

EVALUATING THE MANY BENEFITS OF SUGARCANE TRASH FARMING SYSTEMS

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The primary benefit of trash farming is the reduction of N fertilizer that is required to maintain high crop yields because of asymbiotic N fixation from the decomposing trash litter. Studies indicate that 50-200 kg N/ha can be fixed/year in a trash-mulched ratoon crop. Phosphorus fertilization can also be reduced, as the mulch protects the soil from drying, leading to more root proliferation in the soil surface where P levels are high. Sugarcane trash farming can lead to about 50% reduction in tillage expenses through extended ratooning under a 1:3 years plant-crop:ratoon-crop cycle compared to current practice (normally 1:1 or 1:2 years). Other benefits of a trash mulch: It reduces need for inter-row cultivation by 50%, improves soil fertility, prevents soil erosion, increases water retention, and minimizes lodging of de-trashed cane crops. Not burning the trash removes the human health hazards associated with the exposure to airborne particulate matter (fly soot and biogenic amorphous silica) when the canefield is burned.

Trash farming significantly increases the economic return of cane production when compared with conventional farming methods. Although net revenue decreases by 4% in the plant crop (₱ 1184/ha), the net revenue increases by 28% (₱ 8924/ha) in the ratoon crop. This is primarily due to increased yields and 10% reduced cost of production on per ton cane (₱ 568/TC in conventional ratoon, ₱ 508/TC in trash-farmed ratoon).

Trash farming decreases the overall energy input required per ton of cane produced. Conventional cane is estimated to consume 0.52GJ in the plant crop and 0.46GJ/TC in the ratoon crop. Trash-farmed ratoon cane reduces the energy demand to 0.24 GJ/t. The 48% improvement in energy use was the result of a 20% increase in cane ratoon yield under trash farming and a 110-kg/ha reduction in N fertilizer input per year. The 36% savings in energy per ton cane translates to about 3.24 M GJ energy savings for the sugar industry, equivalent to 618,000 barrels of oil or \$18.54 M (₱ 964 M) at ₱ 30/barrel. Ways on how to promote and optimize sugarcane trash farming are presented.

Keywords conventional farming, energy savings, N fertilizer, P fertilizer, plant crop, ratoon crop, sugarcane farming, trash farming, trash mulch

INTRODUCTION

Sugarcane is the major crop in the world that is most efficient at converting solar radiation into plant biomass. Unfortunately, this scientific fact is not being fully harnessed in the Philippines. The industry is in a long-term state of decline. From a high of 2.6-2.8 Mt of raw sugar in the mid-1970s, production has dropped to about 1.6-1.8 Mt by the 1990s. The country was the world's fourth largest exporter of sugar in the early 1980s. In 1995-96, the Philippines imported 816,668 mt of raw and

refined sugar, whereas in 1977-78, the Philippines supplied 10% of the world's sugar requirements. Sugar exports contributed to about 20% of the country's export earnings at that time. The sugar industry is a major contributor in terms of employment as it provides about 500,000 jobs directly and an additional 5.0 M jobs indirectly (Zabaleta 1999).

The decline in production can be attributed to many factors which include typhoons, floods, drought, pests, low application of inputs, reduced production land base, and most importantly, deteriorating soil fertility. Soil

organic matter, an important indicator of soil fertility, was 2.3% in the 1970s in the Victorias mill district of Negros, Central Philippines. It dropped to 1.7% by 1988, representing an approximate decline of 26% in organic matter (Alaban et al 1990).

Implementation of more resource-efficient farming practices, such as trash farming, which also results in avoidance of field burning, can decrease the overall energy input, improve soil fertility, increase productivity, and enhance profits in sugarcane production.

In this particular paper, we review several studies related to trash farming and assess varied agronomic aspects of sugarcane grown through trash farming. We focus our review on the benefits of trash farming on the following: sugarcane yield, ratooning cycles, tillage

operations, fertilizer use and soil fertility, soil conservation, economics, fossil fuel usage and human health. We also examine the requirements on how to promote and optimize its adoption, and generate the implications of sugarcane trash farming to green cane harvesting.

Sugar yield

Trash farming increases sugar yield. As early as the 1950s, it was already noted that trash mulching improves the yield of sugarcane (Pineda 1956). While the results of this study were presented in the annual convention of the Philippine Sugar Technologists in 1956, sugarcane planters did not appreciate the findings. Three important reasons can be cited:

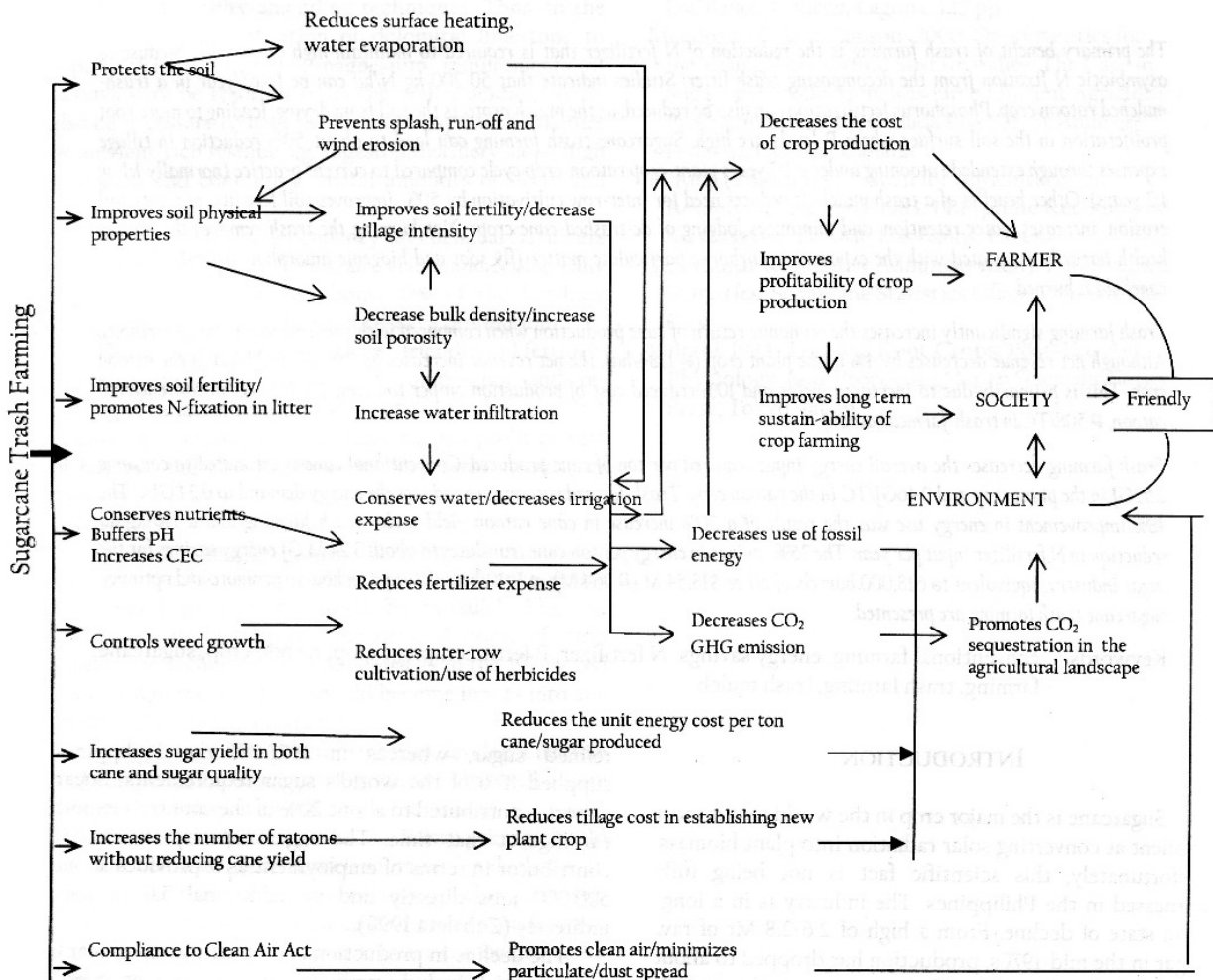


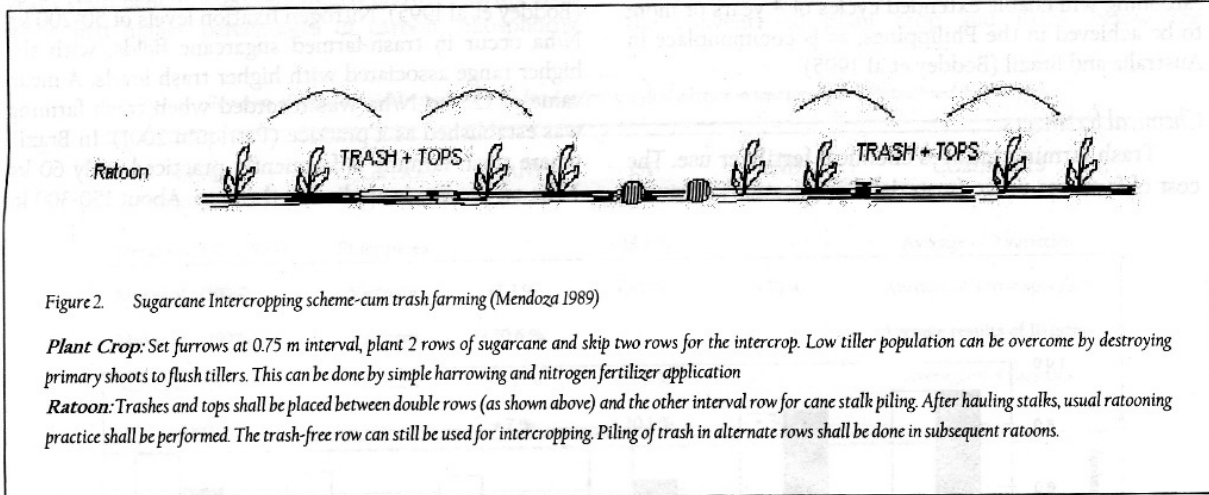
Figure 1. Summarized interactive benefits of sugarcane trash farming to the soil, farmer, society and the environment.

1. Pre- and post-harvest burning was the standard practice to facilitate harvesting and the subsequent ratoon cane establishment; in fact, this is generally true up to the present.
2. Soils were relatively fertile and the need for annual carbon contributions to the soil was not considered as necessary to maintain soil fertility.

yields in small farm with trash-mulched canes compared with non-trashed farms.

The internetworking of benefits of trash farming to the soil, farmer, human health, society and the environment is shown in Figure 1.

The rest of the paper supports the following contentions:



3. The price of fertilizer at that time was relatively low.

In the early 1970s, increasing oil prices resulted in augmented production costs. Fertilizer prices were particularly affected, ie, they went up. To some, this was a natural working of the system and did not warrant a reexamination of the commercial fertilizer as a means of providing a supply of necessary nutrients to crops. To others, this emphasized the need to recycle nutrients back into the soil.

Decades ago, it was already recognized that organic fertilizer, from sugarcane trash serving as a soil amendment, increases sugar yield (percent polarization) both in tonnage and sugar quality (Abrigo 1981). High sugar yields are desirable as they increase mill efficiency and returns to the farmer. Moreover, higher quality canes delivered to the mill reduce the cost per unit of sugar manufactured.

Subsequent studies indicate that mulch farming can increase sugar content, 11.6% according to Mendoza et al (1989) and 3% according to Tan (1995). In 2 of the 4 studies cited, mulching was shown to significantly improve the sugar level of ratoon crops. Long-term fertility improvement of degraded soils through trash farming could lead to an overall increase in sugar levels and boost economic returns.

Mendoza et al (1987) showed that yields in the ratoon were 33% higher in the trashed field than the non-trashed fields (128.6 PS/ha vs. 96.5 PS/ha), especially with good ratooning varieties for both tonnage and sugar quality. Delos Santos (2000) recorded 50% higher sugar

1. Trash farming extends the ratooning cycle and, therefore, productivity.
2. Trash farming reduces chemical fertilizer use.
3. Trash farming improves soil properties.
4. Trash farming conserves the soil.
5. Trash farming improves the economics of sugarcane production.
6. Trash farming reduces the fossil fuel usage of sugarcane production.
7. Trash farming is conducive to human health.

Ratooning cycle

Trash farming extends the ratooning cycle. A summary of research studies in the Philippines and Vietnam on trash farming systems (Table 1), indicates that sugarcane yields increase, on the average 20.1% in the first and 30.0% in the second ratoon crop. These findings have major implications in increasing the profitability of sugar cane production. Extending ratooning cycles is a cost-reducing practice in sugarcane production. Ratooning means savings on land preparation, cane points and planting which account for about 20 to 25% of the total cost of production.

Trash farming reduces the yield decline associated with the ratooning practice (Figure 2). It enables sugarcane to be cropped an additional 1 to 2 ratoon crops before yields become economically non-viable. Ratoon cropping is most easily extended on soils with high soil fertility and high moisture-holding capacity. On well drained alluvial soils in the humid tropical zone of northern Australia, trash farming sustained yields above

65 t/ha for 5 consecutive ratoon crops, while yields fell below 65 t/ha in the second ratoon in a burnt cane field (Figure 2).

Improving soil fertility through trash farming will gradually create a positive feedback system with longer ratoon cycles. Improving cultural practices along with widespread screening of cane trash varieties for ratooning will enable extended cycles of 4 years or more to be achieved in the Philippines, as is commonplace in Australia and Brazil (Boddey et al 1995).

Chemical fertilizers

Trash farming reduces chemical fertilizer use. The cost of fertilizer usage (material + application) accounts

without N fertilizer are associated with greater biological N_2 fixation and include *Acetobacter diazotrophicus* (Boddey 1995). Trash farming conserves significant amounts of nitrogen in the soil (approximately 30-35 kg N/ha).

In Brazil, gains in soil nitrogen equivalent to 54 kg N/ha/yr over 9 years were reported for unburned cane (Boddey et al 1995). Nitrogen fixation levels of 50-200 kg N/ha occur in trash-farmed sugarcane fields, with the higher range associated with higher trash levels. A mean value of 125 kg N/ha was recorded when trash farming was established as a practice (Patriquin 2001). In Brazil, where trash farming is frequently practiced, only 60 kg N/ha on average is applied to the crop. About 150-300 kg

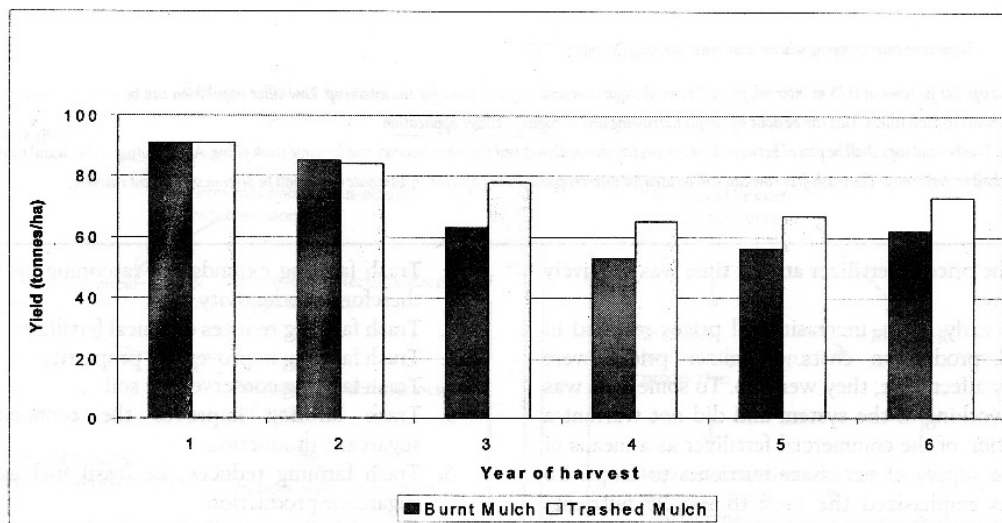


Figure 3. Effect of trash mulching on sugarcane yields (average of 5 sites in Northern Australia)

for about of 16% in plant cane and 26% in ratoon. When trash is burned, the nitrogen is lost as nitrous oxide (N_2O). Burned cane equals loss of soil N at an average of 44 kg N/ha/yr. Some of the P and K can also be lost through burning (Cook 1994). In trash farming, P uptake appears more efficient as the mulch protects the soil from desiccation and permits root proliferation in the soil surface where P levels are high. Mulching permits a greater recycling of P from residues than burning, and Ball-Coellno et al (1993) suggest that lower P fertilization rates could be used to maintain productivity on sites where burning is practiced. Trash farming not only helps conserve organic matter in the soil during the decomposition process but encourages N fixation in the sugarcane litter. Hill & Patriquin (1990) described a highly active system involving a microaerophilic N_2 fixing *Azospirillum brasilense* and adematiaceous fungus *Helicomyces roseus*. In Brazilian cane varieties, high yields

N/ha are used in most non-trash farming cane producing countries such as Cuba, Peru, India and the United States (Boddey 1995).

Soil properties

Trash farming improves soil properties. Upon decomposition, sugarcane trash (as organic matter) is transformed into a stable product called humus, which is of agro-ecological importance (Table 2). Also, Hodge (1998) pointed to the importance of organic matter for long-term sustainability of agriculture. Conserved as mulch, sugarcane trash decomposes into humus, improving soil tilth, and decreasing tillage required. By increasing water infiltration into the soil, water retention is improved, thereby decreasing the need for irrigation. Trash-mulched canes can tolerate the normal dry season and El Niño events better than ratoon crops in burned cane fields, which have no trash mulch cover. This effect

is even more evident in long term trash-mulched fields with higher soil organic matter levels and a permanent surface mulch cover.

The effects of mulching on soil fertility have been studied in research stations and on-farm field trials in Vietnam (Mui et al 1997a, Mui et al 1996). During a three year experiment, it was consistently shown that mulched fields had higher percentages of carbon, phosphorus,

trash ratoon farming was done. Trash ratoon farming was found to be more financially beneficial than conventional ratoon farming (Table 3). Where trash farming was implemented, net returns increased by 43% in the first ratoon crop, with a net improvement in return over the years of ₱ 7740. The trash-farmed ratoon crop achieved the lowest cost (₱ 508/t). It was 31% below the cost of the conventional plant crop and 10.0% below the

Table 1. Summary of sugarcane yield response to trash farming (percent yield increase in cane tonnage) in Vietnam and the Philippines

NAME OF RESEARCHER	LOCATION	PLANT CROP	1ST RATOON	2ND RATOON	COMMENTS
Mendoza, T.C. (1989)	Philippines		+ 18.7 %	-	Average of 2 varieties
Mui et al., (1996)	Vietnam	+6.3 %	+20 %	+30 %	Average of 3 row spacings
Mui et al., (1997a)	Vietnam	+ 10.6 %	-	-	Average results of 10 farms
Mui et al., (1997b)	Vietnam	+ 4.2 %	+21.6 %	-	Average of 4 varieties
Average	-	+ 7 %	+ 20.1 %	+ 30 %	

potassium, nitrogen, and lower bacteria, actinomycetes and fungi than unmulched fields. The higher percent carbon denotes the unique contribution of mulching in terms of carbon sequestration into the soil, which is important in reducing greenhouse gas emissions (Mendoza 2001).

Soil conservation

Trash farming conserves the soil. Trash mulching sugarcane fields helps protect the soil as it minimizes and/or prevents soil erosion which is the principal factor leading to massive land resource base degradation, even on relatively flat to gently sloping lands (Rosario et al 1992). Without soil conservation, an annual loss of 20 to 200 t/ha of fertile topsoil can occur depending on soil type, slope and rainfall intensity. This rate far exceeds the tolerable rate of soil loss at 10 t/ha. Soil organic matter is also lost through erosion. Between 0.4 to 4.0 t/ha of organic matter is lost in a soil with 2% organic matter. A 200-t/ha soil loss corresponds to a 2.0 cm loss of topsoil, a resource that takes about 100 years to form. Such a reduction can occur over a 1-year period if soil conservation measures such as trash mulching, contour tillage and use of biophysical barriers like buffer strips or hedgerows for steeper slopes are not employed (Rosario et al 1992).

Economics of sugarcane production

Trash farming improves the economics of sugarcane production. A comparative profitability analysis of conventional ratoon cropping with that of

ratooned conventional crop. In the final year of the ratoon crop, additional returns could be generated after harvest of the sugarcane trash, about 8 to 10 tons of trash available, of which 60 to 70% could be harvested as a biofuel. For example, at Hacienda Luisita, 8.6 t/ha of trash per year (representing 68.8% recovery) are harvested on average. The peso value of this trash based on its nutrient content was estimated to be ₱ 143/t. Its peso value based on its equivalent oil energy value was estimated to be ₱ 2,899/t (Mendoza et al 2003). In the future, farmers may sell the material to mills. This would enable farmers to generate an additional income in the final ratoon year.

Fossil fuel usage

Trash farming reduces the fossil fuel usage of sugarcane production. The effects of trash farming practices on fossil fuel usage from agricultural operations were compared between conventional cane and trash farming (Table 3). The trash farmed crop had a higher ratoon yield (78 t/ha) than conventional cane (65 t/ha). While the increased yield in the trash farmed cane also increased the harvest/hauling energy usage, it also reduced the overall energy input per ton (mainly due to lower nitrogen fertilizer inputs and the impact of the increased yield). Fertilizer reduction was estimated to be 99 kg N/ha to 110 kg N/ha. The total fossil energy requirement for the fertilizer in the ratoon crop is thereby reduced to 9.1 GJ/ha (Mendoza et al 2003).

The other apparent way by which sugarcane trash farming reduces fossil fuel energy inputs is through the

reduction of tillage. There are two ways on how this occurs and they are as follows:

1. By increasing the number of ratoons, the frequency of land preparation associated with new plant cane establishment decreases. The most energy-intensive component is primary tillage or deep plowing (40-50 cm) as sugarcane is deep-rooted. Extending the number of ratoon cycles from the conventional system of 1P:1R plant crop:ratoon crop to 1P:3R or 1P:4R results in considerable reduction of energy inputs due to land preparation. A trash farming scheme of

originating from agricultural operations. A case-control study in the US suggests that people engaged in sugarcane farm-related occupations have significantly higher rates of lung cancer (Mulvey & Rothschild 1983). According to the US Occupational Health Department (1999) sugarcane workers have an increased risk of lung cancer and this may be related to the practice of burning foliage at the time of cane cutting. The burning of the sugar fields releases fly soot to the atmosphere which contains polycyclic aromatic hydrocarbons that have mutagenic and carcinogenic properties (Zamperlini et al 1997). A recent cancer study involving agricultural

Table 2. Agro-ecological importance of humus

<ul style="list-style-type: none"> • Humus gives the top soil a dark or brownish color, indicative of a fertile soil • Humus serves as stock of nutrients for higher plants • Humus provides several active agents, plant hormones and antibiotics • Humus supports nitrogen fixing organisms that supply additional nitrogen to the crop • Humus enhances the physical and chemical properties of soil by: <ol style="list-style-type: none"> 1. enhancing soil cation exchange capacity 2. improving the soil water holding capacity (4 to 5 x more than clay, humus absorbs water 80- 90% of its weight) 3. acting like glue to link mineral soil particles to so-called clay-humus complexes, thus improving soil-particle aggregation • Humus reacts with many substances to form complexes. For example, humus: <ol style="list-style-type: none"> 1. Reacts with oxides of iron and aluminum to form a stable aggregate, thus reducing toxic metal concentrations 2. Reacts with herbicides applied in the soil 3. Serves as buffer system for the pH value in the soil
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1P:3R results in a 50% reduction in tillage requirements, while a 1P:4R scheme results in a 60% reduction. This is a considerable amount of energy and cost savings due to reduced demand for diesel and lubricants, and fewer repairs and maintenance costs. Thus, about 8.2 GJ/ha of energy could be saved from crop establishment (Table 4). Likewise, farmers can reduce their capital outlay for equipment or animal (usually carabao or water buffalo), as well as widening the service area of farm tractors and implement. From 2 Hp of farm power, which would normally farm only 1 ha, 2-3 ha can be worked. The use of tractors for farming is energy intensive, and their manufacture also uses considerable amounts of energy.

2. Under trash farming, trash-mulched inter-rows need no cultivation. As per the trash farming scheme (Mendoza 1979, Mendoza 1985), the ratio of non-trash and trash mulched rows is 50:50. This represents a 50% reduction in inter-row cultivation.

Human health

Trash farming is conducive to human health. Sugarcane workers have been observed to have significantly high rates of mortality due to illnesses

workers in India (Amre et al 1999) also found an increased risk of lung cancer for workers employed in a sugarcane farm. Work involving burning after harvesting and exposure to fibers of biogenic amorphous silica during fieldwork may account for the increased risks of lung cancer and possibly mesothelioma among sugarcane farmers (Poolchund 1991). By eliminating the field burning of residues, trash farming reduces the health hazards associated with exposure to airborne particulate matter (fly soot and biogenic amorphous silica).

Promotion of trash farming

The positive impacts of trash farming on sugarcane production are yet to be fully recognized. Pre- and/or post-harvest burning of trash is still the dominant practice in the Philippines. Minimum estimates of burned cane fields in the Philippines are placed at 64% (Mendoza & Samson 2000). This value would be larger but burning is frequently prevented by wet weather during early and late harvest schedules. In contrast to the Philippines, the tropical zone of Northern Australia has undergone a recent rapid transition from burned to green cane harvesting and retention of crop residues as a surface trash blanket (Wood 1991).

There are many reasons for pre- and post-harvest burning of sugarcane fields in the Philippines (Mendoza, 1989) (and they are shown in Table 5. Pre-harvest

burning facilitates cutting and piling of sugarcane stalks. Post-harvest burning removes remaining obstruction to operations in establishing the ratoon crop.

Optimizing the trash farming system

It must be recognized that the adoption of trash farming is not simply the non-burning of cane. Some remedial measures have been tested to optimize the trash farming method. These are as follows:

1. *The use of self-detrashing varieties.* A few locally adapted and high-yielding cane cultivars exist that are self-

- Minimization of the bulky trash to be managed at harvest time. Detrashed leaves 8-9 months after planting represent about 25-33% of the total trash (12 t/ha) at harvest time.
- Creation of an active microbial inoculum that will initiate rapid decomposition of the remaining trash at harvest time (if moisture is available)
- Reduction of crop lodging caused by typhoons
- Suppression of weed growth and conservation of soil moisture

Table 3. Comparative profitability of conventional and ratoon cane and trash farmed ratoons.

ITEM	CONVENTIONAL RATOON CANE	%	TRASH FARMED RATOON	% OF TOTAL COST
Costs items (₹)				
Maintenance	3,510	10	5,488	14
Fertilizer	6,916	19	4,474	11
Harvesting/hauling	16,250	44	19,675	50
Land lease and management	10,000	27	10,000	25
Total Costs (₹)	36,676		39,637	
Net Return (₹)	21,694		31,038	43 % increase
Cost/ton cane (₹)	564		508	10 % decrease
Base Yield (TC/ha)	65		78	

detrashing (ie, VMC 86-550). Identifying and selecting cane cultivars that are self-detrashing in addition to their desirable agronomic traits is a novel breeding objective. Self-detrashing of varieties is becoming a more popular trait associated with new cane introductions.

2. *Wider row spacing to ease trash deposition.* Studies on spatial arrangement have been conducted to accommodate trash-mulching, in ways that would not require so much handling of the trash (Mendoza 1979, Mendoza 1985). A double row spaced at 0.5-0.75 m and a wider interval space of 2.0 m was found to be suitable for intercropping cum-trash farming (Figure 3Figure 3).
3. *Pre-harvest detrashing of canes.* The dried and non-functional leaves of the cane are manually removed starting 6-7 months after planting or 3-4 months before harvesting. The sugarcane plant requires only 7-8 leaves functional leaves. About 30 30-40 dry/non-functional leaves can be removed per plant, resulting in 3-4 t/ha of trash. If detrashing is done in the rainy season, the detrashed leaves will be largely decomposed by harvest time. The benefit of pre-harvest cane detrashing are listed below:

- Elimination of the difficulties/delays in cane stalk cutting at maturity
- Improved air (CO₂) circulation. Sugarcane can be sweeter at harvest (more sugar per ton cane). In one study, detrashed canes had 21.7% higher piculs of sugar per ton than trashy canes (Dosayla 1994).
- Exposure of the base of the stalk, facilitating the use of the mechanical cane cutter which could speed harvesting and reduce costs
- Improved sugar recovery and mill efficiency from cleaner (less trashy and muddy) canes
- Provision of essential employment during the off-milling season. The added benefits from detrashing readily offset the added cost.
- Facilitation of the introduction of short-maturing intercrops, especially in association with the double row planting patterns as described in Figure 3.

On the other hand, both small and large planters with tight budgets may find detrashing to be an added cost. Pre-harvest detrashing along with modified (double) row spacing is suggested (tested) as remedial measure to offset the difficulties associated with trash farming. More on-farm trials should be conducted to

explore and promote the benefits of this system. Since some Filipino farmers are already practicing trash farming on their farms, their efforts can serve as on-site examples for demonstrations to others.

Table 4. Comparative fossil/fuel energy use in conventional and trash farmed canes

	CONVENTIONAL	%	TRASH FARM	%
Plant Crop	GJ/ha		GJ/ha	
Land preparation	4.9	11.7	4.9	14
Planting	2.3	5.5	1.6	4
Inter-row cultivation	1.7	4.0	1.7	5
Fertilizer	21.3	51	17.7	50
Harvesting/hauling	11.5	27.5	9.7	27
Total	41.7	100	35.6	100
Energy per ton (GJ/TC)	0.52		0.42	
Base yield (TC/Ha)	80		84	
Ratoon				
Inter-row cultivation	0.57	2.0	0.9	5
Fertilizer	19.8	66.0	9.1	48
Harvesting and hauling	9.6	32.0	9.0	47
Total	30.0	100	19.0	100
Energy per ton (GJ/TC)	0.46		0.24	
Base field (TC/Ha)	65		78	

If the sugarcane producer is to realize the benefits of in-situ trash utilization:

- He must be flexible, tolerant, and ready to adjust to the labor/management requirements of trash farming. It may also be necessary to re-design planting patterns (furrow spacings) to accommodate trash and minimize trash handling difficulties.
- He must be able to define a plan of action outlining the conversion from burned to green cane harvesting.

CONCLUSION

In conclusion, trash farming provides the following benefits:

- 1) It increases the yields in the ratoon crop, ie, 20% in the 1st ratoon and 30% in the 2nd ratoon.
- 2) It extends the ratoon cycles; it is 1-2 ratoons initially, but the potential for a cycle of 4 or more ratoons (as practiced in Australia & Brazil) can be realized under Philippine conditions.
- 3) Nitrogen fixation can contribute about 110 kg N/ha (₱ 2,700/ha) or ₱ 0.8 B worth of N if 80% of sugarlands is trash farmed.
- 4) It improves soil properties, eg, soil tilth, which decreases need for tillage intensity, improves water

infiltration and water retention. This allows sugarcane to tolerate drought especially during the El Niño years.

- 5) It conserves soil and soil OM by preventing soil erosion. Eroded soils ranging from 20-200t/ha contains 0.4-4.0 t/ha OM.
- 6) It improves the economics of sugarcane production. It leads to 43% increase in net return in the 1st ratoon and costs 10% less to produce 1 ton of cane.
- 7) It reduces the fossil fuel oil usage of sugarcane production. A 48% reduction of energy use per ton cane was computed. This was due to the 9.1 GJ/ha energy savings from chemical fertilizer and 8.2 GJ/ha savings from new crop establishment.
- 8) It eliminates the health hazards associated with exposure to airborne particulate matter (fly soot and biogenic amorphous silica).

LITERATURE CITED

- Abrigo CC, ed. 1981. Organic fertilizer from cane trash as soil ameliorant. Proceedings of the 28th Annual Convention, PHILSUTECH. pp 448-462
- Alaban R, FC Barredo & AL Aguirre. 1990. An assessment of some indicators and determinants of farm productivity and soil fertility in VMC district. Trends Associations, Interactions. Paper presented during PHILSUTECH 37th Annual Convention, August 8-10 1990. PICC, Manila

Table 5. Reasons for pre- and post-harvest burning of sugarcane fields in the Philippines (Mendoza 1989)

Pre-harvest burning facilitates cutting and piling of sugarcane stalks.
<ul style="list-style-type: none"> • Unburnt canes slow the harvest. Of the 25-40 leaves produced by a sugarcane plant, only 7-8 are green at harvest. It is laborious to remove the dead leaves during the busy harvest period and burning accelerates harvesting by about 40%. • Sugar mills impose stiff penalties for delivery of trashy canes, since the mill extraction efficiency declines by 0.47% for every 1% of cane trash processed. While a trash loss factor table is available, farmers can be over-penalized for trashy canes, as it is somewhat a subjective measurement.
Post-harvest burning of remaining trash and tops (or even those unburned canes before harvest) is done for the following reasons:
<ul style="list-style-type: none"> • Unburned fields are perceived as "dirty" fields. Farm workers are accused of being lazy by the landowner ("haciendero") if the fields are "dirty". • Remaining trash and tops obstruct the operations involved in ratoon crop establishment or in land preparation for new cane establishment. • There are cases or experiences where properly piled trashes between cane rows are accidentally or deliberately burned together with the established cane crop. • It is laborious to pile the trash between cane rows to provide space for cultivation and fertilizer application. Harvest is also the time to establish new cane crops or ratoons. Competition for "labor" is severe. • Piled trash is perceived as hiding and/or breeding places for rats.

- Amre DK, C Infante-Rivard, A Dufresne, PM Durgawale & P Ernst. 1999. Case-control study of lung cancer among sugar cane farmers in India. *Occupational and Environmental Medicine* 56(8):548-252
- Boddey RM, OC de Olivera, S Urquiaga, VM Reis, FFL de Olivarea, VLD Baldani & J Dobereiner. 1995. Biological Nitrogen fixation associated with sugarcane and rice: contributions and prospects for improvement. *Plant and Soil* 174:195-209
- Boddey RM. 1995. Biological Nitrogen Fixation in sugar can: A key to energetically viable biofuel production. *Critical Reviews in Plant Science* 14(3):263-379
- Dosayla, R&D. 1994. The influence of trash on the yield components of sugarcane varieties. Paper presented at PHILSUTECH 41st Annual Convention, August 17-20, 1994, Cebu Plaza Hotel, Cebu City, pp 198-203
- Hill NM & DG Patriquin. 1990. Evidence for the involvement of *Azospirillum brasilense* and *Helicomyces roseus* in the aerobic nitrogen-fixing/cellulolytic system from sugarcane litter. *Soil Biology & Biochemistry* 22, 313-319
- Hodge R. 1998. Soil organic matter: Its central position in organic farming. In *Advances in Soil Organic Matter Research*. pp 355-363
- Mendoza TC. 1979. Optimum spatial arrangement in sugar cane-legume intercropping. MS Thesis UPLB College, Laguna, Philippines
- Mendoza TC. 1985. Bioproductivity and economic evaluation of some sugar cane production alternatives. PHD Thesis UPLB College, Laguna, Philippines
- Mendoza TC. 1989. Development of Organic Farming Practices for sugarcane-based farms. IFOAM Proceedings of the 7th Int'l Scientific Conference. Onagadougou. January 2-5 1989. Burkina Fasso. pp 189202
- Mendoza TC. 1993. Assessment of Sugar Yield Trends in the Philippines and their Implications. *Philippine Agriculturist* 76(2): 133-145
- Mendoza TC. 1995. From Sugar Exporting to Sugar Importing Country : What are the Reasons? Occasional Paper. Dept of Agronomy, College of Agriculture, UP Los Baños, College, Laguna. Nov 7 1995. 9 pp
- Mendoza TC. 2001. CO₂-greenhouse gas-reducing potentials of some ecological agriculture practices in the Philippine landscape. *Philippine Journal of Crop Science* 26(3): 31-44
- Mendoza TC & R Samson. 2000. Estimates of CO₂ Production from the burning of crop residues. *Environmental Science and Management* 3(1): 25-33
- Mendoza TC & R A Samson. 1999. Strategies to avoid crop residue burning in the Philippine context. Conference on Canadian International Initiatives toward mitigating Climate Change. April 24-May 2 1999, San Salvador, El Salvador
- Mendoza TC, ER Celestino & CJ Andam. 1987. Developing trash farming practices in sugarcane production: a preliminary report, PHILSUTECH Proceedings of the 34th Annual Convention, Amigo Terrace Hotel, Iloilo City, Philippines. pp 249-252
- Mulvey JJ & H Rotchschild. 1983. Sugarcane farming – Is there a link with cancer? *Ecology of Disease* 2(4): 267-270
- Mui Thi Alguyen, NT Dung, D Van Binhn & TR Preston. 1997a. On-farm evaluation of planting distance and mulching of sugarcane. *Livestock Research for Rural Development* 9(3): 1-6
- Mui Thi Alguyen, TR Preston, I Ohlsson. 1997b. Response of four varieties of sugarcane to planting distance and mulching. *Livestock Research for Rural Development* 9(3): 1-10
- Pineda FA.1956. Trash mulching improved the yield of sugarcane. PHILSUTECH Proceedings of the 196-198
- Poolchund HN. 1991. Aspects of occupational health in the sugarcane industry. *Journal of the Society of Occupational Medicine* 41(3): 133-136
- Patriquin D. 2000. overview of N₂ fixation in sugarcane residues: Levels and effects on decomposition. Zoology Department, Dalhousie University, Halifax, Nova Scotiat.
- Rosario EL, EP Paningbatan, A Gerwin & P Dionora. 1992. Study on the Causal Factors of Declining Sugarcane Quality in the La Carlota Mill District. PHILSUTECH Proceedings of the 39th Annual Convention, Bacolod Convention Plaza Hotel, Bacolod City. p 168-184
- Wood AW. 1991. Management of crop residues following green cane harvesting of sugar cane in north Queensland. *Soil and Tillage Research* 20:69-85
- Zabaleta JMT 1999. The Sweet Spot of Philippine Agriculture. The Food and Agriculture Centennial Book. 100 years of Philippine Agriculture. University of Asia and the Pacific, Manila, Philippines
- Zamperlini GCM, MRS Silva, and W Villegas. 1997. Identification of Polycyclic Aromatic Hydrocarbons in sugar cane soot by gas chromatography-mass spectroscopy. *Chromatographia* 46(11/12): 655-66