The Environmental Economics Dollars and Sense of Composting in San Diego County[1]

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Compost applied to soils has many benefits, among which are improved soil productivity, water conservation, carbon storage and enhanced sequestration, fertilizer and pesticide replacement, plant yield increase, and reduced pollution of surface and ground waters from nitrogen and phosphorus runoff. The two tables included herein provide a life cycle assessment (LCA) of potential human and ecosystem health and other environmental benefits from compost and mulch use in San Diego County. Benefits assessed include reductions in nine categories of environmental impacts: climate change; human health impairments from particulates, toxics or carcinogens; waterways eutrophication; atmospheric acidification; aquatic ecosystems toxicity; stratospheric ozone depletion; and ground level smog formation.

For this study Sound Resource Management Group's Measuring Environmental Benefits Calculator (MEBCalc) computes quantitative estimates of pollution reductions for each of these nine environmental impacts associated with diverting organic discards to use as composts or mulches. In addition to estimating benefits of pollution reductions, MEBCalc also estimates the reduced economic costs associated with each environmental category of pollution reduction. This yields an overall environmental benefit measured in dollars that supplements conventional calculations of economic costs and benefits associated with using composts and/or mulches as substitutes for conventional synthetic fertilizers and pesticides.[2]

Life Cycle Stages for Green Materials, Food Scraps, Fertilizers, and Pesticides

The life cycle stages for organic materials begin with generation and collection. For example, a household or business generator places food scraps in a suitable container, perhaps along with landscape materials and soiled paper. That container is generator-hauled or emptied into a contracted hauler's collection truck and transported to a consolidation point such as a transfer station. Or else driven directly to a composting or landfill facility for emptying. These facilities manage the materials by, respectively, processing them into marketable compost and mulch products or burying them.

Purchasers of compost use them in a variety of ways – for example, blending them into agricultural or garden soils or top spreading them on lawns. Managers of landfills may capture and use some of the methane and other pollutants emitted from the landfill following organics burial to generate energy, simply burn some pollutants in a flare, or let all the pollutants escape from the landfill's surface into the atmosphere. Thus, one of the benefits of diverting organic materials to composting is avoidance of pollution generated at the landfill, after adjusting for any decrease in pollution if the landfill energy is less polluting than other energy sources it displaces.

The other benefit of diverting organics to composting occurs when the compost purchaser reduces their purchase and use of synthetic fertilizers and/or pesticides. This would include avoidance of pollution during the entire life cycle for these manufactured synthetic products. Their life cycles begin with extraction of material and energy resources from natural ecosystems. Then come resource refining, fertilizer and pesticide manufacturing, distribution of these products through wholesalers and retailers, use by their purchasers, end-of-life (EOL) management of any product leftovers, and transportation usages incurred between some or all the foregoing life cycle stages for fertilizers and pesticides.

Results for Compost Produced from Green Materials and Food Scraps

Table 1 shows the pollution reductions associated with the substitution of one cubic yard of compost produced from yard and food discards generated in San Diego County for an amount of synthetic fertilizer containing an equivalent amount of nitrogen as that contained in one yard of compost.[3] Table 1 estimates also include environmental benefits from not landfilling the feedstocks used to make compost.

Each environmental benefits impact shown in Table 1 is measured in equivalent metric tons of one particular pollutant's emissions. This summarizes the effects of all pollutants that cause that impact. For example, climate change is summarized as metric tons of carbon dioxide equivalent emissions that are prevented or reduced by substituting compost for synthetic fertilizer and avoiding landfilling of compost production feedstocks.[4]

The compost environmental impact reductions for each category of environmental impacts are based on multiple national and local sources, mostly peer-reviewed, that take into account pollutant releases across the entire life cycle of organics materials and synthetic fertilizers and pesticides.[5] The organic materials lifecycle includes collection in source separated organics for composting versus collection in refuse for disposal, hauling to composting versus landfill, composting facility processing versus landfill, and hauling of finished compost or mulch to end markets where they are purchased as replacements for synthetic fertilizers and pesticides. The life cycle of synthetic fertilizers and pesticides includes resource extraction and refinement, manufacturing into synthetic fertilizers and pesticides, and hauling of those products to end markets.

The organics, fertilizer and pesticide life cycle impact assessments should also include impacts from the use phase of their life cycle.[6] The use phase is particularly difficult to assess. For example, "Nitrate leaching and contamination of water bodies is a function of a combination of many complex factors, including N fertilizer rate and timing, rainfall, irrigation, soil type, depth of the aquifer and geology."[7] Similarly, phosphorus (P) leaching and contamination of water bodies depends on, *inter* alia, P fertilization rate and timing, and the same additional influences as indicated for nitrate leaching. Due to these complexities, the use phase assessment for organics, fertilizer and pesticide herein only covers surface water eutrophication from runoff of nitrogen (N) as nitrates (NO_3) and runoff of P to surface waters.

To calculate surface water eutrophication from N and P runoff that seem reasonably representative for synthetic fertilizers versus compost, calculations for the life cycle use phase estimates included in Table 1 results are based on the following:

1. N equivalent content of applied fertilizer and compost = 1%.
2. P content of applied fertilizer = 0.8%[8]; P content of compost = 0.2%[9].
3. NO_3 surface water runoff rate = 24% of fertilizer N[10], and 14% of compost N[11].
4. P surface water runoff rate = 3.2% of fertilizer P[12], and 0.01% of compost P[13].

Fugitive emissions of methane and nitrous oxide are included for composting facility operations assuming a composting technology mix of 15% windrow and 85% aerated static pile (ASP) to reflect current and near-term-planned San Diego region processing ratios.[14]

Table 2 shows results when each impact is monetized. The monetization estimates are based on a review that the author conducted for Oregon's Department of Environmental Quality (DEQ) and Portland Metropolitan Area Oregon Metro referenced in endnote 2. The low and high estimates from that 2019-20 study for each of the nine environmental impact categories listed in the table were averaged and updated to 2020 dollars based on the U.S. national annual average all items consumer price index (CPI) for 2020 versus 2019.

As indicated on the table, climate change accounts for $139, or 69%, of the overall $200 monetized value in environmental benefit from using compost as a soil amendment which substitutes for synthetic fertilizers and pesticides. Waterways eutrophication reductions due to lower nitrogen and phosphorous surface water runoffs from compost account for $33, or 17% of total environmental value for compost; particulate pollution reductions account for $14, or 7% of total environmental value; and human toxics reductions for $11, or 6%, of total value from replacement of synthetic fertilizers and pesticides with compost amendments to soils.

Tables 1 and 2 also show the environmental benefits when using mulch as a replacement for herbicides on roadsides and other areas where weed suppression might be desirable. It should be noted that much of the reductions in environmental benefit associated with mulching are due to avoidance of the environmental impacts of use of resources for, and manufacturing of, pesticides. The use of mulch instead of herbicides for weed suppression provides estimates of quantities for mulching compared with herbicides. The increase in environmental impacts for particulates is associated with chipping and grinding operations during mulch production.

This study assumes that mulch is used mainly for weed suppression and is not incorporated into soils during use. That is, mulch does not displace synthetic fertilizer production or improve soil productivity like compost does when incorporated into soils.[15] Thus, mulching's overall environmental value is much smaller at $21 per cubic yard than compost's value at $200 per yard.

Climate change benefits account for virtually all the environmental benefits of mulch use. The environmental burdens in terms of particulate emissions from chipping/grinding reduce the per yard value of mulching by $0.62. However, the remaining 7 impacts show a mulching benefit in total of $0.57, offsetting most of the particulate emissions' environmental burdens from grinding and/or chipping mulch feedstock inputs.

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Table 1

Organics Processing Facility Outputs	Net Composting/Mulching Life Cycle Environmental Emissions Reductions/Increases(-) Metric Tons (MT) per Cubic Yard								
	Climate Change	Human Health - Particulates	Human Health - Toxics	Human Health- Carcinogens	Waterways Eutrophication	Atmospheric Acidification	Aquatic Ecosystems Toxicity	Ozone Depletion	Smog Formation
	eCO2	ePM2.5	eToluene	eBenzene	eN	eSO2	e2,4-D	eCFC-11	eO3
Compost	6.5E-01	2.3E-05	3.3E-02	4.0E-04	1.3E-03	7.3E-04	2.9E-06	1.7E-06	4.9E-03
Mulch	9.9E-02	-1.0E-06	-1.4E-05	1.1E-04	3.8E-06	7.4E-05	2.9E-07	4.9E-07	5.9E-04

Table 2

Organics Processing Facility Outputs	Economic Value of Net Composting/Mulching Life Cycle Environmental Emissions Reductions/Increases(-) 2020 US Dollars per Cubic Yard									
	Climate Change	Human Health - Particulates	Human Health - Toxics	Human Health- Carcinogens	Waterways Eutrophication	Atmospheric Acidification	Aquatic Ecosystems Toxicity	Ozone Depletion	Smog Formation	Total Dollar Value
	eCO2	ePM2.5	eToluene	eBenzene	eN	eSO2	e2,4-D	eCFC-11	eO3	
Compost	$138.89	$14.14	$11.46	$1.00	$33.00	$0.30	$0.01	$0.10	$1.21	$200.11
Value Distribution	69.4%	7.1%	5.7%	0.5%	16.5%	0.2%	0.0%	0.1%	0.6%	100.0%
Mulch	$21.21	-$0.62	$0.00	$0.26	$0.10	$0.03	$0.00	$0.03	$0.15	$21.15
Value Distribution	100.3%	-2.9%	0.0%	1.2%	0.5%	0.1%	0.0%	0.1%	0.7%	100.0%

[1] The City of Chula Vista Economic Development Department – Office of Sustainability funded this analysis on the environmental benefits and monetized environmental benefits of compost use in San Diego County. Republic Services' Otay landfill in Chula Vista and Republic's composting operation at that site are important inclusions in the data base that provides the San Diego County specific operational characteristics for landfilling and composting used in this analysis. Overall results assume a distribution of urban and rural uses for composts in San Diego County that is 46.5% to homeowner use on gardens and shrubs, 10.5% homeowner use on established lawns, 5.0% homeowner use on new lawns, 12.0% use on roadsides, 25.0% use in agricultural applications, and 1.0% use by nurseries. This distribution is used to compute compost benefits from enhanced soil carbon storage and above ground biomass growth induced when compost displaces synthetic fertilizer.

[2] See *Genesis, Methodology & Sources* for MEBCalc available at https://srmginc.com/images/GMS-MEBCalc.pdf for details on MEBCalc's methodology and basic data sources. *Economic Damage Costs for Nine Human Health and Environmental Impacts*, prepared by Dr. Jeffrey Morris from SRMG for Oregon Department of Environmental Quality and Oregon Metro, July 2020, details estimated costs and their peer-reviewed sources for each of the nine environmental pollution impact categories. This report is available at https://srmginc.com/images/Final-DEQ-Metro-Report.pdf . Both reports provide definitions and explanations of the nine mutually exclusive categories of environmental impacts. The latter report provides the basis for the costs shown in Table 2.

[3] Organic materials inputs and compost and mulch output estimates for San Diego County used in MEBCalc to compute the environmental impact reductions from compost or mulch use are, as follows:

Compost feedstock composition - green materials 70% (composed of leaves/grass 90% and prunings/trimmings 10%) and food & paper materials 30% (composed of food 80% and soiled paper 20%). Mulch feedstock composition – lumber 8%, leaves/grass 28%, prunings/trimmings 60%, branches/stumps 4%. Collected contaminants – 5% for compost feedstocks and 1% for mulch feedstocks.

Compost output by weight 58% of incoming feedstock (excluding contaminants) totaling 1.45cubic yards per short ton (2000 pounds) of clean feedstock at 800 pounds compost per cubic yard. Mulch output by weight 100% of incoming feedstock (excluding contaminants) totaling 5 cubic yards per ton of clean feedstock at 400 pounds mulch per cubic yard.

Sources: *Historical Incoming and Outgoing Greens Report for the Miramar Greenery* (2009-2019), City of San Diego and Hidden Resources communications with facility operator, April 2020; Seattle (WA) Public Utilities *2016 Organics Stream Composition Study: Final Report*, prepared by Cascadia Consulting Group, May 2018; Hidden Resources analysis of *San Diego Mulch and Market Study*, 2019, and *Regional Capacity Analysis*, 2020; Outgoing compost and mulch contaminants restricted per CA legislation and CalRecycle regulations to less than 1.0% of total weight, and chip and grind facility output for land application after January 1, 2018, no more than 0.5% of dry weight of contaminants greater than 4 millimeters, of which no more 20% by dry weight of this 0.5% shall be film plastic greater than 4 millimeters; California Air Resources Board (CARB) of California EPA, Industrial Strategies Division, Transportation and Toxics Division, *Method for Estimating Greenhouse Gas Emission Reductions from Diversion of Organic Waste from Landfills to Compost Facilities*, May 2017, Table 9; 14 CCR Section 18993.1(g), Recovered Organic Waste Product Procurement Target, The following conversion factors shall be used to convert tonnage in the annual recovered organic discard product procurement target for each jurisdiction to equivalent amounts of recovered organic discard products: …(E) 0.58 tons of compost or 1.45 cubic yards of compost. … (F) One ton of mulch.

[4] See references cited in endnote 2 above for discussion of the summarizing pollutants for the other 8 categories of environmental impact.

[5] These include sources cited in endnote 2, Carnegie Mellon University Green Design Institute's Economic Input-Output Life Cycle Assessment (EIO-LCA) model available at www.eiolca.net ; Powers, S. E., *Quantifying Cradle-to-Farm Gate Life Cycle Impacts Associated with Fertilizer Used for Corn, Soybean, and Stover Production*, Technical Report NREL/TP-510-37500, May 2005, p. 19 indicating 24% of fertilizer nitrogen leaches and notes that the Intergovernmental Panel on Climate Change (IPCC) estimates that nitrogen runoff to surface water as nitrate is 30%; (24% is used in MEBCalc's calculations for waterways eutrophication impacts from synthetic fertilizers nitrogen runoff to surface waterways); Nielsen *et al*, Deriving Life Cycle Inventory Factors for Land Application of Garden Waste Products Under Northern European Conditions, *Environmental Modeling & Assessment*, 2019, Vol.

24, pp. 21-35, estimates 14% for garden material without the woody fraction and 10% with woody fraction; Hoeve *et al*, Life cycle assessment of garden waste management options including long-term emissions after land application, *Waste Management*, 2019, Vol. 86, pp. 54-66, estimates 16% runoff for mature compost without the woody fraction and 14% runoff for mature compost including the woody fraction; (14% is used in MebCalc's calculations for waterways eutrophication impacts from compost nitrogen runoff to surface waterways. Runoff of nitrogen to surface waters is in the form of nitrates NO_3); Brown, S. and Beecher, N., Carbon Accounting for Compost Use in Urban Areas, *Compost Science & Utilization*, 2019, Vol. 27, No. 4, 2019, pp. 227-239; and Brown, S. *et al*, Quantifying Benefits Associated with Land Application of Organic Residuals in Washington State, *Environmental Science & Technology*, 2011, Vol. 45, pp. 7451-7458.

[6] The full life cycle of fertilizer and pesticide materials should cover environmental impacts for resource extraction from ecosystems and refining to convert virgin raw resources into inputs for manufacturing fertilizers and pesticides, manufacturing impacts, shipping to sales outlets and from them to consumers, use by consumers on soils, and disposal/disposition of any leftover fertilizers and/or pesticides. The full life cycle of organics converted to compost and mulch should cover environmental impacts from collection, hauling to composting facilities, compost and mulch production, hauling from composting facilities to sales outlets and on to consumers, use of compost by consumers on soils, and disposal/disposition of any leftover compost. These compost environmental impacts with credits for reductions in synthetic fertilizers and pesticides environmental impacts are compared with collection of compost feedstocks in refuse, hauling to transfer stations and on to landfills, and landfill operations themselves.

[7] Powers *et al*, *op. cit*.

[8] CARB, *op. cit*., Table 8. The P value presented in Table 8 represents the P value in synthetic fertilizer having 1% N that would be required for equivalence to the P effectiveness in a mature compost having 1% N.

[9] Moeller *et al*, Improved Phosphorus Recycling in Organic Farming: Navigating Between Constraints, *Advances in Agronomy*, 2018 vol. 147, Table 2, showing P and N estimates for mature composts that yield P/N ratios of 0.19 for green material compost and 0.21 for household material compost. The P value of 0.2% for compost used in our study then follows from our use of 1% N as the amount of nitrogen in what in LCA parlance is the functional unit for our study – one cubic yard of mature compost.

[10] Powers, *et al*, *op. cit.*, page 19.

[11] Nielsen, *et al*, *op. cit.*, Supplementary Materials, average of low and high emissions rates for mature garden material compost under low precipitation for three soil types.

[12] U.S. Department of Agriculture, Model Simulation of Soil Loss, Nutrient Loss, and Change in Soil Organic Carbon Associated with Crop Production, June 2006, page 171.

[13] MN Composting Council, Phosphorus and Compost White Paper, March 2019, Table 2. Based on average of two leaf/yard material/food compost feedstocks

[14] Windrow composting fugitive emissions are based on the CARB study referenced in the sources section of endnote 3. ASP fugitive emissions are based on San Joaquin Valley Air Pollution Control District, *Greenwaste Compost Site Emissions Reductions from Solar-powered Aeration and Biofilter Layer*, available at http://www.valleyair.org/Grant_Programs/TAP/documents/C-15636-ACP/C-15636_ACP_FinalReport.pdf ; and Climate Action Reserve Organic Waste Digestion Project Protocol Version 2.1 (2014) available at http://www.climateactionreserve.org/wp-content/uploads/2009/10/Organic_Waste_Digestion_Project_Protocol_Version2.1.pdf .

[15] Note that as mulch breaks down after surface application as a weed suppressant, it likely does provide soil health benefits like those from incorporation of compost into soils, only at a much-reduced rate.