ill slope was effectively protected and stabilized in rainy season, and its soil erosion was also completely controlled.

Table 4 Tiller formation and plant growth of vetiver grass in the late 2002

Site	Survival rate%	July 28		August 28		October 10		March 20, 2009		Root largest depth cm)
		Height (cm)	Tiller s per	Heig ht (cm)	Tillers per slip	Height (cm)	Tillers per slip	Height (cm)	Tillers per slip	

			slip							
A	94%	64	4-8	89	8-16	130.6	8-18	126.6	14-18	103.3
B	93%	58	4-8	86	8-12	129.7	8-19	119.7	18-19	95.46
C	97%	60	4	76	6-10	110.2	6-12	118.3	16-19	79.76





Three observations were conducted in 2009 (Table 5) when vetiver grass had grown for 13months. The coverage was up to 96% and dense hedgerows were formed; the whole protected slope was firmly stabilized, and soil erosion and landslip did not occur on the slope any longer. The growing trend of vetiver was vigorous and it successfully resisted the extreme drought of 106 days and rainstorm of 74.2 mm in a day. Vetiver grew up to 8-19 tillers averagely for each slip; the maximum tillers were 29 slips, and the highest slip was 176cm, the deepest root was up to 100.6cm. Compared with the surrounding natural contrast slopes, the ecological engineering played a important role in preventing soil erosion and stabilizing slope. Moreover it greatly improved the eco-environment and landscape of the ill slope in rocky desertification.

Table 5 Tiller formation and plant growth of vetiver grass in 2009

Site	Survival rate%	May 20		July 18		October 28		(cm) Mean height	Mean tillers per slip	(cm) Root largest depth
		Height (cm)	Tillers per slip	Height (cm)	Tillers per slip	Height (cm)	Tillers per slip			
A	94%	46	8-18	143	18-29	17.0	29	180	39	120.62
B	93%	48	8-19	121	18-20	16.0	26	163	27	117.68
C	97%	48	6-16	154	18-27	15.0	24	187	33	100.47

5.3 Economic Benefits Analysis of Eco-engineering

According to the temporary market price in Yunnan Province, 2009, the price for stoned-based engineering is around 160-500 Yuan/m^2, while the cost of vetiver eco-engineering is only around 19-20 yuan (Table6), which is only the 11%-18% of the cost of stoned-based engineering. The vegetation eco-engineering, which is used for stabilizing and protecting the slopes that are formed by excavating mountains, has the obvious economic benefits, ecological benefits and social benefits. Although some assistant stone-based projects are needed when the Vetiver Eco-engineering is applied to protect slopes, which will probably enhance the cost, the total cost is still cheaper than that of pure stone-based structure.

Table 6. Cost Contradistinction between Vetiver Eco-engineering and Stonework Engineering

Unit: Yuan/m^2

Engineering Type	Material costs	Human costs	Management fee	Other costs	Total
Stonework engineering	160-500	5-7	2-3	3-5	209-515*
Vetiver eco-engineering	19-26	4-6	1-2	1-2	25-36

6. CONCLUSION

(1). Due to the geological situation of mud-and-rock-caused stony wasteland in Dongchuan District of Kunming which is formed under the special climate, soil condition, the broken structure hillsides are mainly suspended sediment particles which the composition of soil is really low (the gravel content is more than 60% in the land surface); the content of organic ingredient in weathered rock, mudstone and broken mother rock is very little. Ordinary plants are very difficult to grow up in this extremely infertile soil which is lack of matrix and nutrition.

(2). Due to the broken structure has the high water filtration, while the ability of retaining water is poor, the plants are required to have the characteristic of resisting drought and flood so that can root in the land and form a biological barrier rapidly.

(3). The climate of Dongchuan District belongs to Dry-hot valley climate which the precipitation is not well-distributed and the period of drought is quite long, while the rainy season implodes on July to September. Ordinary plants hardly survive in this situation. This project has solved this technical problem which is how to root vegetation rapidly and control the soil erosion effectively on the extremely infertile dry mud-and-rock-caused stony slope (broken structure). This improved pioneer plant, which has the resistant ability that can grow up very quickly, can build the basic platform of degenerated eco-system and form the eco-landscape in tremendous situation which is on the 40°slope that consists 90% Paleozoic broken mother rock and in the extreme climate condition of 330-day drought and 72.4-millimeter rainfall in a single day. The root system of vetiver improved the slope stabilization ability, restored the deposit cohesion and, therefore, solved the erosion problem thoroughly. It indicates that the Vetiver Eco-engineering technique is quite efficient for slope stabilization and protection in mud-and-rock-caused stony wastelands and slopes. Using this technology to control soil erosion and water loss can decrease the costs and gradually replace stonework engineering.

(4). In this study, vetiver needed six months to form the tightly net roots, stabilizing soil; the part of the plant which grew rapidly on the ground, showing the obvious tillers. Planting 150 slips per square meter vetiver among the contours can form an obvious green fence quickly, slow down the slope run-off and control the erosion of runoff on the slopes. It didn’t need the special attendance once the plants have become fence. It did totally adapt to the special soil and climate situation in Dongchuan District and earned a good effect of stabilizing hillsides.

In brief, Vetiver is an ideal pioneer species in the aspects of slope stabilization and environmental protection due to its high efficiency, permanence, cheapness, multi-function. It shows the technology, as an eco-engineering which can control mud-and-rock flow effectively, can improve soil cohesion and shear strength, increasing soil stabilization as the stonework engineering does, make an important function for recovering and rebuilding the degenerated eco-system of mud-and-rock-caused wastelands and hillsides in Donchuan District of Kunming.

7. BY-PRODUCTS TRANSFER TO BIOMASS FUEl

7.1 After technical improve, vetiver has higher photosynthesis efficient which has potential economic benefits. Vetiver can be reaped three or four times each year, obtaining 5-8kg grass biomass fuel on each square meter. The products can increase after the soil nutrition increase. Until the second growth cycle, it can reach bumper, accounting 12-16kg/m^2. If don't reap, it could influence the amount of light energy capture, but the fallen leaves could continually penetrate into underground or cover the land surface which can protect and strengthen the ability of keeping water of the surface. As the organic cellulose biomass can efficiently improve the soil nutrition in the broken structure, and the effects of microbial decomposers, the organic cellulose biomass decay, then infiltrate into the ground, therefore, it improve the adhesion of the broken body so that turn the infertile soil to be arable soil, increasing the products of native plants which are in the eco-system and the biodiversity so that rise the utilization of land resources and offer more raw material for developing biomass fuel and building a animal husbandry platform. However, the unreasonable reap could have negative influence for the output in next year, the tillers would decrease 1/3 compared with the last year.

7.2 As the fourth biggest energy resource, biomass fuel plays an important role in the renewable resources.

This project is to producing new energy material by adding catalyst into the mixture of by-product of eco-restoration, sawdust, straw and the plant wastes and solidifying. The project can transform the low quality biomass fuel to the high quality, easily storing and transporting, and high density biomass fuel which the thermal efficiency is obviously enhanced to 40%-50%, exceeding the energy which is transformed by coal. The study is developed for decreasing the Carbon dioxide emissions, because this biomass can offer the energy which is required by plants growth, by absorbing carbon dioxide from the atmosphere, and then obtain the biomass energy from the mature plants after burning. This process is confirmed is identified as the zero emissions of carbon dioxide.

7.3 The Characteristic of Biomass Fuel

Table 7 Performance Indicators of Biomass Fuel

Items	Index
Calorific Value	>4500kcal/kg
Density	>1.1t/m^3
Outward	Light Yellow Cylindrical φ 8mm
Ash Content	≤ 7%
Water Content	≤ 13%
Burning Rate	≥ 95%
Thermal Efficiency	≥ 81%
Degree of Black Smoke(Ringelmann class)	<1
Dust Concentration	≤ 80mg/m^3

(1). This biomass fuel has high hydrogen content and high volatility which is easy to ignite and has high oxygen which is easy to burn and improve the combustion efficiency, therefore, there is less carbon content in the ash.

(2). This biomass fuel has low ash content (the ash content of straw normally is about 5%, the ash content of sawdust is under 1% and the ash contend of coal is usually about 20%-30%) which can be used as fertilizer.

(3). The colorific of this biomass fuel is about 3,600-4,600kcal/kg, which is almost as equally as moderate quality coal' colorific. Due to this biomass fuel belongs to renewable resources; it could replace a part of fossil fuels, decreasing the emissions of greenhouse gases.

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