Policy Alternatives for Federal Agricultural Subsidies:Fertilization Protocols and Their Effects on Crop Yields,Sustainability, and Food Justice

<u>Policy Alternatives for Federal Agricultural Subsidies: Fertilization Protocols and Their Effects on Crop Yields, Sustainability, and Food Justice</u>

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In the United States, the application of fertilizer in the agricultural industry too often leads to negative externalities, including the runoff of excess fertilizer into local waterways and the atmosphere, as well as the depletion of macro- and micronutrients from the soil over time. The consequences of these externalities can be costly, such as algal bloom in waterways, ozone depletion in the atmosphere, and perhaps most importantly a depletion of the nutrition value and hardiness of future crops. Given that these are broad-spanning problems that affect societal issues, including environmental sustainability and food justice, it is important for the federal government to ensure that the most efficient, effective, and equitable fertilization alternative is being put into practice. As the government's most direct method of regulating behavior in the agricultural market is the utilization of subsidies, the alternatives laid out for this analysis include maintaining the status quo of compensating for conventional fertilizer shortfalls with pesticides and herbicides by maintaining the current subsidy program, limiting subsidy provision to USDA-approved organic farms utilizing organic fertilizer, or limiting subsidy provision to farms utilizing remineralization techniques through the application of rock dust. Through this analysis, it was revealed that the current status quo represents the profit maximization alternative by producing the greatest crop yield, though it is obtained at great cost via externalities. As such, the recommended alternative is to incentivize the utilization of both USDA-approved organic fertilizer and remineralization amendments, which combined together have the capacity to meet or exceed current crop yield figures while also providing for more sustainable agricultural practices.

Longitudinal studies by the USDA have shown that agricultural crops today possess, on average, half the density of micronutrients such as iron, zinc, copper, manganese, and selenium when compared to those same crops in 1941 (Huling, 2001). As a whole, current agricultural processes too often leave the underlying soil depleted of essential minerals due to their tendency to emphasize high immediate crop yields over sustainable practices that would otherwise provide for the replenishment of said minerals. These minerals, as well as macronutrients such as nitrogen, phosphorus, and potassium, are not only vital to soil health and productivity, but also are essential components of the human diet that have become increasingly scarce in the agricultural products that we consume. In addition to these concerns, the continually growing global population has led to a commensurate increase in the demand for agricultural products over time, which has resulted in a great deal of pressure to produce ever-expanding crop yields as efficiently as possible. Under current conditions, this continual increase in agricultural production is not only restrained by mineral depletion but also provides for the risk of increased social costs due to negative externalities, such as the runoff of excess chemical fertilizers into local water sources. Therefore, the question at hand is whether an augmentation of current agricultural processes would adequately meet the demand for food production while also reducing the societal cost of food production through externalities such as the negative health benefits of eating less nutrient rich food and the negative environmental impacts of pollutants.

Clearly, this agricultural problem is also a policy problem. One of the most pressing concerns of any governmental entity is the health and welfare of the public, and thus it behooves these governing bodies to ensure that the most efficient and effective methods of food production are utilized, while also guarding against negative outcomes that are not effectively taken into consideration by the market. For instance, the potential health costs inherent in consuming nutrient deficient food and the potential environmental costs of chemical runoff are unlikely to be internalized in the market system. As such, policy intervention may be necessary to correct for these intervening variables and maximize the public good resulting from agricultural production. With this in mind, the following analysis aims to evaluate three popularly proposed fertilization protocols - conventional, organic, and soil remineralization – in order to ascertain the extent to which each protocol addresses crop production, environmental impact and nutrient density. Furthermore, the political and administrative feasibility of creating federal policies to encourage the use of each protocol is considered.

Background

During the mid-nineteenth century, Justus von Liebig, a German chemist, discovered and detailed the importance of nutrients, especially nitrogen, in maintaining healthy and thriving plant life. While he is today regarded as the father of the fertilizer industry, at the time of his discovery there was no way to effectively isolate and mass produce these nutrients for distribution on a wide scale. That all changed in 1909, when the chemist Fritz Haber of Germany's University of Karlsruhe made a landmark discovery that would forever change the face of agriculture. Through the combination of hydrogen, nitrogen, osmium, and generous amounts of heat and pressure, Haber succeeded in synthesizing ammonia, the raw material that was to become the primary component in synthetic nitrogen fertilizer (Simpson, 2009). At the time, this discovery was looked upon as almost miraculous, as the sheer volume of agricultural production in the developed world ballooned exponentially from previous levels. Unfortunately, the resultant widespread production and use of nitrogen fertilizer over time has revealed the darker side of Haber's discovery. Since nitrogen fertilizer must be applied liberally in order to maximize its positive effects on crop productivity, growers for decades have tended to apply more of it than their crops could absorb independently, leading to large amounts of nitrogen fertilizer running off into local waterways. Nitrogen pollution, while also being a common product of car tailpipes and industrial smokestacks, has wrought havoc on waterways as a result of this widespread industrialization of agriculture. This is because rogue nutrients such as nitrogen spur harmful algal growths as they flow through estuaries towards the ocean, which has led to seasonal dead zones in estuaries around the world. Left untreated, these issues have the potential to develop into more permanent losses of important fisheries and ecosystems that many people rely upon for their livelihood (Simpson, 2009).

The gradual realization of the potentially harmful long-term effects of widespread nitrogen fertilizer application has contributed to the emergence of the so-called organic movement, wherein consumers seek agricultural products that were produced with either less or no reliance on synthetic fertilizers and pesticides. According to the USDA National Organic Standards Board, organic agriculture meets this newfound consumer demand by being "an ecological production management system that promotes and enhances biodiversity, biological cycles, and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain, or enhance ecological harmony" (Delate, 2010). To further elaborate, Kathleen Delate goes on to explain that organic agriculture attains these goals by utilizing practices that consistently yield benefits, such as the use of crop rotation and advanced machinery, while discarding practices that have negative side effects for society and the environment (2010). As a result, organic agriculture relies heavily on organic fertilizer inputs, such as manure and compost, in lieu of synthetic nitrogen fertilizer.

With the emergence of the organic movement, wherein fertilization techniques are rolled back to the status quo of the early twentieth century, another school of thought has emerged that recommends an approach to fertilization that precedes even the use of compost: soil remineralization through the application of rock dust, sea minerals, and other natural means. According to its proponents, soil remineralization is a process of fertilization that occurs naturally over time, as rocks exposed to water and carbon dioxide due to glaciation and other means gradually produce a kind of rock flour that is transported by air and water to deposits called loess across the globe (Campe, Kittredge & Klinger, 2009). The soils affected by these loess, as well as volcanic soils affected by the similar addition of basaltic rock dust, are known to be amongst the most fertile soils in the world. However, even these naturally nutrient-rich soils can, and will, become depleted over time if they are not replenished. The process of soil remineralization, as applied to agriculture, aims to accelerate this otherwise natural process through the use of finely ground rock dust that is readily available as a byproduct of the aggregate and stone industries, which can be applied as fertilizer more readily than it would be otherwise available in nature.

The primary method by which the federal government has historically influenced the agricultural industry, dating back to the mid-1930's, is through the addition of subsidies as a form of farm income support (USDA, 2000). Prior to that point, government intervention in agricultural policy was limited to land distribution, infrastructure, and the provision of economic information meant to help farmers compete in their local markets. During the first World War, a rapidly growing urban populace as well as a large standing army provided more than enough demand for agricultural products, causing prices and therefore incomes of farmers to rise significantly. However, this newfound economic opportunity also led to a flooding of the market, as more and more Americans began to purchase farmland and begin growing crops, leading to a peak number of 6.5 million farms in the United States in 1920 (USDA, 2000). This agricultural production bubble finally burst in the 1930's due to a combination of dramatically reduced foreign demand, as European nations had finally recovered from wartime devastation, and the emergent economic depression of the time (USDA, 2000). This dramatic event, which left millions of Americans veritably destitute, would serve to shape agricultural policy for the next century.

One of the first agricultural policy interventions to be implemented by the United States government in the wake of the Great Depression was the Agricultural Adjustment Act of 1933, which provided a subsidy to farmers to encourage them to allow part of their land to lie fallow, or unplanted, so as to limit the production of agricultural products and thereby keep their prices reasonably high (United States Congress, 1954). Although this policy was renewed in 1938, it became increasingly controversial as it was argued that the government was placing undue constraints on agricultural production and effectively paying farmers to do less work. As such, the Agricultural Act of 1949 was created with the intention of superseding and repealing all prior legislation, with new subsidies being put in place to create price floors and ceilings for agricultural products, such that the government would pay for up to 90% of the parity between price floors and the current market value of most crops (United States Congress, 1954). Under current conditions, these subsidies remain in effect and serve first and foremost to protect farmers against volatile market prices, such that farmers are guaranteed to receive at least a certain predetermined price floor for their wheat, corn, sorghum, barley, oats, cotton, rice, soybeans, minor oilseeds, and peanut crops. Unfortunately, the method of distribution for these subsidies has opened the door for savvy farmers to game the system by locking in high government benefit rates when seasonal crop prices are low, only to store their harvest until market prices rise again to maximize their earning potential (Edwards, 2009). Since the taxpayer money being provided is meant only to ensure that these farmers receive a fair and consistent market value for their crops from year to year, such practices represent a waste of federal funds, especially in light of the fact that the vast majority of farmers receiving these inflated subsidies are large corporate entities that do not necessarily require the extra funding to remain solvent. Regardless, however, studies have shown that the continued provision of subsidies may be preferable to any other funding strategy, because farmers and the public alike are so accustomed agricultural subsidies that the automatic buy-in to the system likely increases the potency and political feasibility of related policy interventions (Whitfield, 2006).

However, given the aforementioned potential weakness of the current subsidy model, it is imperative to evaluate the other policy tools available as alternatives before committing to leveraging subsidies. As Niles and Lubell point out, one policy tool that is available is to simply issue a mandate, although this alternative is less than ideal because it is unlikely to be politically feasible and entails the significant increased administrative cost of blanket monitoring and enforcement (2012). Given these and other factors, Niles and Lubell advocate most strongly for "flexible policy tools" including solutions such as cap and trade and information provision tools (2012, p.42). Unfortunately, these policy tools would be less useful for this analysis than they are for more direct pollution control issues. For instance, the creation of a limited number of tradable permits would be overly complicated by the fact that the externalities being encapsulated are multi-dimensional, including the reconstitution of a wide array of macro- and micronutrients into the soil. Information provision tools, which in this case would increase accountability by requiring that consumers be made aware of the agricultural processes utilized to produce the products they consume, would be weakened for similar reasons because the public at large would likely be unaware of the intricate costs and benefits inherent in variable fertilization protocols, rendering them unable to vote with their purchases to support the most effective methodology.

One of the more direct and common policy interventions that the government utilizes to incentivize behavior is the implementation of new taxes or tax expenditures. According to Belcher and his colleagues, the enactment of taxes on undesired behaviors in the agricultural industry has historically been ineffective, as evidenced by the lack of success of the carbon tax in reducing carbon emissions in Canada (2003). This is likely explained by the fact that agricultural producers need only to pass the added expense on to consumers in order for new taxes to lose their potency as an incentive. On the other hand, tax expenditures such as tax credits have been demonstrated to be highly effective as behavioral incentives in agribusiness (Belcher et. al., 2003). Of course, one significant drawback inherent in any tax expenditure is that it would entail a significant net increase in government expenditures, which is likely to be politically unfeasible in the current federal climate of austerity and budget cuts.

Methods

Given the reliance on federal subsidy funds that has developed in the agricultural industry, as well as the current federal budget crisis that constrains additional spending, establishing criteria which must be met before subsidies can be received is an ideal solution for leveraging change in the current political and economic climate. If the incentivized behavior leads to the reduction of costly externalities without unduly affecting agricultural production, both farms that choose to and not to comply with subsidy regulations will be generating public benefits, in the form of the reduction of externalities or the reduction of federal spending, respectively. With this in mind, three policy alternatives will be evaluated in this analysis. The first, representing a continuation of present trends, is the application of synthetic nitrogen fertilizer, pesticides, and herbicides with blanket agricultural subsidies. The second is the removal of subsidies for all but USDA certified organic farms, so as to promote the application of organic fertilizers such as composts and manure. Finally, the third alternative is the removal of subsidies from farms that do not participate in the application of mineral fines, or rock dust, as a fertilizer and soil amendment. In order to objectively evaluate these alternatives, they will be judged in accordance with their projected performance on a number of criteria that will holistically provide a snapshot of their projected overall benefit to the agricultural industry and society at large, relative to each other.

One factor that must be taken into account when evaluating fertilization practices is the environmental impact of said practices. Specifically, the positive or negative effects of any given fertilization process on neighboring soils, waterways, and atmosphere encapsulates additional benefits or costs beyond those that pertain only to the local farmland upon which such fertilizers are being applied. Therefore, it is important to assess environmental impacts so as to provide the most accurate estimate of the relative cost to society at large of any given fertilization alternative. For the purposes of this analysis, environmental impact will be operationalized through the use of an index representing the relative risk that runoff of fertilization inputs into the surrounding soil, waterways, and atmosphere will occur. The primary methods by which fertilization inputs become external pollutants are soil leaching, storm water runoff, and airborne emissions (Fischer et. al., 2010). Soil leaching is the transfer of fertilizer via groundwater from the fertilization site to external sites. Storm water runoff, by contrast, is the transfer of excess fertilizer on the surface to external sites due to the flow of rain or other forms of irrigation. Airborne emissions, further, represent the vaporization and entrance into the atmosphere of fertilizer inputs. Therefore, alternatives will be assigned a score between zero and three, representing whether the fertilization process being considered entails a significant risk of soil leaching, storm water runoff, emissions of air pollutants, or some combination thereof. For example, a fertilization process with an environmental impact index score of two would entail a significant risk for two of the above avenues of pollutant runoff. This index purposefully avoids the use of numerical estimates as to the magnitude of pollutants produced by any given process, since many fertilization processes produce vastly different levels of runoff based on the quantity of fertilizer applied. For example, some farms make use much more fertilizer per hectare than others, which lends itself to very different measured levels of pollutant runoff for the same fertilization process. Instead of relying on such inconclusive data, this index represents the overall risk of pollutant runoff between alternatives as a function of the array of methods by which runoff may occur.

Of course, in a world of increasingly high demand for agricultural products, one of the most important considerations when weighing fertilization alternatives should be the projected yield of crops upon which said fertilizers are applied. For this analysis, estimated crop yield will be presented as an index with a base value of one, which represents the expected crop yield under the current status quo of an industrial synthetic fertilization protocol. Values below one represent estimated crop yields below the current status quo, while values above one represent estimated crop yields exceeding current trends. For example, a crop yield index value of 0.73 would represent a crop yield output of 73% relative to the expected yield from a synthetic fertilization protocol. These estimates of relative crop yield are drawn from an average of numerous experimental results presented in peer-reviewed journal articles, all of which compare alternative fertilization processes to the current trend of synthetic fertilization.

As an extension of crop yield, a measure of sustainability, or soil health over time, must also be considered. That is, maximizing the output of one's harvest for one year may not be useful if such practices will eventually deplete the soil and cause nutrient density and productivity to suffer as a result. Many nutrients are considered to be essential for the growth of crop plants, with the majority of these nutrients being scarce enough that they will quickly become depleted as a result of intensive farming without the use of soil amendments and fertilizers to replenish them. Of these, carbon, nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur are considered to be macro-nutrients, which are required in large amounts to ensure soil health and productivity (Fageria, 2007). Further, copper, iron, zinc, and manganese are required in smaller amounts, such that they are referred to as micro-nutrients, although this is not to infer that they are in any way less important than macro-nutrients in producing soil that is healthy, balanced, and able to consistently produce crops of a desirable volume and quality (Fageria, 2007). The effects of these individual nutrients with regards to soil and crop health vary, but include such benefits as protection against erosion, protection against pests and disease, and increased nutrient uptake (Amtmann et. al., 2008). Of course, the presence or absence of these nutrients not only serves as a representation of the underlying health of the soil and crops, but also as a reflection of the density of beneficial nutrients within the resultant crops. As such, the benefits of nutrient density for society are two-fold: healthier soil leads to greater agricultural productivity as well as greater health benefits resulting from the consumption of the resultant agricultural products. Therefore, it is clear that the maximization of nutrient density and diversity alike within the soil is of paramount importance when considering a fertilization alternative. There are numerous factors that affect nutrient availability from region to region, including soil composition and environmental characteristics, but the one constant is that the most favorable fertilization alternative is the one that provides for the sustainable provision of the greatest number of essential nutrients possible. To that end, each alternative will be assigned a score from zero to eleven, representing the number of essential nutrients listed above that the alternative has been demonstrated to reliably sequester or supply to the soils it is applied to.

Regardless of the sum total of benefits provided, any choice in the policy arena is necessarily governed by the cost efficiency of the available alternatives, such that the best fit is often the alternative that provides for robust benefits at the lowest cost per unit of benefit possible. This maximization of cost effectiveness is important not only from a budgetary standpoint, but also from a social justice standpoint, since minimizing the cost of crop production would likely lower the cost of fresh fruits and vegetables, thereby making them more accessible to more people who might otherwise be unable to afford such agricultural products. In order to operationalize cost efficiency while encapsulating the other criteria in this analysis, three different cost figures will be generated, representing the cost effectiveness of each alternative with regards to environmental impact, crop yield, and nutrient mineralization respectively. With regards to environmental impact, the cost of fertilizer application per acre will be divided by the environmental impact index subtracted from three in order to generate the estimated cost of each additional reduction of the risk of negative environmental externalities, such as nitrogen pollution. For alternatives with an environmental impact index score of three, it will simply be noted that no environmental impact risk reductions are present. Similarly, the cost of fertilizer application per acre will be divided by the nutrient mineralization index in order to determine the cost of each additional mineral replenished due to the fertilizer's application. Finally, the cost of fertilizer application per acre for each alternative will be divided by its crop yield index in order to generate the estimated cost of generating the same crop yield as an index of score of 1, which represents the average crop yield produced through conventional agriculture. For all of these estimates, the lowest value would represent the greatest level of efficiency, since it would indicate a lower average cost per unit of benefit as operationalized in this analysis.

Finally, it is vital in any policy analysis to take into account the political and administrative feasibility of the presented alternatives. However, due to the difficulty inherent in operationalizing the complex political, social, and institutional interests affecting these variables, no numerical values were assigned to represent them. Instead, they will be analyzed qualitatively for each alternative with consideration given to past legislative precedents and the predominant interests held by relevant stakeholders in the current administration.

Analysis

Blanket Agricultural Subsidies & Conventional Fertilization

Given the continuation of present trends, such that industrial crops are predominantly fertilized with a protocol involving the application of synthetic nitrogen fertilizer, pesticides and herbicides, the outcome would likely continue to be productive in the short term at the cost of sustainability over the long term. As such, this alternative's scores on the environmental impact and nutrient mineralization indices are reflective of this trade-off. Conventional agriculture is known to be vulnerable to all three of the primary forms of runoff, such that excess nitrogen fertilizer has a tendency to seep into surrounding waterways and soils through storm water runoff and soil leaching alike, while also evaporating into the surrounding atmosphere (Hepperly et. al., 2009). In addition, as synthetic nitrogen fertilizer is generally composed only of nitrogen, phosphorus, and potassium, it is capable only of directly replenishing these macronutrients, although it has also been demonstrated to be very effective at sequestering carbon as well (Gong, et. al., 2009). Given this information, conventional agriculture was assigned the highest environmental impact score, 3, and a fairly low nutrient mineralization score of 4. However, conventional agriculture represents the gold standard for crop yield, with an index score of 1, as its relatively high productivity will form the basis by which other alternatives are judged.

According to the most recent estimates of the United States Department of Agriculture, an average of 75 pounds of nitrogen, 46 pounds of phosphorus, and 67 pounds of potassium are applied per acre across the United States (2011). These estimates represent an average across the most commonly produced crops in the United States, including corn, soybeans, and wheat, and thus must be acknowledged to be for the abstract purposes of analysis rather than for the concrete analysis of any one crop. At an average cost of $479 per ton for nitrogen, $633 per ton for phosphorus and $601 per ton for potassium in 2011, and with an average of two fertilizer applications per year, the estimated total projected cost per acre of conventional fertilizer here would be $105.30 annually (USDA, 2011). Note that the cost of synthetic pesticides and herbicides are not internalized in this estimate. This is because these amendments are not applied for the purpose of fertilization but instead are intended to compensate for nitrogen fertilizer's inability to independently protect crops against invasive pests and weeds, and thus are merely additional costs stemming from the deficiency of certain macro- and micronutrients which are already encapsulated in the nutrient mineralization index. Given the above data, the standard level of crop yield per acre costs $105.30, of which each additional nutrient remineralized costs

$26.33, with no reductions in the risk of pollutant runoff internalized in the cost for this alternative. Finally, as is the case with almost any policy analysis, maintenance of the current status quo entails the highest political and administrative feasibility. This is because such an alternative would require no additional legislative action nor any changes to the current administrative structure in order to be implemented.

Subsidy Provision Exlcusively to USDA-certified Organic Farms

Alternatively, the application of screened compost material composed of organic matter and manure would likely produce similar, more environmentally friendly results. Studies have shown that organic compost significantly reduces nutrient runoff due to storm water and soil leaching when compared to synthetic fertilizer, as its application results in a gradual release of nutrients into the soil, reducing the risk that soil will be unable to absorb said nutrients before they can be washed away to outside water sources and soils (Hepperly et. al., 2009). Unfortunately, large-scale composting has been known to release significant amounts of air pollution in the form of greenhouse gases such as methane (California Environmental Protection Agency Air Resources Board, 2010). On the positive side, however, organic compost provides a significantly wider range of nutrients to the soil than its synthetic counterparts, including nitrogen, phosphorus, potassium, carbon, sulfur, iron, zinc, copper and manganese (Alberta Department of Agriculture and Rural Development, 2010). The latter three micro-nutrients, however, have been known to be released inconsistently and in less than adequate quantities by organic compost and manure, leading to production limitations on some organic farms. To compensate for this, researchers have applied rock dust in combination with said organic compost, leading to very positive results as much more abundant amounts of zinc, copper and manganese were able to enter into the soil under these conditions (Shivay, Krogstad & Singh, 2010). In light of this, organic compost was assigned an environmental impact score of 1 and a nutrient mineralization score of 6.

With regards to crop yield, the application of organic compost fertilizer has generally been shown to be relatively as effective as that of conventional synthetic fertilizer. For instance, Marzouk and Kassem found in a recent study that there was no significant difference in the yield of dates between organic and synthetic fertilization alternatives (2011). These findings are corroborated by numerous other peer reviewed studies across a wide range of crops, including one conducted by Francesco Montemurro that found no significant difference in the yield of lettuce between organic and synthetic fertilization protocols (2010). The lone exception to this can be found in the research of Robert Dufault, who found that less than half of the ears of sweet corn per plot were present when organic fertilizer was applied as compared to synthetic fertilizer (2008). However, Dufault acknowledges that this significant difference in yield is likely due to the fact that his experiments spanned only a single planting season, while other experiments tend to study fertilization application longitudinally. Therefore, over the long term, it would seem that organic compost can be safely assigned a crop yield index score of 1. Nonetheless, it is worth pointing out that the application of organic fertilizers may lead to an initial drop in crop yields before stabilizing to provide similar outputs as can be found through the application of synthetic fertilizers.

According to the United State Environmental Protection Agency, the cost of compost per ton ranges from approximately $26 for landscape mulch to $100 for high-grade industrial compost (2011). Since this analysis is focused upon industrial agriculture, the latter price point will be used, although it must be noted that no data is readily available to compare the effectiveness of low-grade and high-grade composts relative to each other, and thus the cost per acre reflected in this analysis may be a somewhat inflated estimate in practice. The nutrients in compost are steadily released over the course of up to six months, although other beneficial effects such as protection against nutrient loss due to runoff can be realized into the second or even third year after application (Pfeiffer, 1954). As such, two applications are recommended annually, although this method differs from that of synthetic fertilizer in that the nutrients provided by highly soluble chemical fertilizers are most readily available between three to six weeks after application, while the nutrients provided by organic compost are released steadily and thereby do not enforce such a short time window for optimal effectiveness. For the high-grade industrial compost being considered, Pfeiffer recommends an application rate of one ton per acre for all soil types (1954). All in all, the total projected cost per acre for this alternative would be $200 annually. In accordance with this estimate, the standard level of crop yield per acre would cost $200, each additional nutrient remineralized would cost $33.33 per acre and each additional reduction to the risk of environmental pollution would cost $100 per acre.

With regards to political feasibility, a shifting of government expenditures away from blanket subsidies and towards a more limited framework that provides funds only to USDA certified organic farms would be highly politically feasible in the current political climate. As is reviewed in this year's Congressional Digest, the current administration's deficit reduction goals have included plans to cut federal spending on agriculture, with recent legislation pulling subsidies from farmers who earn more than one million dollars per year as well as corporations manufacturing corn-based ethanol (2011). Given these recent acts of Congress, which are contrary to the federal government's historically steadfast support for farm subsidy programs, it appears that federal political stakeholders would embrace any reasonable cost-cutting measure, especially one that has the potential to provide for positive environmental and health benefits. On the other hand, the administrative feasibility of such an alternative is somewhat lower, as the addition of stringent requirements for the provision of subsidies would entail commensurate regulatory structures to be put in place. These additional oversight organizations would, in effect, expand the size of government and increase the overall administrative cost of the subsidy program, which would certainly offset the cost savings of reducing subsidy provision to a certain extent.

Subsidy Provision Exclusively to Farms Utilizing Remineralization Amendments

As the final alternative, the application of ground rock dust to soil represents perhaps the greenest and most versatile fertilization protocol. For one, ground rock dust is a material that is already produced and disposed of as a waste product by the quarrying industry, meaning that it is readily available and therefore its production would not entail much in the way of industrial processing, which reduces the need for additional energy inputs as well as the generation of pollutant outputs that are inherent in any form of large-scale industrial production. Beyond this reduced carbon footprint, the application of ground rock dust to soil entails little to no risk of nitrogen pollution or any other pollution due to storm water runoff, soil leaching or airborne emissions, as it releases its nutrients slowly over time and does not give off harmful gases in the process of doing so (Shivay, Krogstad & Singh, 2010). In addition, ground rock dust derived from granite and basaltic rock contains a huge amalgamation of macro- and micro-nutrients, including but not limited to carbon, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, copper, iron, zinc and manganese, all of which are readily available to soil when applied because basaltic rocks weather quickly and easily when exposed to the elements (Coleman, n.d.). Therefore, ground rock dust was assigned an environmental impact score of 0 and a nutrient mineralization score of 11.

Although ground rock dust is clearly far and away the best alternative with regards to reducing negative environmental impacts and providing for the remineralization of a diverse range of nutrients, its independent application sometimes generates somewhat underwhelming crop yields. According to a number of longitudinal experiments conducted by the Institute for Sustainable Tropical Agriculture and Resource Management in Queensland, Australia, the independent application of rock dust generated almost the same crop yield as conventional fertilizer for grain and oats, but only about 60% of the yield generated by conventional fertilizer when applied to field peas and soybeans (1993). Corroborating evidence can be found in the work of Othon Leonardos, as he similarly found that there was a significant difference between crop yields derived from ground rock dust fertilizer and synthetic fertilizer, with crop yields exceeding those expected of conventional agriculture by 10-30% only when rock dust was combined with synthetic nitrogen fertilizer (1987). Based on these studies, it has been hypothesized that ground rock dust alone does not provide enough nitrogen or phosphorus to applied soils, as these nutrients are required in very large quantities to optimize growth (ISTARM, 1993). The data, as a whole, suggest that ground rock dust as an alternative should be assigned a crop yield index of 0.8, as it averages about 80% of the productivity of conventional agriculture for the crops studied. However, it bears mentioning that ground rock dust has been experimentally shown to amplify the positive effects of nitrogen fertilizers, and thus it has the potential to significantly increase crop yields as compared to conventional agriculture when utilized under the right conditions.

Since the use of ground rock dust as a fertilizer is not a practice that is as widespread as the other two alternatives, no meta-analyses were available from which to draw numerical averages for the application rate and cost per acre of rock dust products. As such, this data was drawn from two leading companies that are producing and distributing two different ground rock dust fertilizers, Excelerite and Azomite. According to the producers of Excelerite, the recommended annual application rate for their product is 800-1,000 pounds per acre in the first year to remineralize soil and 450-500 pounds per acre each subsequent year for maintenance, although it is noted that after two or three years Excelerite can be effectively applied every other year (US Rare Earth Minerals Inc., n.d.). By contrast, the producers of Azomite recommend an annual application of 75-150 pounds per acre in the first year and 50-100 pounds per acre each subsequent year (Azomite Mineral Products Inc., n.d.). At a reported cost of only $0.07 per pound for Excelerite and $0.15 per pound for Azomite when purchased by the ton, it is clear that rock dust products represent the least expensive alternative so far, costing between $11.25 and $70 per acre in the first year and between $7.50 and $35 per acre in subsequent years. At an average cost of $40.63 per acre in the first year and $21.25 per acre in subsequent years, the standard level of crop yield per acre would cost $50.79 in the first year and $26.56 in subsequent years. In addition, each additional nutrient remineralized would cost $3.69 in the first year and $1.93 in subsequent years, while each additional reduction to the risk of environmental pollution would cost $13.54 in the first year and $7.08 in subsequent years.

The political feasibility of withdrawing subsidy funding from all but those who elect to utilize mineral rock dust as a fertilizer or soil amendment is somewhat lower than for the other alternatives, if only because federal standards for what constitutes the ideal amount and quality of mineral rock dust do not exist at current. Furthermore, the field of study that has emerged to advocate for this form of fertilization is still in a fledgling state, which could lead to significant difficulties for policymakers attempting to justify the withdrawal of funding for what many may consider an unproven method. Nonetheless, significant cost savings could be realized through this alternative just as they would be through the organic agriculture alternative, although the additional administrative complications could be similarly compounded as the government scrambles not only to establish oversight agencies but also to cement application standards for the fertilization protocol itself.

Figure 1: Summary of Findings

	Blanket Agricultural Subsidies & Conventional Fertilization	Subsidy Provision Exlcusively to USDA-certified Organic Farms	Subsidy Provision Exclusively to Farms Utilizing Remineralization Amendments
Environmental Impact Score	3	1	0
Remineralization Score	4	6	11
Crop Yield Index	1	1	0.8
Cost Per Acre	$105.30 annually	$200.00 annually	$41.63 first year, $21.25 subsequently
Environmental Impact Efficiency Score	N/A	$100.00 per reduction in risk, per acre	$13.54 / $7.08 per reduction in risk, per acre
Crop Yield Efficiency Score	$105.30 to obtain base level yields	$200.00 to obtain base level yields	$50.79 / $26.56 to obtain base level yields on more acreage (1.25 acres)
Remineralization Efficiency Score	$26.33 per nutrient, per acre	$33.33 per nutrient, per acre	$3.69 / $1.93 per nutrient, per acre
Political Feasibility	High	Moderate	Low
Administrative Feasibility	High	Moderate	Low

Recommendations

When considering cost effectiveness solely in relation to crop yield, it is easy to see why conventional agricultural protocols have emerged as the predominant form of fertilization in the United States. Although the application of ground rock dust amendments technically represent the least expensive alternative, even when weighted for the additional acreage necessary to produce the same level of output, this alternative does not necessarily represent the profit maximization alternative. Given the scarcity of farmland and the continually increasing demand for agricultural products, the natural tendency for private corporations is to try to produce the largest volume of crop yield possible per unit of farmland. However, such base-level considerations do not even come close to representing the whole picture of agriculture as it relates to society at large. In order to responsibly consider what fertilization protocol is truly the most beneficial, it is essential to internalize the costs and benefits inherent in the protocol's effects on public health and the environment. In this analysis, the number of vital nutrients remineralized and the relative risk of fertilizer runoff served as proxies for these considerations, and the data show that conventional agriculture represents the largest cost to society with regards to these variables. That is, conventional agriculture provides for both the largest risk of environmental pollution due to runoff and the smallest number of nutrients remineralized, the consequences of which are evident in Ed Huling's research on the decline of essential minerals in the foods that we consume on a daily basis (2001). Conversely, fertilization protocols incorporating organic or ground rock dust products have been demonstrated to either significantly reduce or all but eliminate the risk of environmental pollution due to fertilizer application, while also providing for the remineralization of a more diverse range of macro- and micro-nutrients that not only enhance soil health but also the health of consumers.

While both organic and ground rock dust fertilization protocols are better options than conventional fertilization when taking into account external environmental and health costs, with ground rock dust fertilizer being both the least expensive and most cost efficient alternative of the three, neither alternative satisfies the important goal of increasing crop yield output relative to current conditions. However, as mentioned earlier, studies have shown that hybrid combinations of these protocols that allow for an adequately abundant supply of nitrogen while also replenishing key macro- and micro-nutrients have the capacity to significantly increase crop yield outputs as compared to conventional synthetic fertilizers alone. Currently, academic research has focused mostly on the conjunction of synthetic fertilizer and organic compost or other amendments such as ground rock dust, with promising results including a 5%-20% increase in yield returns for sugarcane when combining synthetic fertilizer with manure and a 10%-30% increase in returns found in Leonardos' aforementioned study combining synthetic fertilizer with rock dust (Bokhtiar & Sakurai, 2005). The current analysis provides evidence that organic compost with manure itself contains sufficient nitrogen, potassium, and phosphorus to fuel adequate crop growth, as its independent application has been shown to produce nearly identical yield returns to those found in conventional industrial agriculture. Therefore, it would seem that using organic fertilizers in conjunction with ground rock dust products such as Excelerite would provide for the ideal fertilization protocol to incentivize through federal subsidies. Additionally, the relative lack of political and administrative feasibility for restricting subsidy provision based on the application of mineral rock dust would be offset somewhat by incorporating it into the well-established USDA standards set forth to define organic agriculture. Although such a protocol would be relatively costly altogether, crop yields would likely surpass current conditions while also allowing for the maximum benefit of aforementioned reductions in environmental and health costs due to destructive runoff and nutrient deficiency. These almost universal improvements to the current conventional agricultural protocol would serve to more than justify the increased cost.

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