Differentiating the Value and Cost of Compost Across Likely Farm Use Scenarios in Western Washington

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Abstract

Despite the expansion of municipal compost production in western Washington, demand from agricultural end users for this compost has lagged. To better understand the demand side of this relationship, this work compared cost reported by western Washington compost facilities with the potential value of compost in likely farm use scenarios for a number of different types of crops grown in western Washington. Scenarios were developed to determine the potential value of compost use in winter wheat, blueberries, raspberries, and direct market mixed vegetables. Compost cost including delivery and spreading was estimated at $27.05 per cubic yard. Compost value was less than cost for winter wheat and blueberry, while value exceeded cost for raspberry and direct market mixed vegetables. Under reasonable assumptions, the value of compost can exceed cost for some crops grown in the region. This study demonstrates that compost can have a wide range of values, depending on the cropping system to which it is applied, and the application rate needed to see impacts. Relevant to the discussion are potential changes to compost collection programs to improve the quality of compost (and hence improve its value to end users) and the potential of subsidies (for example, through shared spreading equipment) to increase demand from agricultural end users.

Introduction

Municipal organic waste collection programs across the country have expanded significantly in recent years including in western Washington. This is driven by a willingness of many citizens to pay to have their organic waste collected separately under the assumption that it will reduce their environmental impact – and by policies that require recycling or recovery of organic wastes. However, in contrast to a typical market, the amount of compost produced is determined solely by population, household food purchases, landscaping, and waste collection programs, which are all "supply side" factors. Compost supply does not depend on the "demand side", which is how much compost different users are willing to purchase at different price levels. For most goods, it is the interaction between the supply and demand-side in a market that fine tunes the quantity transacted and avoids either under or over-provision of the good.

In the case of compost, there is a clear understanding of the cost of supplying compost because this is already occurring. What is less clear is the value of compost from the perspective of potential users (i.e., demand centers). However, it is clear that at prices currently being offered, there is little demand for compost from agricultural end users in western Washington. This could be for two potential reasons:

- The value of compost to agriculture is underestimated or inadequately understood, and/or
- The value of compost in farming is lower than the cost of producing it.

Ideally, results from extensive field trials and long-term agronomic and horticultural research would provide evidence that could quantify the production relationship between compost and yield. However, while there are published studies of this nature, they are not extensive enough to develop precise compost value estimates.

The value of compost to a certain user depends on both agronomic (i.e., crop and soil) and economic factors. A useful step is to separate the two and quantify the extent to which compost values vary depending on economic factors, which includes prices for the crop and other inputs. Information is available on price ranges for most inputs and crops, so it is easy to run realistic best and worst case scenarios. Then, uncertainty in agronomic relationships can be handled by assuming a range (low, medium, high) of values for the effect of compost on crop yield. From this range, farmers can adjust the assumptions based on their own situation and knowledge. Assuming that the low end of the range may be near zero for compost, we have therefore focused on establishing a realistic "good" estimate that can elucidate whether or not there are likely to be situations in which the value exceeds the cost.

This report builds upon previous studies to further refine estimates of the economic value of compost which can provide a basis for this type of decision support. The value of compost depends on the feed stocks used in the compost and on the farm characteristics where it is applied including soil and crop type. While previous studies (discussed in the next section) have represented these relationships from a crop production perspective, this work updates previous syntheses and converts them into economic values. In particular, this report builds on earlier work in two important ways:

- It determines more accurate values for key parameters such as delivery and spreading costs, and a range of possible effects on crop yield based on the most relevant research available.

- It uses these parameters to build a range of compost values mainly driven by differences in crop type.

The results of this work should be interpreted in parallel with the results from the technical report *Lessons for Compost Policy: What Can Recycling Policy Tell Us?* While this present report focuses on the potential overlap between cost and agricultural value of compost under current conditions, that report provides perspective on possible interactions with the waste and compost stream at various points along the system.

Compost Characteristics and Longer-Term Effects

Compost has multiple uses in agricultural systems, and can be used to improve soil properties through the addition of organic matter, and as a crop nutrient source (though nutrient content of most compost is relatively low). Characteristics of compost can vary immensely and are influenced by both the feedstock and the composting process (e.g., nutrient content, particle size, stability, pH, soluble salts, physical contaminants). Some of the most frequently measured characteristics that are important for crop production include nitrogen (N) content and carbon to nitrogen ratio (C:N), both of which affect the availability of N, which is typically the limiting nutrient in agricultural systems. In terms of providing N to crops, a low C:N and high N content is preferable in composts. For compost with lower C:N (< 20) a percentage of total N becomes plant-available during the first year after application depending on multiple factors (e.g., soil conditions, compost particle size). Composts with C:N between 20 and 30 don’t release N during the first year and those with C:N greater than 30 will immobilize N in the soil and thus can *reduce* crop yield in the short run (Bary, n.d.; Gale et al., 2006). While particle size also affects nutrient availability, it is rarely reported in the scientific literature on this topic, and thus is not discussed further here. Table 1 shows examples of C:N, N, and percent plant available N during the first season for three different composts from municipal and non-municipal feedstocks used in a study conducted in Washington and Oregon (Gale et al., 2006) as well as C:N and N values from analysis of Cedar Grove compost, a large producer of municipal compost in western Washington.

Table 1. Comparison of characteristics of compost produced from different feedstocks and the municipal compost used in the scenarios in this report.

Compost Feedstock	C:N	N (%)	% Plant available N (first season)[c]
Broiler litter[a]	8-9	3.7-4.2	28 - 40
Dairy solids[a]	19-27	1.9-2.0	-2 - 16
Yard trimmings[a]	12-20	1.4-2.0	-10 - 19
Municipal compost used for the scenarios in this report[b]	15-18	2	No data

[a] values reported by Gale et al. 2006; plant available nitrogen was measured in the field after a full growing season.

[b] values from personal communication with Howard Stenn and from compost analysis from Cedar Grove Compost (Maple Valley, WA) from Jan. 2018. According to records from the Department of Ecology, feedstocks at this facility included food waste including pre-consumer food waste, land clearing debris, sawdust and shavings, other wood debris, and yard debris. (https://ecology.wa.gov/Asset-Collections/Doc-Assets/Reducing-and-recycling/Organic-materials/Washington-compost-facilities-and-material-types-2)

[c] Negative values for plant available nitrogen indicate immobilization of nitrogen in soil in the first season, which would negatively affect crops.

Inherent differences in soil properties (e.g., texture, mineralogy, pH) will also affect the response of a particular soil to compost application. In general, soils that are coarser in texture (sandier) have an inherently lower level of organic matter, and thus may show a greater response to the addition of organic amendments such as compost.

Though this report focuses on yield response during the first year after application, it should also be noted that compost application can have benefits to agricultural productivity that extend beyond this time frame. Likewise, potential benefits such as suppression of soilborne diseases affecting crops, where applicable, may take more than a single application to develop. Organic amendments such as compost may have benefits that improve the profitability of an agricultural operation in ways other than yield increases, such as by decreasing the need for inputs (e.g., lowering the need for irrigation water through increased water holding capacity) or increasing drought resilience. These benefits are more difficult to quantify. While these are important factors in the overall economic analysis of compost use, this report focuses solely on the more easily quantified first year yield response as a starting point for understanding the value of compost to agricultural users.

Other qualities of compost unrelated to agronomic performance can have a significant effect on demand from end users. A common issue in municipal compost is contamination with plastics, glass, or other unwanted materials mixed in with feedstocks that are difficult for composters to remove, has been an issue deterring farmers from purchasing compost from municipal sources. Processes to remove contaminants from feedstocks or finished compost (e.g., additional screening, picking line) add to the cost of production and are only able to remove a portion of contaminants. While this report is focused on the value of compost as related to its potential to increase crop yield, policy-based changes to reduce contamination are discussed later in this report.

Compost Use Scenario Development

Scenarios were developed to illustrate potential cost and value for compost used in the production of specific crops in western Washington (Table 2). While there are diverse crops also grown in eastern Washington, the longer transport distances, and in some areas, the availability of other composts (e.g., manure-derived) led to a focus on western Washington crops. The purpose of these scenarios is to examine the value of compost in specific situations where there is likely to be an impact, rather than assuming it has equal value across all agricultural production areas. Below we outline the process used for developing the scenarios in Table 2, and outline the assumptions associated with the scenarios.

Crop choice

Crops were chosen to represent the range of crop values grown in western Washington, with both low value (wheat -) and high value (raspberries, blueberries, direct market mixed vegetables) examples represented. These crops represent significant acreage in western Washington with wheat, caneberries (a category that include raspberries), and blueberries representing 4,003 acres, 9,924 acres, and 10,654 acres, respectively, in 2016 (WSDA). Though direct market mixed vegetables are not tracked specifically in western Washington, there are over 5700 acres of vegetables crops (various types) grown in the region and an additional 5,000 acres of “market crops” (largely consisting of mixed vegetables). Though 13,000 acres of potatoes are grown in western Washington, there has been reluctance from potato growers to apply organic amendments because of concerns about the potential to increase scab (a soilborne disease), thus potatoes were not considered in this analysis. Crops were also chosen based on the availability of regionally relevant crop enterprise budgets and research results to guide yield effect assumptions. These scenarios represent “good case” realistic scenarios - those combinations of location (close to Seattle metro area for lower transportation costs), high application rates, and, with the exception of wheat, high value crops that offer the best chance of maximizing value for the compost.

Yield effects

A meta-analysis by Wortman et al. (2017) included 53 studies worldwide examining first season crop responses to organic soil amendments when compared to a non-fertilized control. Wortman et al. found that across all amendment types considered (including animal manures, composts, and plant-based amendments), crop yield increased by an average of 43% over the non-fertilized control during the first season after amendment, though for plant-based amendments (e.g., municipal yard waste compost), the yield increase over the non-fertilized control averaged 27%. There are drawbacks to using this type of meta-analysis for estimating yield responses from application of municipal compost in western Washington including 1) the wide diversity of soils and climates in which studies were conducted may not be representative of conditions in western Washington; 2) the inclusion of many organic amendments (e.g., poultry manure) with nutrient concentrations greater than municipal compost in the meta-analysis; 3) the focus of the study was on annual crops, while some of western Washington's highest value crops are perennial berries; and 4) a comparison was made to a non-fertilized control, which does not reflect the reality of how farmers operate in conventional production systems.

Because of these limitations of the Wortman et al. meta-analysis, studies from the region (Afeworki et al., 2015; Benedict et al., 2017; Collins et al., 2015; Larco et al., 2014; Miles and Bristow, 2004; Youngquist, 2014; WSU Snohomish County Extension, 2013), and, in one case, a study from England (Lillywhite et al., 2009) conducted on the specific crops of interest were used to develop more accurate estimates of potential yield increases following compost application.

Compost application rates and projected yield increases were chosen that seemed possible based on the available literature for each crop type. Actual yield increases in these systems would, of course, vary and be dependent on many factors that are not addressed in these scenarios. Crop yield increases beyond the first year of compost application would be expected based on the fact that compost application is known to have effects beyond the first year (Reeve et al., 2012), but the calculations of compost value in this report only reflect value from first year effects of compost application.

Application rates

While the application levels in many of these scenarios are high, we are basing application levels on studies in which yield responses were observed for the crops of (see the *Compost Use Scenario Narratives* section for details on application rates chosen for specific crops). The authors of this report recognize that, like conventional fertilizer, compost should be applied to match nutrient needs of cropping systems as closely as possible to follow best practices for nutrient management and avoid potential losses of nutrients from the system. The scenarios are meant to illustrate a potential range of compost value for different cropping systems based on varying crop values, not to prescribe specific application rates or predict associated yield effects.

Fertilizer replacement value

Because the N, phosphorus (P), and potassium (K) contributed by the compost would presumably reduce fertilizer costs, this scenario underestimates the value of compost by not considering the fertilizer replacement value. For example, based on a recent analysis from Cedar Grove (January 2018), a compost sample contained 2.0% N, 0.8% P, and 0.96% K, on a dry weight basis. Based on this analysis, 20 dry tons per acre of municipal compost could provide 800 lbs N, 320 lbs P, and 384 lbs K. per acre. Based on personal communication with a regional fertilizer dealer and the nutrient analysis above, it would cost $18.84 to replace the total nutrient value (N-P-K) in one yard of compost with synthetic fertilizer in April 2019. It should be noted that because the nitrogen from compost is not all immediately available to the crop, there are some limitations on the usefulness this nutrient replacement value. It is estimated that 5% of N from municipal compost would be available during the first year after application (Andy Bary, personal communication).

Compost, transportation, and spreading costs

Much of the cost of using a bulky amendment, such as compost, is associated with transportation. For the sake of these scenarios, transportation cost was estimated from Seattle (an area of concentrated production of municipal compost) to three locations relatively close to the Seattle Metro area where substantial agricultural production exists: Enumclaw, Carnation, and Marysville. While these areas are not necessarily the most common locations for production of the crops mentioned, they were chosen as "best case scenarios" to minimize transportation costs. Cost of compost was estimated by getting quotes from a local compost producer on the cost of compost, delivered, to farmers in the specific locations chosen. The cost was the same for each of the three locations, and was $20 per yard, delivered.

Spreading cost was assumed at an additional $15 per ton (wet weight). Eastern Washington spreading costs are typically $9-10 per ton for compost or other bulky material with a minimum of 120 acres (Thad Schutt, Cedar Grove, personal communication). We assumed a slightly higher cost than this based on the fact that smaller field sizes, common west of the Cascades, are likely to have higher costs, even if some economy of scale could be achieved if custom spreading was more common in western Washington.

Calculation of net returns

Crop enterprise budgets were used to calculate per acre net returns without compost and with compost, taking into account assumed yield increases and increases in variable costs (harvesting) associated with these yield increases. The difference in net returns was used to calculate the value of a yard of compost. See the *Compost Use Scenario Narratives* section for specific details on the crop enterprise budgets used for each scenario. For the wheat, raspberry, and blueberry scenarios, net returns are calculated in terms of prices received for a conventional crop sold through standard marketing channels. The budgets for the mixed vegetable farms are based on direct market sales.

Additional assumptions

Along with the assumptions outlined in the above section, the following assumptions were made in the scenarios in Table 2:

1.) The compost being applied is generic compost from mixed municipal feedstocks and does represent a more nutrient rich or specialty compost product; and

2.) Compost is applied to soils that will show a yield response. We do not consider how compost value varies with soil conditions, though we recognize that soil conditions and past management history will play a major role in the potential value of compost in a given crop production setting.

Compost Use Scenario Narratives

A description of the process used to develop each scenario in Table 2 is provided below, including summaries of the research used to develop yield increase values and changes in net returns.

Soft white winter wheat scenario

Compost is spread at a rate of 20 dry tons per acre (76 yards per acre) prior to planting of conventional soft white winter wheat. A yield increase of 10% is assumed at an application rate of 20 dry tons per acre, based on the following studies:

- Municipal compost from western Washington applied to triticale (wheat/rye cross) at 18 dry tons per acre resulted in a doubling of yield in the Washington State University (WSU) Snohomish County extension research trials compared to business as usual (the farm's standard fertilizer regime) (WSU Snohomish County Extension, 2013).

- Biosolids compost (C:N 23-25, 1.5% N) was applied to wheat in Mt. Vernon, Washington at a rate of 28 dry tons per acre had no effect on wheat yield the first year. The second year wheat yield increased by 28% compared to plots with no compost and no N fertilizer and by 5% compared to plots with N fertilizer alone (Youngquist, 2014).

- A variety of municipal composts with feedstocks including green waste, kitchen waste, fruit and vegetable waste, and paper (C:N 11.7-31.8) were applied to wheat fields in England at rates of 5.8-13.2 dry tons per acre. These applications resulted in average yield gains of 7.5% for wheat compared to plots receiving no compost or fertilizer (Lillywhite et al., 2009)

Table 2. Compost application scenarios for different crop types in western Washington

	Crop	Application rate[a]	Per acre net returns without compost (standard fertilizer regime)	Assumed yield increase	Per acre net returns with compost	Per acre increase in net returns	Compost value[b] ($/yard)	Compost cost[cd] ($/yard; including delivery and spreading;)
Low Value	Soft white winter wheat	20 dry tons/acre	$644	+10%	$708	**+$64**	$0.85	$27.05
High value	Blueberry	20 dry tons/acre	$2,719	+10%	$4,233	**+$1,514**	$19.93	$27.05
High value	Raspberry	7.5 dry tons/acre	$3,913	+10%	$5,066	**+$1,153**	$38.43	$27.05
High value	Direct market mixed vegetable[e]	20 dry tons/acre	$12,549	+20%	$17,398	**+$4,849**	$63.80	$27.05
High value	Direct market mixed vegetable[f]	20 dry tons/acre	$16,144	+20%	$20,581	**+$4,437**	$58.38	$27.05

[a] Relationship between tons and yards of compost: Assumed compost bulk density of 44.5 lbs/cubic foot or 1200lbs/cubic yard and moisture level of 44%. (Moisture from Cedar Grove analysis: 39.8% [June], 48.6% [January]. average = 44%). 20 dry tons = 76 cubic yards; 7.5 dry tons = 30 cubic yards.

[b] Compost value is based on assumed yield increase. Actual compost value will be dependent on soil type and management history, which are not accounted for in this scenario.

[c] Cost quoted by Cedar Grove Compost as price for standard fine grade compost at cost that they could provide to farmers ($15 per yard FOB at Cedar Grove). Freight to Enumclaw, Marysville, or Snoqualmie is an average of $5/cubic yard based on a full load of 50 cubic yards. Total cost delivered is $20/yard.

[d] Spreading cost is assumed at $15 per ton (wet weight). Eastern Washington spreading costs are typically $9-10 per ton for compost or other bulky material with a minimum of 120 acres (Thad Schutt, Cedar Grove, personal communication). Though some economy of scale could be achieved if custom spreading was more common in western Washington, it’s unlikely that the cost would ever get as low as it is in eastern Washington because of the smaller field size that is common west of the Cascades.

[e] Net returns based on Colorado enterprise budget.

[f] Net returns based on British Columbia enterprise budget.

Yield and price information for soft white wheat was based on obtained an average yield in Skagit County for soft white winter wheat was reported to be 125 bushels per acre and in August 2018 soft white winter wheat was selling for $6.15 per bushel in Portland, with growers paying $1.00 per bushel for transport to Portland (Steve Lyon, personal communication). Assuming no change in variable costs with increased yield, net returns per acre would increase from $643.75 to $708.13, a net increase of $64.38 per acre. $64.38 per acre divided by 76 yards per acre equals a compost value of $0.85 per yard.

Blueberry scenario

Commercial yard debris compost (C:N 21, 1.1% N) was applied at a rate of 20 dry tons per acre (76 yards/acre) to conventional blueberries. This amount was determined based on application rates in Larco et al. (2014). The authors found that compost mulch applied at 80 yards/acre with sawdust resulted in 27% higher yields in organic blueberries in Oregon compared to sawdust alone. Since this scenario is for conventional blueberries, we have assumed a 10% increase in yield. Since nitrogen is generally not as limiting in conventional production as it is in organic production, it's likely that there would be less yield response as a result of additional N in the compost.

Costs and returns for blueberries are based on 2015 crop production budget for conventional highbush blueberries for western Washington (Galinato et al., 2016). Per acre production is based on blueberries in full production (year 7) and are 4,860 lb @$1.90/lb (fresh) plus 11,340 lb @$0.95/lb for total returns of $20,007 per acre. Net returns for the no compost scenario are $2,718.69 per acre. With the application of compost, we assume a 10% increase in yield, we assume a 10% increase in variable costs associated with harvest (hand harvest, mechanical harvest labor, loading and hauling) and no changes in fixed costs. In the compost application scenario, net returns are $4,233.38 per acre, or $1,514.69 per acre more than the no compost scenario. In this scenario, the compost value is $19.93 per yard.

Raspberry scenario

Compost is side-dressed onto existing conventional raspberry plantings at full production at a rate of 7.5 dry tons per acre (or about 30 yards per acre). Yield increase due to compost is assumed to be 10%. The following literature was reviewed and used as a basis for determining the yield increase value:

- Benedict et al. (2017) sidedressed dairy manure compost (C:N 16.5, 2.2% N) at 10 dry tons per acre on established raspberry plantings by found no significant difference in yield across treatments including composted dairy manure.

- In a study of methods to organically control root rot in raspberries in Vancouver, Washington, Miles and Bristow (2004) found that 20 dry tons per acre of dairy manure (1.1% N) increased raspberry yields 11 to 26% above the control plots, which received only synthetic fertilizer.

- Some of the benefits of compost use in raspberries are potentially related to the possibility of extending the life of a planting by suppression of soilborne pathogens, but there is not much literature supporting this.

Costs and returns for raspberries are based on Galinato and DeVetter (2015) crop production budget for conventional Meeker raspberries grown in Washington. Full production (starting in year 3) is 11,300 lbs/acre @$1.14/lb = $12,882 total returns without compost. Assuming a 10% yield increase and an associated 10% increase in costs of harvest labor and no changes in fixed costs, net returns per acre with compost are $5,066, or $1,153 more than net returns per acre without compost. In this scenario the compost value is $38.43 per yard.

Direct market mixed vegetable scenarios

The application rate of 20 dry tons per acre (or approximately 76 yards per acre) and assumed yield increase of 20% are based on unpublished results from replicated trials conducted by WSU Snohomish County Extension using municipal compost from western Washington and reported by Collins et al. (2015):

- 2012 conventional pumpkin trial: compost applied years 2011-2012, 20 dry tons per acre, 28% increase in yield compared to business as usual (synthetic fertilizer)

- 2013 conventional sweet corn trial: compost applied 2011- 2013, 15 dry tons per acre, 24% increase in yield compared to business as usual (synthetic fertilizer)

- 2014 conventional cucumbers trials: 3yrs compost (15-20 dry tons per acre) vs. Control, no new compost applied, 35% increase in yield compared to business as usual (synthetic fertilizer)

- 2014: organic green beans: 6.5 dry tons per acre, 19% increase in yield compared to business as usual (the farm's typical organic nutrient regime)

Costs and returns values are presented based on budget information from two sources:

- An enterprise budget based on four Northern Colorado mixed vegetable farms (median farm size 4 acres; Sullins, 2013). Using this enterprise budget, net returns are $12,549 per acre without compost. With compost, it is assumed that there would be a 20% increase in returns and an associated 20% increase in field and mechanical labor costs (as related to additional harvest costs) and no change to fixed costs. These changes in net returns of $17,398 per acre, or $4,849 per acre more than the no compost scenario. Dividing by 76 yards of compost, we calculate a compost value of $63.80 a yard.

- Enterprise budgets for British Columbia mixed vegetable production (16 different crops on approximately 3.5 acres; Afeworki et al., 2015). Values were converted from Canadian dollars per hectare to U.S. dollars per acre. In this scenario, net returns before compost application are $16,144 per acre. We assume that a 20% yield increase would result in a 20% increase in variable costs. Net returns with compost are estimated at $20,581, or $4,437 more than the no compost scenario. Dividing by 76 yards of compost, compost value is $58.38 per yard.

Results and Discussion

The scenarios outlined above offer a comparison of compost value across different crop types. In each of the scenarios the estimated cost of compost, including delivery and spreading, is $27.05 per yard. When the crops are soft white winter wheat and blueberry, the value of the compost is less than the cost ($0.85 and $19.93 per yard, respectively). For the raspberry and mixed vegetable scenarios, the situation is different, with the value of compost exceeding the cost ($38.43, $63.80, and $58.38 per yard for raspberries, and the two mixed vegetable scenarios, respectively).

The scenarios above represent "good case scenarios" for a number of crops grown in western Washington. These scenarios provide a framework for a decision tool that would allow farmers can adjust the assumptions based on their own situation and knowledge. While these examples are not comprehensive of every crop grown in every location in western Washington, they do demonstrate two important points:

- Under reasonable assumptions, the value of compost appears likely to exceed cost for some crops grown in the region, especially for higher value crops in locations that minimize transport costs.

- Compost can have a wide range of values, depending on the cropping system to which it is applied.

Two important items should be noted in these scenarios: First, while the increase in net returns per acre was greater for the blueberry scenario than it was for the raspberry scenario, compost was more valuable in raspberries because only 7.5 dry tons was applied as opposed to 20 dry tons for blueberries. This difference highlights the importance of further field testing to refine application rate and yield increase assumptions. Second, while these scenarios assume transportation to locations within King and Snohomish Counties, most raspberry and blueberry production in western Washington actually occurs further away, in Skagit and Whatcom Counties. In these areas, municipal compost would likely be competing with compost derived from dairy manure. These complexities are not addressed in this report, but would be a relevant topic for future study.

Hopefully, this report stimulates a greater sharing of information on practices and benefits of compost on crop production within specific production systems. It also sheds light on the agronomic dynamics that most need to be clarified if funding for field trials were available. In particular, field trials could provide more information on the effect of soil properties and past management on yield response due to municipal compost application in western Washington soils and allow more finely tuned estimates of yield responses for particular crops based on site-specific conditions (i.e., prediction of whether the crop yield response will be low, medium or high based on site conditions and management history). Further analysis on the question of compost value could benefit by research on the following questions, particularly in high value cropping systems:

- What is the value of non-fertility benefits of compost (e.g., disease suppression, water holding capacity, infiltration) that may impact yield over time or improve returns by reducing other inputs, or may take longer to appear?

- How do benefits vary between different soil types and based on past management?

- What are the effects of screening and other value-added processes on improving the value of compost (i.e., how relevant is a "generic" compost versus a specialty compost in this type of analysis)?

A related report, *Lessons for Compost Policy: What Can Recycling Policy Tell Us?* also provides insights that can be used to consider possible changes to the overall municipal waste and compost collection program. These could include changes to the feedstocks included in compost, subsidies to farmers for purchasing compost, or subsidies of equipment used to spread compost (e.g., via equipment sharing programs) to name a few.

Compost quality is an important driver of demand from end users. Concerns that farmers have over contamination of fields can outweigh the potential benefits to soil health or yield resulting from application of municipal compost. This has been perceived as a significant enough issue to motivate the creation of a working group to identify solutions (see the report Washington State Organics Contamination Reduction Workgroup: Report and Toolkit, 2017). Though this issue is not unique to agricultural end users, it may be especially problematic for them due to their price sensitivity (thus unwillingness to pay for further processing to remove contaminants), sensitivity to how their products are perceived, and preference for giving up modest gains to avoid risk of significant losses, even if that risk is small. On the last point, most farming operations are sole proprietorships with limited financial resources. It is therefore reasonable that they would give up a guaranteed modest improvement in profitability to avoid a calamitous outcome even if it is unlikely. This is probably how many farmers view the trade-off between using and not using compost, when contamination is a concern.

For the reasons outlined above, efforts to increase municipal compost use on farms must include consideration of the contamination issue. Policy interventions to minimize contamination of compost could take a variety of forms. Changes to materials and standards on consumer goods such as banning certain items like plastic silverware and straws could be one effective approach. Another alternative is to reduce the items that can be composted to reduce the chance that households mistakenly put contamination items into compost. It is true that these possible changes – and any other changes considered – would not be easy socially or politically, as they may require either public willingness to give up some conveniences provided by single use plastics, or accepting a lower rate of diversions of compostable materials from landfills.

Conclusion

The development of “good case scenarios” for utilization of compost within a number of crops grown in western Washington suggest that under reasonable assumptions, the value of compost appears likely to exceed cost for some crops grown in the region, especially for higher value crops in locations that minimize transport costs. This analysis also suggests that consideration of strategies to improve compost value by reducing contamination, and/or strategies to overcome the high investment costs needed in some cases to use compost (e.g., via equipment share programs) may be worth additional attention. In tandem with ongoing field trials to elucidate the farm situations where compost is likely to provide the greatest benefit, creative policy approaches could be taken to increase use of organic household waste in regional agricultural production, enhancing food system sustainability and reducing the use of non-renewable agricultural inputs.

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