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Utilization of Forestry Residue in Erosion Control and Soil Moisture Conservation

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Abstract: Chip material obtained from forestry residue was converted into boards by the pressurized steam and compression technology without using any chemical adhesives. These biomass boards were tested as erosion control materials, and found to be very effective in reducing soil erosion with extremely high soil retention efficiencies of 94% and92 % on steep and gentle slopes respectively. Our investigations also revealed that the moisture retention capacities of biomass boards are relatively higher and could be used to reduce soil moisture losses. The impregnation of urea does not only improve the durability of the boards but also allows them to retain more moisture. All these benefits suggest that converting forestry residue into boards before applying them as ground covers in farms could result in more benefits such as yield improvement, soil moisture conservation, elimination of weeding or herbicide application, erosion control, hill slope stabilization and an overall improvement in ecological services.

Key Words: Biomass boards, Forestry residue, Pressurized steam technology, Soil erosion, Soil moisture conservation

1. Introduction

Soil erosion and soil moisture loss are two major issues that need to be seriously considered when dealing with degraded land restoration especially in arid and semi-arid regions as well as projects to rehabilitate deserts. Measures to combat desertification are usually not only time-consuming but also have higher cost implications. The problem of desertification is worsening in recent years and arid land areas also expanding at unprecedented rates. To address these issues, many national and international organizations are drawing programs to increase farmers' land conservation awareness (Aqil and Mihara, 2010) and promote the use of organic amendments such as the direct application of forestry or agricultural residue to farmlands. It was recently reported that wood waste material was effectively used to improve soil infiltration and soil loss (Andy *et al*., 2011). However, a greater part of these materials are likely to be washed away by runoff after heavy storms or blown away by strong winds. The use of plastic sheets is quite popular in modern agriculture but they are not biodegradable, act as a barrier to infiltration of water from rainfall and also their means of disposal poses a threat to the environment. Furthermore, plastic mulches are not sustainable and their prices are likely to go up with the depletion of oil resources. Meanwhile, large volumes of biological materials like weeds, forestry residue, agricultural waste, etc are generated at places where land is still productive in many parts of the world but only a small fraction is utilized with the rest mostly burnt to waste.

Several research works on waste utilization has been conducted to convert biomass into particle boards (e.g. Akaranta, 2000; Odozi *et al.*, 1986; Sampathrajan *et al.*, 1991) but most of the methods employ chemical adhesives. To effectively utilize these bioresources, a pressurized steam and compression technology has been developed and used to produce mulching materials, hereby referred to as biomass boards, from forestry residue (Ito *et al*., 1998a, 1998b, Onwona-Agyeman *et al.*, 2002). With this technology, boards can be fabricated from all types of biomass without using any chemical adhesives. The purpose of this research is to investigate the possibility of enhancing the functions of these biomass boards by testing their abilities to reduce soil erosion, conserve soil moisture, suppress weeds, and most importantly examine how all these multiple functions of biomass boards may be integrated into a sustainable agricultural system. A second type of boards, hereby referred to as urea-impregnated boards, were fabricated by first impregnating urea into the chips. These boards would be very useful by slowly releasing nitrogen to support plant growth in areas where nutrients are easily washed or leached from soils.

2. Materials and Methods

2.1. Board fabrication process

The main raw material used was wood chips obtained from

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thinned (whole trees) sugi (*Crpytomeria Japonica* D. Don) logs. With the high-pressure steam method, dry chips are initially placed in a metallic frame and compressed to a target thickness of 2 cm, after which they are placed in an autoclave where steam at 180°C is injected for a 30-minute duration. The steaming process, referred to as permanent fixation, is carried out to ensure that the boards become dimensionally stable after pressing. The urea-impregnated boards were fabricated by first soaking the chips in urea solution for a period of three days after which the procedure described above was followed.

2.2. Moisture absorption and retention property tests

In accordance with JIS A5908-2003 specifications, physical property tests such as water absorption capacity and the internal bonding strength (IB) of both types of boards was also determined. The water retention property was determined by soaking samples in water for 24 hours and then allowing them to dry in the open air while their moisture contents were monitored.

2.3. Soil moisture conservation tests

The effectiveness of the biomass boards and urea-impregnated boards in conserving soil moisture was evaluated in the laboratory by the following simple method. Flowerpots partially filled with equal weights of sandy soil were covered by test samples of both materials to serve as mulches. One set of sand-filled flowerpots were not covered to serve as the control. Next, equal amounts of water were applied to all the treatments until saturation point. After that, monitoring of the soil moisture content was periodically done until all the moisture evaporated.

2.4. Erosion control tests

Runoff tests were conducted to compare the sediment trapping efficiency of biomass boards with wood chips and rice straw on a gentle (5°) slope and a steep (30°) slope respectively, using natural storm events (**Fig. 1**). The site for the runoff experiment was on the campus of Gifu University and it lasted for a period of four months, commencing from October 2006 and ending in January 2007. Bare plots were initially prepared by clearing weeds on a 30-degree steep slope and a 5-degree gentle slope. Each slope was then divided into equal areas of 120 cm length and 30 cm breadth and corrugated plastic sheets were used to hydrologically demarcate them into zones. Funnel-shaped stainless plates fitted with mesh were carefully placed at the bottom edges of each zone to trap eroded sediment. After every rainfall event, trapped sediment were collected from the four different treatments (three replications) of fully covered biomass boards, rice straw, wood chips and the bare ground area to serve as the control.

Fig. 1. Site for runoff experiments.

Table 1. Physical properties of biomass boards. IB: internal bonding, MOR: modulus of rupture, MOE: modulus of elasticity, TS: thickness swelling, HB: Brinell hardness.

Density (g/cm^3)	IB (KPa)	MOR (MPa)	MOE (MPa)	TS (%)	HB (N)
0.64	10.7	0.53	44.6	12	4.16

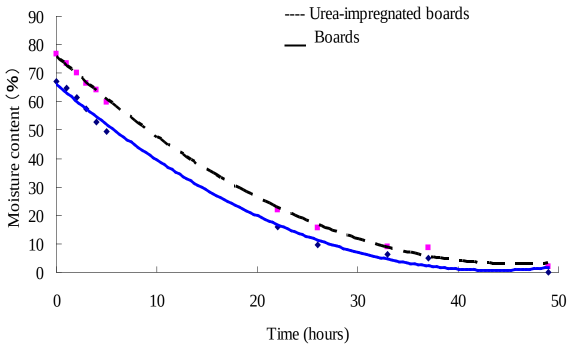

Fig. 2. Moisture absorption and retention of biomass baords.

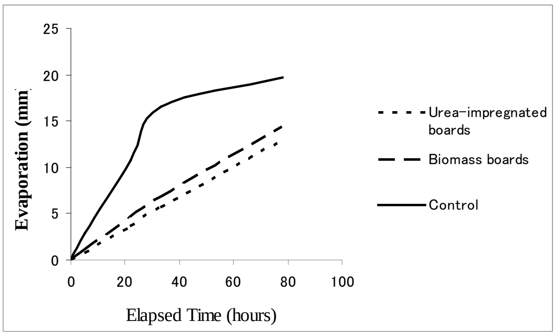

Fig. 3. Soil moisture evaporation under different mulches.

3. Results and Discussion

3.1. Physical properties of biomass boards

The physical properties of the biomass boards used in the experiments are shown in **Table 1**.

Although the other properties remained unchanged, urea-impregnation into the boards resulted in a slight increase in density (0.65 g/cm^3) and internal bond strength (Onwona-Agyeman *et al*., 2007).

3.2. Moisture absorption and retention by biomass boards

After soaking samples in water for 24 hours, it was found that the urea-impregnated boards absorbed more water (77%) than the compost boards (67%) as shown in **Figure 2**. It can also be seen from the graph that urea-impregnated boards

Table 2. Erosion control effectiveness of different materials. (SS: Steep slope; GS: Gentle slope)

	Erosion (t/ha)	Erosion (t/ha)	Reduction (%)	Reduction (%)
Treatment	SS	GS	SS	GS
Boards	0.2	0.12	94.4	92.3
Rice straw	0.27	0.32	92.4	70.7
Wood chips	0.5	0.48	86.1	80.3
Bare ground	3.6	1.6	0	0

could retain more moisture for longer durations (over 50 hours) than the boards (40 hours).

Figure 3 shows the relationship between the amounts of moisture loss from the sandy soils covered with the two types of boards and the control (uncovered). It can be clearly seen that the moisture loss through evaporation was much higher for the control compared with the boards. Although there was not much difference in the evaporation amounts between the pots mulched with the two types of boards, the urea-impregnated boards exhibited a better mulching characteristic by retaining more soil moisture compared with the biomass boards.

3.3. Erosion control by biomass boards

Throughout the 4-month duration, a total of 254.3 mm of rainfall was recorded. The total amount of eroded soil collected at the end of the experiment from each treatment is shown in **Table 2**. From the results, the amount of eroded material, estimated in tons per hectare, were found to be least for the areas fully covered by biomass boards while the bare ground showed the highest erosion for both the steep and gentle areas as expected. By taking the amount of erosion on the bare ground as the reference, the percentage reductions in soil erosion were highest for the boards and estimated as 94.4% and 92.3% for the steep and gentle slopes respectively. Although raindrop impact and other environmental stresses led to a slight degradation of the boards after four months, the average density had reduced to 0.54 g/cm^3 while thickness swelling changed to 9.24%.

4. Conclusion

Biomass boards are biodegradable materials and with time will be expected to decompose and return into the soil as a source of organic matter without leaving any traces of hazardous compounds. Using wood chips will allow weeds to compete for vital nutrients but converting them into boards and subsequently using them as mulches in small-scale farming systems can eliminate or significantly reduce the cost of weeding and the need to apply weedicides. Results from our earlier tests in Ghana indicates that biomass boards will be very suitable in semiarid agricultural environments, where annual rainfall is scanty but rainfall events are so intensive that ordinary wood chips are easily washed and carried away (Onwona-Agyeman *et al.*, 2008). The idea of impregnating urea or any type of fertilizer into boards is to render them very useful in soils where nutrients area easily leached. Our experiments also revealed that impregnating urea into boards could improve their moisture holding capacities, retarded soil moisture loss and serve as a source of nitrogen for crops, thereby boosting their overall function as mulches. The slight increase in the strength of boards as a result of urea impregnation could be due to the bonding between urea and wood constituents, particularly vanillin.

Biomass boards have an added advantage of preventing or lessening on-site erosion. This advantage was also echoed by Reeder (2006) who reported that soil management practices that kept soil particles in place should be preferred to ones that were designed to intercept eroded sediment after it had moved a considerable distance. In a separate experiment Onwona-Agyeman *et al.* (2007) found out that the use of biomass boards as mulches could reduce weed growth from 0.5 ton/ha/month to 0.05 ton/ha/month.

It is worth noting that the rice straw and wood chips are lighter, decompose within a matter of months and can be easily washed by runoff and strong winds. The biomass boards on the other hand, are heavier and can last for nearly two years. All these benefits suggest that converting wood chips into boards before applying them as ground covers will result in more benefits such as yield improvement, soil moisture conservation, elimination of weeding or herbicide application, erosion control and an overall improvement in ecological services.

In the near future, we intend to test how these biomass boards can slow down overland runoff and improve soil infiltration characteristics. These desirable features of boards used as mulches can be applied in the stabilization of hill slopes and reduce sediment flow, thereby reducing the loss of soil fertility and the threat of flooding. Although the boards were very effective in limiting the amount of soil eroded with extremely high retention efficiencies of 94.4% and 92.3% on steep and gentle slopes respectively, their effectiveness should also be evaluated with respect to sand and silt components of soils. As a recommendation, the boards could be laid along contours to reduce erosion in large-scale agriculture on sloping lands. In small-scale vegetable production, the boards could be laid in a much more compact way and then planting the crops in the gaps between them as shown in **Figure 4**. This will ensure weed suppression, moisture conservation, less soil loss and overall protection of the soil.

Fig. 4. Corn production under biomass board mulching.

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