Farmer and Practitioner Conceptions and Experiences with Soil Balancing

RESEARCH REPORT

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Executive Summary

For decades, many farmers and independent consultants in the United States have reported benefits from following a "soil balancing" or Base Cation Saturation Ratio (BCSR) approach. A BCSR fertilization program seeks to attain a particular balance of base cations (particularly calcium, magnesium and potassium, or Ca, Mg, and K) to improve soil properties and crop performance. At the same time, the effectiveness of BCSR as a strategy to manage soil fertility has been largely dismissed by most Land Grant University soil scientists and agronomists. Indeed, the scant published scientific literature on the topic has failed to replicate any consistent effects of a BCSR approach on crop yield and other agronomic outcomes. Rather, the scientific community and most mainstream agriculturalists prefer to design fertilizer recommendations that provide a sufficient level of available nutrients (SLAN), often integrated with a buildup and maintenance (B&M) program, to meet the annual requirements of common field crops.

The persistence of soil balancing practitioners in the face of scientific skepticism provides an example of a gap between knowledge derived from rigorous scientific experiments and expertise drawn from practical experience. Moreover, there has been little systematic effort by the scientific community to capture information about the beliefs, behaviors, and observations of soil balancing practitioners. To fill this gap, we conducted semi-structured interviews with 33 organic farmers and crop consultants and surveyed 859 organic corn growers in 2017 and 2018.

Soil balancing consultants in our study described soil balancing using a much broader definition than had been previously realized by researchers. While they continue to value achieving base cation ratio targets, their approach to soil balancing usually includes a broader suite of cultural practices (e.g., application of micronutrients, use of manure, crop rotations, and tillage) that work together to improve the chemistry, biology, and physical structure of soils. According to these consultants, calcium interacts with other essential nutrients to influence soil physical properties (particularly drainage), nutrient availability, and soil biology to provide optimal conditions for crop growth and crop quality. Moreover, they believe that calcium is central to facilitating the plant availability and utilization of soil macro and micro-nutrients. In contrast, the standard SLAN/B&M framework focuses more on levels of individual nutrients and looks less at the potential interactions among different elements.

In our farmer interviews, producers often framed soil balancing ideas around an even wider range of concepts and behaviors. Their understanding of soil balancing was expressed in terms of the use of particular soil amendments and soil management practices (not as complex theories of base cation interactions). For example, in response to questions about soil balancing, most farmers described a wide set of management practices (including but going beyond BCSR amendments) designed to improve soil quality. Compared to consultants, they were also more skeptical about the economic returns from the use

of purchased soil amendments, including high-calcium products. More broadly, they expressed a preference for maintaining soil 'balance' through applications of on-farm manure and compost, as well as cultural management practices like crop rotations and cover crops.

Our survey results demonstrated that over half of organic farmers in Indiana, Michigan, Ohio, and Pennsylvania reported using soil balancing methods (defined as seeking to hit BCSR Ca:Mg ratio targets). Farmers who self-identified as soil balancers were more likely to report using high-calcium (Hi-Cal) and gypsum amendments and were more likely to use a wide range of other soil amendments (organic NPK fertilizers, micronutrients, and microbial inoculants and stimulants) than other organic farmers. They were just as likely to use manure and compost as non-soil balancing organic farmers.

In surveys and interviews, self-described soil balancers reported a wide spectrum of positive effects from soil balancing. Consultants and farmers generally attributed these effects to the interactions of a diverse set of practices rather than just the BCSR component of soil balancing. While improved yield and economic returns were mentioned, these outcomes were not cited as frequently as improved overall soil quality and soil structure. Economic analysis of self-reported soil amendment expenditures and crop yields from our survey suggests that farmers using high-calcium amendments experience higher corn yields, but higher expenditures offset increased revenues, leading to similar net returns. Many farmers discuss concerns for amendment costs while also indicating satisfaction with positive results from soil balancing. Future soil balancing research would benefit by better incorporating the complexity of consultant and farmer views, conceptions, and experiences.

Contents

I. Introduction

Soil health management is increasingly a concern for farmers and scientists (e.g., (Wander and Drinkwater 2000; Carlisle 2016; Roesch-McNally et al. 2018). This is particularly true for certified organic farmers as soil health was the central focus of organic agriculture since its beginnings as a distinct farming movement. There is growing awareness among organic and conventional farmers, alike, of long-term declines in soil organic matter and other indicators of soil quality, and growing interest in conservation tillage, crop rotations, cover crops, and other management practices thought to boost soil health. Among the scientific community, there is an increased understanding of and interest in the complex relationships between physical, chemical, and biological processes in soils that are associated with soil quality and soil health.

Farmers and scientists use different approaches to assess the performance of soil management practices on soil and crop health. Farmers tend to rely on personal experience and sensory observations and focus more on *whether* a management practice works, whereas scientists prefer using controlled experiments and are more interested in *why* something happens. For example, scientists rely heavily on analyses of soil samples and repeated randomized trials to make soil fertilizer application recommendations and track changes in soil health, whereas farmers tend to approach soil health descriptively, dynamically, and holistically (Romig et al. 1995). These different ways of knowing contribute to divergent belief systems about the effectiveness of alternative management strategies designed to manage soil fertility and promote soil health.

For example, there are three main philosophies which can be used to interpret soil test reports and provide appropriate fertilizer recommendations. Those include (i) sufficiency level of available nutrients (SLAN), (ii) buildup and maintenance (B&M), and (iii) basic cation saturation ratio (BCSR) concepts (Black, 1993). To manage soil fertility, university soil scientists and agronomists nearly all recommend a hybrid of the SLAN and B&M approach. SLAN focuses on applying macronutrients to the soil that are deficient according to soil tests. Sufficiency is defined as the level beyond which it is unlikely there will be a yield response to fertilizer application. The B&M concept involves the idea that once a field contains sufficient nutrient levels, farmers should apply fertilizers and other amendments at volumes equivalent to the estimated amount of nutrients removed in harvested crops (Eckert and McLean 1981; Olson et al. 1987; Chaganti and Culman 2018).

Soil balancing is an alternative theory of managing soil fertility that is based on maintaining an ideal Base Cation Saturation Ratio (BCSR). Soil balancing theory emphasizes the important role played by calcium on crop growth and soil physical and chemical properties. Because soil particles have a fixed capacity to hold cations (known as cation exchange capacity, or CEC), soil balancing advocates recommend raising or lowering levels of three key base cations – calcium (Ca), magnesium (Mg), and potassium (K) – to achieve Ca:Mg and Ca:K ratios that optimize soil health and the availability of nutrients to plants.

Although the basic soil balancing idea was first articulated by Oscar Loew in 1892, most current consultants and practitioners look to William Albrecht's writings as laying the foundation for the approach (Chaganti and Culman 2018). Albrecht, a soil scientist from the University of Missouri who wrote extensively on the BCSR idea from the 1940s through the 1960s, believed that a heavy reliance on the use of inorganic chemical fertilizers in modern agriculture was depleting soils of adequate levels of nutrients, particularly calcium. He also believed that declines in soil calcium levels were adversely affecting soil health, crop/forage quality, and animal and human health. Albrecht's ideas have been further developed and disseminated by a group of soil and crop consultants, particularly Charles Walters, the founder of ACRES, U.S.A. Currently, most BCSR practitioners recommend using soil amendments (particularly Hi-Cal forms of lime and/or gypsum) to achieve recommended levels of soil base cation saturation of 60-75% Ca, 10-20% Mg, 2-5% K, and 15% of other cations (Kopittke and Menzies 2007). For several decades, BCSR has been a common approach to soil fertility management among both conventional and organic farmers and is supported by a large number of books, workshops, and conference presentations from private sector soil balancing consultants around the country.

Although the BCSR approach has been promoted and practiced for several decades among farmers and consultants, it has received little support from the scientific community (Kopittke and Menzies 2007), and the handful of published peer-reviewed papers in the literature have been unable to reproduce the benefits reported by farmers and consultants (Chaganti and Culman 2018). Moreover, there has been little systematic research to document the extent of its use in different farming systems and to measure outcomes other than crop yield.

In this paper/report, we seek to fill this gap by addressing five key research questions:

1) What do practitioners do when they say they are using soil balancing practices, and how does it compare to a standard definition of the approach?
2) Are there differences between the ways farmers and consultants practice soil balancing?
3) How common is the use of soil balancing among organic corn farmers?
4) How do organic corn farmers who use soil balancing differ from others in their soil management behaviors?
5) What economic and agronomic outcomes do farmers and consultants observe from the use of soil balancing practices?

Our work is part of a larger interdisciplinary effort to test the impact of soil balancing on a wide range of outcomes (crop yield, crop and soil quality, weed pressure, etc.) in collaboration with farmers and consultants in the state and region. The project was motivated by reports of positive outcomes from farmers and consultants who practiced soil balancing (Linder 2015; Zwickle et al. 2014). The larger project involves (1) on-station research trials to test the impacts of changing the Ca:Mg ratios; (2) on-farm research trials that tested for the effects of different soil balancing amendments; and (3) systematic social science research using interviews and surveys to capture the perspectives, practices, and perceived outcomes from soil balancing practitioners and consultants. This report summarizes the results of this third component of the project.

II. Methods

A. Interviews

The data for this report was drawn from 28 semi-structured interviews with 33 individuals conducted by the first two authors of this study starting in June 2017 and ending in August 2018.[1] The interviewees were located primarily in Ohio but included participants from Illinois (1 farmer), Michigan (1 consultant), and Pennsylvania (1 interview with two consultants and three farmers). Most interviews were with a single individual, but several included multiple informants in a single interview. The majority of the interviews were conducted in person with seven interviews being conducted over the phone due to distance or problematic weather conditions. Interviewees were recruited to the project because they were identified as a soil balancing practitioner or consultant by members of The Ohio State University (OSU) research team and our advisors. Some of the interviewees served on the OSU project advisory board (N=5), hosted on-farm trials on their farm (N=8), or had soil samples taken at their farm by project scientists in 2015 (N=5). Others self-identified as a soil balancer through a sign-up sheet distributed at a meeting of the Ohio Ecological Food and Farm Association (OEFFA). Additional farmers and consultants were identified by asking interviewees if they knew of other farmers and consultants who practiced or advised on soil balancing through snowball sampling. Of the 33 participants, 11 worked primarily as consultants,[2] and the remaining 23 were farmers who operated a diverse mix of operations.[3] It should also be noted that 11 of the 33 participants were members of different types of Plain Anabaptist communities (Old Order Amish, Mennonite, or Apostolic).[4] Plain farmers tend to have distinct and tightly interconnected social networks and also may have distinct farming practices related to technological restrictions prescribed by their church.

Interviews lasted from 30 minutes to several hours, with the majority lasting about an hour and a half. Topics included questions about the history and background of the respondent and their farm operation, details on how they manage soil fertility and soil quality on their farm, and information about changes they had observed in their soils over the last 5-10 years. After capturing their general approach to soil management, we asked a detailed set of questions about their familiarity with, conception, and use of soil balancing practices. If they reported the use of soil balancing methods, they were invited to share their observations about the impacts of soil balancing on their soils, crops, weeds, or other aspects of their farms.

Interviews were recorded with the permission of the respondents. The digital recordings were transcribed and reviewed for accuracy, then uploaded to NVivo 11, a software tool used to categorize and organize themes systematically as they pertain to research questions (Saldana 2016). Through structured analysis of the interview transcripts, we identified the prevalence of different soil management practices among our respondents, captured the conception of soil balancing and specific practices which farmers and consultants identified as being part of a soil balancing approach. We also kept track of reported outcomes interviewees attributed to the use of soil balancing methods. The primary author constructed a codebook that identified key themes in the answers to these questions and defined decision-criteria for coding farmers using these themes. The second author reviewed the codebook against the transcripts, and

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[1] The researchers obtained permission from the Institutional Review Board at The Ohio State University to conduct this research.

[2] Five of the consultants were also farmers. Two were corn farmers, two were vegetable farmers and one was a dairy farmer. One person was classified as consultant because of his reputation and influence on the farm community, although he did not do actual paid consultancy work.

[3] Farmers interviewed (excluding consultants) had diverse farm enterprises: Vegetable/Berries (9); Cash grain (5); Dairy (6); Diversified Vegetable and Livestock (2); 1 Retired Dairy farmer.

[4] Anabaptists are Christians who formed in the Protestant Reformation period based on their emphasis on baptism as a conscience choice and ideas of separation of church and state. Plain refers to groups who have made collective restrictions on certain types of clothing and/or technology because of deeply held values.

areas of disagreement or ambiguity were discussed. The codebook was updated iteratively until consensus was reached about the proper definition and application of key themes. These peer debriefings enabled the researchers to comprehend, compare, and challenge each other's interpretation of theme identification in the interview transcripts (Creswell and Miller 2000). On the whole, the interview results are shared qualitatively in the results below. However, to give an approximate sense of importance for different concepts, we also quantified the number of farmers or consultants who mentioned a concept and the percent of the interview transcript during which a concept was discussed.

B. Literature Review

Another source of data was a review of the practitioner literature[5] on soil balancing, including books and websites associated with some of the most prominent regional and national advocates of the BCSR approach. Many of the core texts on soil balancing, including collections of Albrecht's original papers, are printed by ACRES, U.S.A., an organization that disseminates information about production-scale organic and sustainable farming practices (Kinsey and Walters 2006; McKibben 2012; Brunetti 2014). These include *Hands-On Agronomy by* Neil Kinsey, the founder of Kinsey Agriculture Services in Missouri, who was trained by William Albrecht (Kinsey and Walters 2006). We also incorporate information from *The Art of Balancing Soil Nutrients* by Bill McKibben, an Ohio-based independent consultant who was at one time affiliated with Brookside labs where William Albrecht once offered workshops (McKibben 2012). Other key resources are *The Biological Farmer* by Gary Zimmer, who founded Midwestern BioAg in Wisconsin (Zimmer and Zimmer-Durand 2017), and *The Farm as Ecosystem* written by Jerry Brunetti, the founder of Agri-Dynamics, a comprehensive farm consulting service based in Pennsylvania (Brunetti 2014). Finally, we also read and synthesized the limited peer-reviewed scientific literature on the topic building on (Chaganti and Culman 2018).

C. Mailed Survey

Finally, to ascertain how widely soil balancing practices are used in the region, we conducted a mail survey of organic corn growers during the spring of 2018. The sample frame included all 1,662 growers listed on the 2015 USDA certified organic list who raised corn in Ohio (OH), Indiana (IN), Michigan (MI), and Pennsylvania (PA). An advance letter and three waves of surveys were mailed, followed by reminder postcards after each wave. The survey was promoted through short articles in newsletters associated with several regional organic certification agencies. The 8-page survey contained questions about the overall farm operation, and detailed information about a typical field on which certified organic corn was raised in 2017. Field-level questions explored soil characteristics, field crop rotation history, use of various inputs, crop yield, and financial information about purchased inputs and crop sales. The survey also included questions about overall approaches to soil management and details about respondents' understanding and use of soil balancing (or BCSR). A total of 859 farmers returned useable surveys, and an additional 166 farmers were disqualified because they did not grow certified organic corn in 2017 or were no longer farming at this address, which resulted in a final response rate of 57.4%. Response rates were highest in IN and OH (66 and 62%, respectively) compared to 53% in PA and 47% in MI.

[5] The focus of the literature was influenced to some degree by the content of the interviews in the sense that the key players and organizers were identified by the interviewees. It is possible we did not identify the full gamut but at least in the area around Ohio, we feel fairly confident we have identified the major soil balancing consultants at least in the overlapping organic world.

III. Results

A. What are we talking about? Consultant Definitions of Soil Balancing

A significant number of consultants, organizations, and soil testing labs use variants of the Albrecht BCSR framework to make recommendations for organic and conventional farmers in the Midwest and the Eastern United States. We used privately published books and articles written by soil balancing advocates[6] and interviews with 11 soil balancing consultants to better understand the theory and practices behind current soil balancing practices. In all of the publications, and for nearly all of the consultants in our interviews, the core of a soil balancing approach involved balancing base cations (Ca, Mg, and K) in the soil to levels similar to Albrecht's original recommendations. Building on this common core, consultants also discussed a wide range of practices and management strategies that they viewed as integral to their successful implementation of soil balancing. There is a significant amount of variety between consultants in how they approach soil balancing, as described below.

1. Soil Chemistry Management

As previously discussed, the **conventional and dominant SLAN/B&M approach used in U.S. agriculture focuses on providing sufficient levels of key individual nutrients to meet crop requirements**. Under SLAN/B&M, most attention and fertilizer amendments focus on three primary nutrients: nitrogen (N), phosphorus (P), and potassium (K). Calcium is used mainly to raise soil pH, though it is also recognized as important for crop growth and improving soil structure. SLAN/B&M recommendations may include the addition of secondary nutrients like magnesium (Mg) and sulfur (S) in situations when soil tests indicate deficiencies (Espinoza et al. 2018). However, most soils in our study region have sufficient levels of calcium and these secondary nutrients and other micronutrients to support plant growth (Vitosh et al. 1995).

By contrast, **soil balancing theory emphasizes the importance of targeting a specific ratio of base cation saturation levels (BCSR).** Soil balancing theory differs from SLAN/B&M in its emphasis not only on overall levels of each nutrient in the soil but more importantly, on how levels of one cation relate to levels of the others. Albrecht's recommended rates to maximize crop yields are 60-75% calcium, 10-20% magnesium, 2-5% potassium, and 15% of other cations. The emphasis on ratios and percentages reflects the special attention soil balancing consultants place on interactions between nutrients.

Calcium received the most attention in soil balancing publications and in our consultant interviews. Calcium is viewed by soil balancing proponents as having a vital role in crop growth, in shaping soil physical properties, and in facilitating the availability and utilization of other soil macro and micronutrients. Albrecht argued that calcium deficiency, rather than soil acidity, was the root cause of many soil and crop problems in the latter half of the 20th century (Albrecht 2011). In his book, Kinsey noted that farmers who "worship at the altar of pH need to understand that a good pH does not guarantee a balanced soil" (Kinsey and Walters 2006, p. 68). Brunetti and McKibben also focus on how calcium interacts with other nutrients to influence their availability to plants (Brunetti 2014; McKibben 2012).

BCSR consultants and organizations frequently recommend the use of specific calcium amendments – e.g., Hi-Cal lime and gypsum – which are believed to have higher and more plant-available levels of calcium than traditional agricultural lime. One consultant explained this preference for Hi-Cal lime over standard liming amendments when he stated "you have the hydrated lime that does not have the carbon in it, the carbonate. That's more like quick lime. That would be more fertilizer grade calcium. It's not really soil balancing." Another consultant emphasized that you need to use Hi-Cal lime first, citing Kinsey's belief that, "for gypsum to work well…you need to have calcium levels already at 60 plus percent base saturation" (Kinsey and Walters 2006, p.22). Some consultants avoid the use of

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[6] All of the books and articles listed here reflect publications outside of the peer-reviewed scientific literature, and include material available both in print and in on-line websites. Our interviews suggest that these resources are widely utilized as touchstones by soil balancing consultants and practitioners.

dolomitic lime because "some research has found that dolomite does not supply enough calcium because exchangeable magnesium outcompetes exchangeable calcium for some crops" (Zimmer and Zimmer-Durand 2017, p. 153). There is also considerable attention to the 'fineness' of calcium amendments since it can determine how available the calcium is to plants. As one consultant stated, "There are all kinds of lime out there. Some of it is just sand, and it's not available[7]. It's not going to be any use to the plant for years." Many soil balancing organizations sell or recommend branded Hi-Cal amendment products (such as Midwestern BioAg's BioCal and OrganicCal.

A key motivating factor in balancing soil base cations is the belief that high Mg (or low Ca) can produce poor soil structure that reduces infiltration and constrains drainage. High Mg soils are associated with "tight soils," which "means that they have small pores that restrict water flows" (Zimmer and Zimmer-Durand 2017, p. 69). One consultant we interviewed stated that one of his goals is to "try to move that calcium into those high 60s first, flocculate that soil to where you can get some leachability with it." Another consultant stated, "if you balance things correctly, you see soil flocculation open up, and the soil porous phase opens up. If it's not, then it will tighten right up and be much more prone to compaction and blockiness."

Soil balancing books and interviewed consultants often noted how **the effectiveness of a BCSR approach could be influenced by a soil's cation exchange capacity (CEC) level.** In the words of one interviewee, "You can think of your soil's CEC as its nutrient gas tank; it is the amount of fuel the soil could hold, often translated as yield potential." Kinsey explained that "exchange capacity is merely a measure of capacity of the soil to exchange nutrients." He goes on to explain that the CEC "affects the soil's capacity to hold nutrients such as calcium, magnesium, and ammonia nitrogen… A lighter soil will hold less of everything" (Kinsey and Walters 2006, p. 33). He stated that determining the CEC is "the first thing we need to know" (Kinsey and Walters 2006, p. 50). For some consultants, farms with relatively low CEC soils may be poor candidates for a BCSR approach.

In his book, Bill McKibben provides a decision tree which suggests that if the CEC is below eight, he advises his clients to manage the soil with the SLAN/B&M method. In one interview, a consultant indicated that on fields with lower CEC levels, "Take everything I just told you and throw it out the window because you cannot do that on a low exchange soil." This consultant went on to state, "the calcium, magnesium relationship means absolutely nothing on a low exchange soil." Another consultant stated that on "sands … or the real light exchange capacity soils…you can't balance those 'cause they just don't have enough holding capacity." Conversely, the same consultant went on to say that, "if you get into the lake bed soils, where you've got a lot of clay content, you can probably push that 65% calcium up to 70-72%".

2. Additional Chemistry Guidelines beyond BCSR

While the core idea of BCSR emphasized balancing base cation ratios in the soil, **many consultants discussed other aspects of soil chemistry as integral parts of their soil balancing recommendations**. One common theme is that good soil fertility management should go beyond the traditional focus on nitrogen (N), phosphorus (P), and potassium (K). Consultants often expressed the view that too much focus on those three nutrients has contributed to soil quality problems. Concern about the depletion of soil quality from an overemphasis on synthetic nitrogen fertilizers goes back to Albrecht's original writings (Albrecht 1975). One consultant discussed how synthetic nitrogen is "leaching calcium away and acidifying the soil." Midwestern Bio-Ag focuses on fertilizers that they consider "life-promoting," and their literature expresses a concern that the high levels of chloride in some

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[7] Lime products sold in Ohio, Indiana, and other states are regulated by their respective state department of ag. For example, in Ohio, lime products are registered with ODA (Ohio Department of Agriculture) and tested to assign an ENP (effective neutralizing power)—this essentially normalizes various lime materials based on how effective they are in neutralizing acid. ENP takes into account the chemistry of the material, the fineness of the grind and % moisture to tell a farmer how effective the material will be on a per acre basis of increasing soil pH. This takes some of the guesswork out of different liming sources

synthetic fertilizers may kill the biology of the soil. As Gary Zimmer's book stated, "Ammonia is a highly toxic gas. It will kill any life near the injection point" (Zimmer and Zimmer-Durand 2017, p. 19). This idea was echoed in Jerry Brunetti's book, where he wrote that "the mismanagement of nitrogen is the single largest agriculturally destructive practice. It burns humus, leaches calcium, acidifies the soil, contaminates the ground and surface water, and produces nitrous oxide…" (Brunetti 2014, p.33).

Concerns about destroying natural soil fertility through excessive use of nitrogen, phosphorus, and potassium fertilizers (particularly synthetic nitrogen) are related to the commonly expressed view that SLAN/B&M approaches ignore the importance of other macro and micronutrients. Soil balancing consultants frequently pointed to ways in which a limiting nutrient may be holding back the system. The Midwestern BioAg website discussed how limiting nutrients (e.g., micronutrients) could "stop a plant from producing yields that match its genetic potential." Neal Kinsey argues that important interactions are occurring between micronutrients and macronutrients and that "micronutrients respond best" when soils are in balance with calcium, magnesium, and potassium (Kinsey and Walters 2006, p. 278).

Sulfur and boron were frequently mentioned as vital to the function and role of calcium within the soil balancing approach. One consultant shared his observation that "sulfur and boron are the main ones" they focus on because, due to their negative charge, "they move very quickly down through the soil with rainwater." In his area, there is "plenty of rainwater that leaches them out of the root zone." Another consultant stated that when calcium is already at target levels, "what I want to do is apply sulfur and boron to get that calcium working." Midwestern BioAg's website uses the analogy that "calcium is a truck" and "boron is the steering wheel" because it works hand-in-hand with calcium to "build cell walls and get nutrients into the plant" (Zimmer and Zimmer-Durand 2017, p.290). There is a concern among some soil balancers that soils are becoming more deficient in sulfur as the acidity of rainfall has declined with the implementation of the Clean Air Act (Kinsey and Walters 2006; McKibben 2012). One consultant noted that "if you want a healthy plant protein to build the plant amino acids," it is important to use sulfur.

Other trace minerals were also discussed. One consultant stated, "Copper is your main one for disease prevention." He also discussed how "zinc is another main one for reproduction and better, bigger corn yields." He went on to discuss how trace minerals are very important overall "if you're pushing for less disease pressure, less insect pressure, higher yields, and higher test weight."

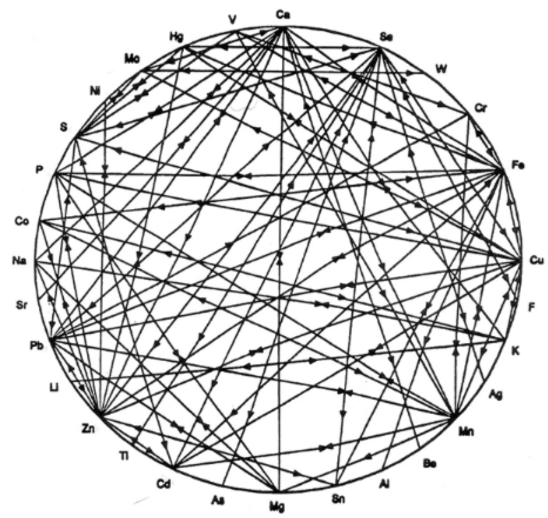
Overall, the soil balancing literature and our consultant interviews often expressed the idea that **the benefits or impacts of individual nutrients or minerals are influenced by the presence or absence of other soil nutrients**. These complex interconnections are highlighted in the Mulder Mineral Wheel (Figure 1), a graphic that appears originally in Watts (1995) and is highlighted by the major contemporary books on soil balancing (Kinsey and Walters 2006, p.192; Zimmer and Zimmer-Durand 2017, p. 94; Brunetti 2014, p.64)

According to soil balancers, these complex interactions influence the absorption and availability of soil constituents to plants. Kinsey Ag's website explains that adding a nutrient can alleviate an excess of another nutrient, and this "is the meaning of soil balance using the Albrecht Model." One informant noted that ideal BCSR ratios not only increased calcium absorption but also provided "better absorption of the entire trace mineral profile."

3. *Beyond Chemistry: The Three-Legged Stool*

While BCSR chemistry is at the core of soil balancing, most consultants and farmers in our study reported using a wide range of practices under the umbrella of soil balancing. Indeed, it is fair to say that nearly all soil balancing practitioners in our study used BCSR as part of a broader approach to managing for overall soil health. For example, when asked about soil balancing, one consultant stated: "it means a lot more to me than it does to a lot of soil scientists." This consultant would prefer to use the term soil health since it encompasses a broader range of parameters.

An overarching theme in our research on soil balancing suggests a commonly used **three-pronged approach which begins with BCSR chemistry but also incorporates management of the biological and physical structure of soils** (see Figure 2). The core of this approach is a recognition that "each of these is related and influences each other." One consultant emphasized that growers like himself need to be aware that "everything works together" so that if you "focus solely on one and forget the other two, you won't have success." This idea goes back to Albrecht's early work, which suggests "that none of his findings" should be considered "in neat little compartments." Rather, the idea that "everything is related to everything else becomes evident every time we enlarge even a single factor" (Albrecht and Walters 2011, p.xv). Gary Zimmer emphasizes that if you throw one of the three prongs "out of balance…it will affect the health of the entire soil system" (Zimmer and Zimmer-Durand 2017, p. 27). This is not to say that chemistry is not important. BCSR was often cited as an important determinant of the physical structure or the "looseness" and "tightness" of soil, and both chemistry and physical structure can affect biological life. One consultant tied all three prongs together in this way: "The higher your magnesium, the tighter the soil. So the tighter the soil is, the less air, oxygen is in it, the fewer microbes and biology…" Another consultant explained that achieving the soil chemical balance leads to improvements in soil physics and then to "better aeration," "better root development," and "better biological activity." For him, all of these changes in combination are part of soil balancing. He goes on to state that, "all that, in combination, is, is what is part of that balance."



Ag – Silver Al – Aluminum As – Arsenic Be – Beryllium Ca – Calcium Cd – Cadmium Cu – Copper Cl – Chlorine Co – Cobalt Cr – Chromium F – Fluorine Fe – Iron I – Iodine K – Potassium Li – Lithium Mg – Magnesium Mn – Manganese Mo – Molybdenum N – Nitrogen Na – Sodium P- Phosphorus S – Sulfur Se – Selenium Zn – Zinc

Figure 1. Mulder Mineral Wheel

(Watts 1995)

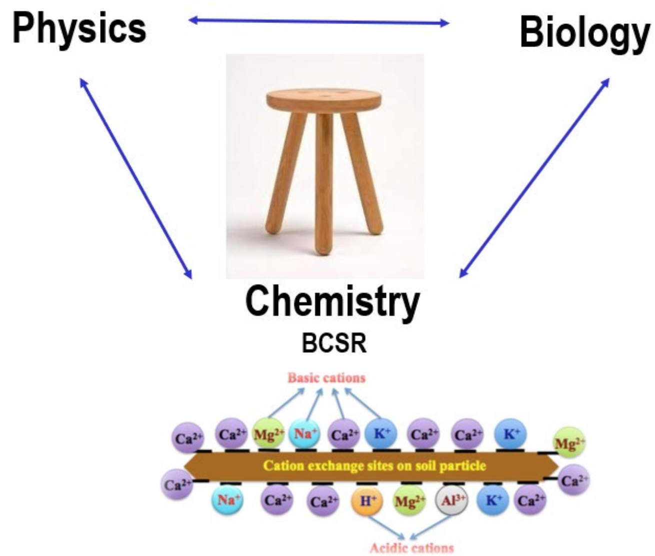


Figure 2. Conceptual Representation of the "Three-Legged Stool" of Soil Balancing

For some contemporary soil balancing consultants, managing **biology may be more important than the chemistry around BCSR.** Gary Zimmer stated that he would rather have "soil with a fairly good balance of nutrients in the medium-testing range with lots of biological activity and a good structure than a structureless, dead, high-testing soil" (Zimmer and Zimmer-Durand 2017, p. 133). In one of our interviews, a consultant stated that "biology trumps chemistry" and even if you have a soil that is "perfectly balanced from an Albrecht perspective" you can still have a "disastrous crop if you do not have good biology to have good nutrient availability on the soil profile." Another consultant expressed the belief that because of deteriorating soil biology the Albrecht base cation saturation method may not be "as strong today as it was 40 years ago when it was first developed" so, therefore, we may not get the same response.

Given this holistic view, **many soil balancing consultants report using and recommending a diverse set of management practices** in addition to hi-calcium amendments. For example, attention to the physical properties of soil often means strategic use of tillage to avoid compaction while still mixing nutrients throughout the soil profile. Though their views on, structure" (Zimmer and Zimmer-Durand 2017, p. 312).

Some recommended **soil management practices are prescribed explicitly because of their influence on soil biology**. One common example is the use of crop rotations and cover crops. In the words of one consultant, they are a way to "to foster biology, not inhibit biology." Gary Zimmer writes that "both green manure crops and other types of cover crops provide a lot of benefits to soil quality and to soil life." They can be useful for building humus but also for nutrient cycling and "holding nutrients that might otherwise leach away, such as nitrogen" (Zimmer and Zimmer-Durand 2017, p.362). One consultant explained that "I've always been taught to think diversity above ground mirrors diversity below ground." He attributes the connection to the idea that "different crops are essential for feeding different types of soil biology."

The application of manure and compost is also commonly cited as a key part of good soil balancing management programs, particularly on organic operations. Gary Zimmer noted that "without animal manures, it is more difficult and more expensive to provide the necessary nitrogen for crops." He added that "animal manures really do make biological farming work better -- as long as they are managed properly" (Zimmer and Zimmer-Durand 2017, p. 366). Kinsey also wrote that manure application is an important way to improve soil structure (Kinsey and Walters 2006, p. 58).

There is **more variability among consultants in the extent to which they recommend the use of biological stimulants and inoculants**. One consultant told us that if "we can get the balance" and "can get the aeration and the soil physics correctly," then he thinks "the microbes will readjust." He is skeptical of the effectiveness of seeding microbes into the farm system. Bill McKibben and Neil Kinsey are similarly cautious about the use of biologicals. Kinsey wrote that they "can be helpful if soils are worked correctly. But if soil fundamentals are not correct and in place, you can get into all kinds of trouble relying solely on biologicals" (Kinsey and Walters 2006, p.115). At the other end of the spectrum, consultants working for Agri Dynamics and Midwestern BioAg were more likely to report regular use of biological stimulants and inoculants[8] as a key part of their soil balancing approach.

Those who recommend using biological inoculants and stimulants describe a wide array of products. Kauffman et al. (2007) defined biostimulants as "materials, other than fertilizers, that promote plant growth when applied in low quantities." Sugar sources like molasses are sometimes used to provide a carbon source for plants and soil biota. Fish fertilizers are also recommended since they contain enzymes that can work as a biostimulant in addition to providing nutrients for plant growth. Humates, kelp, humic and fulvic acids, and mycorrhizal fungi are also viewed as good sources of stimulants and inoculants. One consultant reported using "biological food sources. I suppose I look at them as a way to compliment good fertility or a good fertility program." Humates can "help hold nutrients in plant-available forms" (Zimmer and Zimmer-Durand 2017, p.201) as they "chelate positively charged cations" and can increase "plant cell membrane permeability" (Zimmer and Zimmer-Durand 2017, p. 105). Fulvic acids can "act in a hormone-like way to increase the plant's physiological activities" (Brunetti 2014, p. 106).

There is even **less consensus among consultants about the appropriate use and function of foliar-applied** products as part of a soil balancing management system. The idea behind foliars involves feeding the plant or leaves directly rather than the soil. Jerry Brunetti found that "the uptake of nutrition via foliage can be ten to twenty times more efficient than what plants can take in the root"(Brunetti 2014, p.145). However, he also emphasized the importance of context, such as the timing, temperature, and spraying equipment (Brunetti 2014). Another consultant emphasized foliar applications as a central part of his approach to soil management as he believes that the foliars induce the plants to release nutrient-rich exudates into the soil that feed the soil biome. As such, this consultant indicated that foliars may be "the fastest way to regenerate soil and to rebuild soil health." In one interview, a consultant stated that foliars work together with other soil amendments to achieve a greater response than there would be if they were working singularly. In contrast, another consultant stated that "there are many foliar products touted in the industry" as the "next best thing to sliced bread." He goes on to say that "far too many of these are unproven and sold as some sort of magic bullet," but he feels that it is "very difficult to get consistent results."

4. The Issue of Nutrient Availability

Another common theme that emerged from our literature review and interviews was the view that **conventional SLAN/B&M approaches often fail to appreciate how soil chemical, physical, and biological conditions mediate the availability of soil nutrients** to the plant. For example, the increased emphasis on micronutrients within soil balancing is related to the idea that soils with different levels of micronutrients may prevent primary and secondary nutrients from getting absorbed by the plant. According to Zimmer's book, "a lot of nutrients are not available" so "what matters most is what gets into the plant, not what gets into the soil" (Zimmer and Zimmer-Durand 2017, p. 89). Therefore, "even if a standard soil test says there is enough there is not usually enough *plant available*" (Zimmer and Zimmer-Durand 2017, p.191). Similarly, McKibben writes about "restrictors that may be present, preventing nutrients from going into solution and being available to the plants" (McKibben 2012, p.58).

[8] (e.g. Soil Boost and other products like humates, folic acid PKT myco seed, Flora-Stim, fish fertilizers, Earth Gem).

This emphasis on availability is also related to the need to manage all three components of the three-legged stool. One consultant felt that practicing soil balancing went beyond achieving ideal base saturation ratios since *"*the air and the biology makes a huge difference in the availability of these nutrients…" He went on to emphasize the importance of focusing on "soil tilth, biology, and fungals so that all these nutrients are more available to plant." Another consultant felt that "availability, storage, those things are really important, because if you don't have a real balance there, you may not get the value out of adding minerals." Yet another stated that "good biological activity should help make available some of those nutrients that are there in the soil, but not readily available."

Concerns about nutrient availability lead some soil balancing consultants to use alternative tests for measuring soil and plant availability of nutrients directly (e.g., soil paste tests and plant tissue tests). One consultant shared his view that the paste test can sometimes detect problems in the soil when the standard soil testing approach cannot, particularly with regards to what is "moving…in the solution and being available to the plant." Some consultants also recommended tissue tests as a direct measure of plant availability and uptake; however, opinions varied about their accuracy compared to standard soil tests.

5. Crop Quality

Consultants working within a soil balancing paradigm assert that they focus more on crop quality than those who follow the standard SLAN/B&M approach, which could be connected to some of the different nutrient recommendation levels associated with soil balancing. Albrecht's original work argued that there was a connection between poor soil quality and declining animal and human health, and contemporary soil balancing consultants articulated a similar theory in their writings and interviews with our team. Specifically, Zimmer has argued that although crop yields have risen over the years, crop quality has gone down (Zimmer and Zimmer-Durand 2017, p.163). Bill McKibben includes a table in his book that documents the decrease in calcium levels from 1963 to 1999 of some major food crops (McKibben 2012, p.63). There is also a commonly expressed view that if you focus on increasing crop quality, increased yields will follow. As one consultant stated, his focus "is not necessary yield…We don't make that a…goal post…" Rather he goes on to say, "... our goal post is the quality of the crop, and so as we achieve that the yield takes care of itself." Agri-Dynamics and other consultants who work with vegetable operations argue that Brix (i.e., measures of the sugar content of the crop) can be used as a proxy for how well balanced is the soil.

6. The Role of Context

While there are some general principles behind the practice, our readings and interviews suggest that **soil balancing practices are frequently adapted to the unique qualities of specific fields, farms, and farmers**. In addition to the importance of soil CEC mentioned above, one consultant noted that "recommendations are going to vary, depending on if it's a high magnesium situation, a high calcium situation, et cetera." It is also important to consider the farm's management history and soil biological state. One consultant noted that farmers who have high organic matter could "start paying a lot less attention to the ratios." Farm type can also influence soil balancing recommendations. Vegetable farmers raise higher value crops and thus have a larger budget to purchase amendments. One consultant stated that he generally runs an "Albrecht type soil analysis every year for his vegetable and fruit growers." In contrast, he runs these soil analyses for broadacre crops every three years. This consultant went on to say, "dairy farmers are the number one users of our high calcium lime…[because] they sell their calcium every day. It leaves in the truck."

7. Other Common Themes in Soil Balancing Books and Interviews

A number of other themes emerged in the interviews and literature that are worth mentioning. For example, we heard in many of our interviews that a soil balancing approach requires patience and takes time. Kinsey writes that "if someone tries to tell you that the Albrecht system does not work, first find out if they are judging it based on only one year of results" (Kinsey and Walters 2006, p.380). He goes on to to say that "after three years of properly following the program on a soil that needs the fertility levels to be rebuilt, it will do even better" (Kinsey and Walters 2006, p. 380). Proponents also believe the need for external inputs will decrease once soil balance has been achieved.

The soil balancing literature and our interviewees frequently linked soil health to livestock and human health. This was a predominant theme of Albrecht's work. One consultant reported instances in which livestock was given a choice of balanced and unbalanced fields and regularly spent more time grazing on balanced soils. One commonly expressed idea is that soil nutrient levels should ideally mirror natural levels in the human body. As one consultant stated, "If you look at uh, the human body, you have a 7:1 ratio of calcium to magnesium" – roughly the same ratio recommended by Albrecht. For this consultant, this similarity was connected to how "we were created from the earth." In his book, Kinsey talks about a conversation he had with a medical doctor where "after explaining that the calcium level in the soil ought to be 68% saturation" the doctor responded, "that's the same thing you and I need in our bodies to have the right calcium balance" (Kinsey and Walters 2006, p.17). Kinsey and the medical doctor had a similar exchange about the connection between plant and human needs for magnesium and potassium.

Throughout our research, we noticed **soil balancing consultants often preferred naturally sourced soil amendments** that are perceived as releasing nutrients more slowly than synthetic products and frequently contain more trace elements. Gary Zimmer argues that "commonly used fertilizer materials…may be too soluble," thus "they leach easily, or cause an imbalance in soil nutrients or plant nutrition when plants take up an excess" (Zimmer and Zimmer-Durand 2017, p.18). He goes on to note that synthetic fertilizers "may be cheaper per unit source of a nutrient, but they are not cheap in the long run because they degrade soil structure, harm soil life, or injure plants" (Zimmer and Zimmer-Durand 2017, p.163). While these ideas were echoed in some of our consultant interviews, not all soil balancing consultants have an aversion to the use of commercial synthetic fertilizers (at least with their non-organic clients).

Some soil balancing consultants pointed to how different sources of soil amendments present diverse electromagnetic and biophysical properties. Interest in these traits can be traced to Carey Reams, who also contributed to early soil balancing approaches. In his book, Jerry Brunetti discussed the "diamagnetic energies, such as found in limestone and paramagnetic energies, such as found in basalt…" (Brunetti 2014, p.9). In one interview, a consultant shared the belief that "there is this tremendous untapped potential" with regards to "plant nutrition," and he connected this to "biophysics." He noted that you could have calcium carbonate "from two different quarries" and they could have the same levels of calcium and the fineness of ground but yet "you put it on the same field, side by side, and you get two completely different results." In his view, these differences could be explained by biophysical or paramagnetic energies.

A couple of consultants reported using weeds as an indicator of soil nutrient levels and soil quality. One consultant discussed how the presence of foxtail, can indicate that calcium availability in the soil is low. Another referred to two books (*Weeds, Control Without Poisons* and *Weeds and Why They Grow)* published by Acres, U.S.A., that discuss the concept of indicator weeds (Pfieffer 2007; Walters 1999). This consultant further explained that "each weed is not just associated with a specific nutritional profile, but more appropriately, it's associated with a specific microbial profile."

8. How does BCSR differ from SLAN/B&M?

While soil balancing advocates are frequently critical of the traditional SLAN/B&M approach, it would be **misleading to believe that the approaches are mutually exclusive.** Indeed, most soil balancing books regularly incorporated information from standard soil science textbooks, and most consultants still pay close attention to N, P, and K levels. Neil Kinsey stated that "in any long-range program, calcium comes first." However, he went on to say, "primary elements always come first where needed for growing the immediate crop." (Kinsey and Walters 2006, p.74). Another consultant stated that while he focuses on BCSR, “we did not overlook the fundamentals of sufficiency or excess.” He emphasized that this is particularly true for phosphorus and potassium. Soil testing remains a critical tool for BCSR consultants, and they rely on similar soil tests as conventional soil consultants (i.e., Bray and Mehlich).

Soil balancers also recognized the negative side effects of excessive Ca levels. One consultant stated that with high calcium levels (i.e., over 80%), it is more appropriate to use a “SLAN approach.” Gary Zimmer discussed the complementarities of the standard and soil balancing approaches in his book, writing that “most scientists agree that twenty plus nutrients are needed for crop production; they also agree on certain sufficiency levels of those nutrients.” Those levels of sufficiency “will also give you ‘ratios’ of those nutrients in the soil.” Thus, in effect, either approach is “very similar as long as you also deal with excesses” (Zimmer and Zimmer-Durand 2017, p.120).

Likewise, while Albrecht and some modern consultants deemphasized the importance of pH and soil acidity compared to conventional SLAN/B&M approaches, most soil balancing advocates still pay attention to soil pH levels as a key regulator of nutrient availability (including base cations). One consultant emphasized that “I don't think pH should be left out of the equation...(and) calcium certainly shouldn't be the only thing I'm looking at.”

It’s clear that under a BCSR approach recommended levels of some primary and secondary nutrients are likely to be much higher than under a SLAN program. Under the SLAN/B&M approach, calcium is used to manage soil pH and to provide for crop growth and improve soil structure. Calcium is usually applied in the form of agricultural lime (calcium carbonate). When secondary macronutrients are needed, other forms of lime are used (e.g., dolomitic lime to provide Mg). When pH levels are adequate, but calcium or sulfur is needed, the use of gypsum is increasingly recommended by SLAN/B&M consultants (Batte et al. 1993). According to the Tri-State Fertilizer recommendations, in the Indiana, Ohio, and Michigan region “if the exchangeable calcium level is in excess of 200 ppm, no response to calcium is expected” (Vitosh et al. 1995, p.17). Rather the focus is on “if the soil pH is maintained in the proper range” as “then the added calcium from lime will maintain an adequate level for crop production” (Vitosh et al. 1995, p. 17).

The solid lines in Figure 3 below show the amount of soil-available calcium (Ca), magnesium (Mg), and potassium (K) required to achieve targeted BCSR ratios for soils with different cation exchange capacity (CEC). The figure shows that as CEC increases, much larger amounts of the three base cations are required to achieve the target cation ratio (the shaded grey area) than would be recommended under the SLAN/B&M approach (represented by the horizontal dotted lines). Adding this additional calcium, magnesium, and potassium would require significant expenditures in soil amendments that might not generate corresponding yield increases and return on investments.

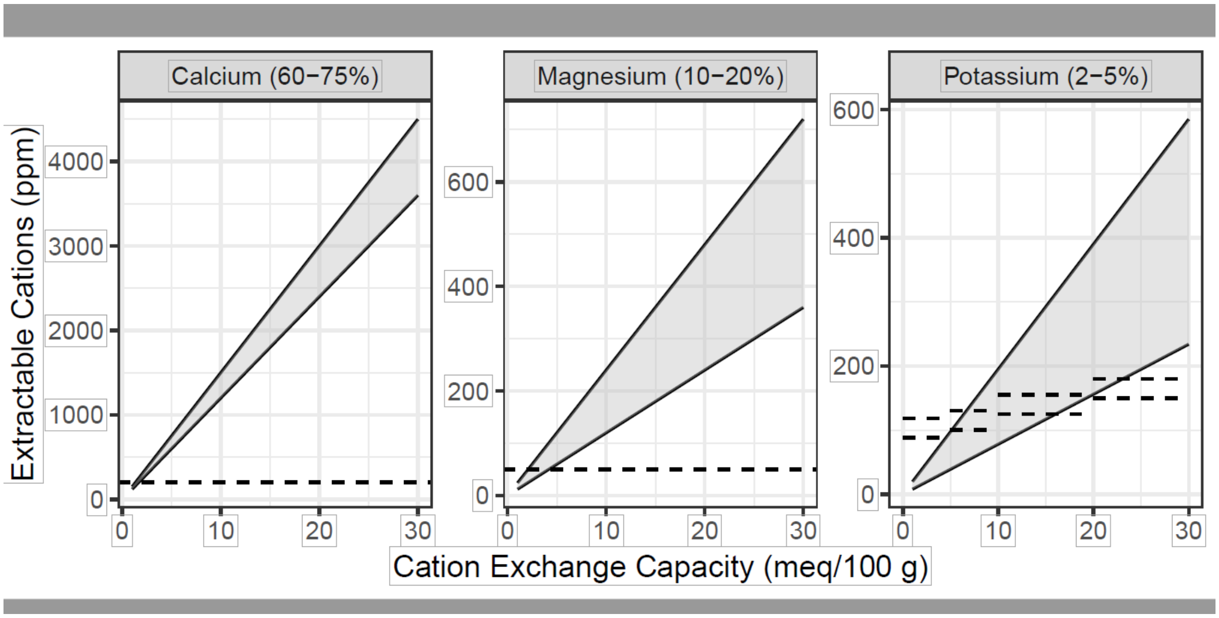


Figure 3. Comparing Recommended Extractable Soil Test Levels When Subscribing to BCSR vs. SLAN (Culman et al., unpublished).

The BCSR approach may also involve higher recommendations for other secondary and micronutrients**.** SLAN/B&M approach does not generally recommend applying micronutrients, particularly in the states in our study region. Most soils in the Tri-state region of Ohio, Indiana, and Michigan contain enough micronutrients for plant requirements, according to SLAN/B&M soil and plant analysis and recommendations (Vitosh et al., 1995). A recent review of micronutrient trials in Ohio found that yield responses from applications of micronutrients were extremely rare in corn, soybean, and alfalfa. Out of 144 total trials, only 9 showed positive yield responses from applying micronutrients (Sharma et al. 2018). The SLAN/B&M approach is also concerned that excessive amounts of micronutrients can generate risks of toxicity to the plant (Vitosh et al. 1995).

Interestingly, a number of soil balancing consultants in our interviews also recommend using higher levels of phosphorus (not one of the base cations) than would typically be recommended under SLAN. In most situations, major field crops (corn, soybeans, and wheat) and most vegetable crops do not respond to soil phosphorus levels above 15 ppm according to University research (Bray P) (Vitosh et al., 1995). Soil test phosphorus levels above 50 have been linked to losses of dissolved reactive phosphorus, a principal driver of harmful algal blooms in the Western Lake Erie Basin and other inland waterways (Duncan et al. 2017). By contrast, Gary Zimmer stated, that "25 ppm gives you good yield, but 50 ppm also gives better quality, and potential for higher yields" (Zimmer and Zimmer-Durand 2017, p.129) partly because "the total amount of nutrient present in a soil can be many times greater than those in available form" (Kinsey and Walters 2006, p.206). In one of our interviews, a consultant reported that he sets the desired level of "75 parts per million" with "the Mehlich 3 test." However, he is not "afraid to go up to 200 ppm." He has farmers who claim that phosphorus "starts working really well on your yield when you're at 200 or over…" Bill McKibben's book indicates he may recommend using application rates of 250 lbs/acre of phosphorus (P_20_5) because he has "seen phosphorus levels on the standard test well over 1,000 lbs per acre, but because of high soil pH and cation interference the soluble phosphorus fell below the detection limit" (McKibben 2012, p.61). He also notes that stratification can be a problem and cautions that care should be taken to make sure phosphorus is incorporated throughout the root zone.

B. Farmers' Understanding and Use of Soil Balancing

1. Farmers' Understanding and Use of BCSR

While the consultants painted a fairly nuanced picture of the ideas and practices associated with soil balancing, **the understanding and practice of soil balancing described by farmers in our interviews were even more diverse.** Among the 23 working organic farmers, we interviewed, most reported using a mixture of approaches to soil fertility management, and only a few described using a strict "BCSR" approach that included specific Ca:Mg:K saturation ratio targets. Farmers were also less likely than consultants to use the terms "BCSR" or "soil balancing." One farmer did discuss actively managing Ca:Mg ratios, but said that each time he tried to define "soil balancing," he would "run into a brick wall." Considering that these farmers were explicitly recruited for interviews because they were identified by their peers and referred to our team as good examples of practicing soil balancers, their reluctance to express a BCSR-focused definition of the practice was surprising and illustrates the complexity involved in studying how well it works in practice.

While none of the farmers who were interviewed framed soil balancing solely around a strict BCSR approach, when pressed, 18 of the 24 farmers we interviewed expressed **general adherence to the idea that maintaining appropriate cation levels** (particularly for calcium and magnesium) **was important to a "balanced soil."** A number of farmers shared stories where high magnesium (or low calcium) produced poor soil structure that inhibited drainage. As one farmer related, "we started doing a little soil testing and then applying" what consultants recommended as that "improved our hay...We had too much magnesium in the soil." Farmers were less likely to mention numeric cation ratios than consultants. Rather than trying to achieve exact percentages, farmers were more likely to seek a general target range of saturation values. As one farmer stated, "you don't have to thread the needle on soil balancing, but you have to be...in those good ranges."

The consultants in our interviews articulated fairly sophisticated theories and concepts to describe how chemistry, physics, and biology interact to produce a balanced soil. In contrast, **when asked to describe soil balancing, farmers typically listed the practices they follow, particularly the application of soil amendments**. In the interview transcripts, farmers used words describing amendments three times more frequently than words involving BCSR concepts such as of "cations" and "saturation ratios." Farmers were less likely than consultants to distinguish between forms of calcium amendments (particularly Hi-Cal vs. agricultural lime). One farmer indicated that he was unsure which soil amendments were used on his fields: "we do add lime…on a regular basis. We tried, uh.." After he hesitated and was further probed about his use of specific soil amendments, he responded, "I know it's... gypsum was one thing. Gypsum, the soft rock. I think some boron and zinc maybe." Compared to consultants, farmers were less likely to talk about the importance of CEC concerning soil balancing. However, farmers did recognize the importance of context and soil type more generally related to the effectiveness of soil balancing. As one farmer noted, "I don't think you can just put minerals in and expect sand to produce."

Farmers also blurred the distinction between SLAN/B&M and BCSR approaches to soil fertility and most described management strategies that combined elements of each approach. For example, when asked how they would define soil balancing, **most farmers described it as a general approach to managing soil quality through the use of soil tests to achieve desired crop performance results.** One farmer stated soil balancing is like "taking a test and... checking what's low and applying, you know, lime or phosphorus...". Another farmer explicitly linked soil balancing to the SLAN/B&M approach when he noted that "the first thing I think of is what the state universities put out for recommendations for NPK and micronutrients." He added that he also checks tests to get information about "organic matter and cation exchange capacity--the CEC." A third farmer stated that when he thinks of soil balancing, he looks for a "benchmark…we want our phosphorous levels here, we want our potassium levels there, and our calcium levels and, you know, we want our pH and our CEC and base saturation." This farmer mixed ideas of base saturation and calcium with a discussion of pH and the use of other NPK nutrients. In other words, unlike consultants, when describing what they do to balance their soils, farmers were as likely to discuss traditional SLAN nutrients (NPK) as calcium or magnesium.

2. Farmer Soil Balancing beyond BCSR

While less common than references to calcium or NPK amendments, a number of **producers indicated that micronutrients (particularly boron) were important to their practice of soil balancing**. One farmer stated, "I'm a firm believer in trace minerals and balancing our soils by base saturation levels." Another expressed his interest in micronutrients while simultaneously placing a greater emphasis on macronutrients when he stated, "Most soil nutritionists will tell you that…there's no point in addressing them until you get everything else in line."

Farmers also frequently focused on the **importance of soil biology** in their soil management systems. One farmer discussed how "I had a lot of agronomists look at my soil analysis and say, 'Wow, you know you're doing good. That soil's balanced.'" But the farmer noticed that the soil was not "not producing anything." He attributed this to a lack of healthy soil microbes. He went on to explain that if you can get the "bacteria back. You make your soil alive." When asked to define soil balancing, another farmer mentioned microbes right after discussing the minerals and further elaborated that soil balancing is "trying to have the right amounts of minerals in the correct ratios or whatever. Then also having… a lot of microbial activity in the soil for digestion."

Farmers also frequently described using cultural management practices to achieve a balanced soil, like **crop rotations, cover crops, and the use of manure or compost**. One suggested that "management is key; that's what defines a farmer. It's one who knows how to manage that soil, not one that knows all about the amendments and stuff." Another drew on advice from "old-timers" like his grandfather who taught him the saying, "lime, manure, and clover make the farm-rich all over." One farmer stated he drew on advice from his father, who emphasized: "keeping your rotation using animal manures" and "having good farming practices." Another likened the amendments he uses to "Band-Aids" and pointed to cover cropping as "more of a long-term cure." Yet another farmer emphasized the importance of his managed grazing system over-relying "strictly on applying certain amendments."

3. Farmer Information Sources about Soil Balancing

Farmers' varied and complex understandings of the idea of soil balancing likely reflect their **use of diverse information sources to guide their soil management decisions**. Farmers indicated using information from multiple sources about soil management, and some were more explicitly tied to soil balancing than others. The most frequently mentioned sources of information that farmers discussed in the context of soil balancing were (in descending order): information from multiple consultants, soil testing labs, farm input supply meetings, other producers, their family, published soil balancing reference material, and alternative agriculture organizations and newsletters. Observations from their own experience were also important.

Some farmers heavily relied on soil balancing consultants, sometimes seeking advice from multiple consultants, but usually, fall back on their own intuition and experiences to make final soil management decisions. Particularly when discussing advice that led to their application of Ca and Mg amendments, 17 of 24 farmers mentioned using soil balancing consultants. Notably, seven of those farmers mentioned more than one soil balancing consultant. Soil testing labs were mentioned in eight of the farmer interviews (particularly Brookside Labs, which is popular among soil balancing consultants). Agricultural input suppliers were mentioned as sources of information in eight of the farmer interviews. Some farmers said they prefer to obtain information from other producers than from consultants. Seven interviewees mentioned farmers and five listed family as important sources of information. As one farmer stated, "soil balancing or soil fertility meetings" can be "extremely tedious." Rather, he emphasized the importance of "personal conversations with other producers." Other farmers mentioned having relied on information from organic agriculture organizations (3 interviews), particularly written sources of information such as the Midwest Organic & Sustainable Education Services Organic Broadcaster newsletter (3 interviews). One farmer described participating in a farmer group within the Ohio Ecological Food and Farming Association (OEFFA), and how “everybody's got a different slant on things” so they “pick up information from each other.” Four farmers mentioned reading and using material from the original soil balancing books written by people like Albrecht and Reams.

Perhaps most importantly, a large number of farmers described how they **rely principally on their own experience and observations** about whether or not a given soil management practice seems to be working. Five farmers explicitly referred to the role of intuition or observation in working to balance their soils, with one who noted that “I do soil tests about every three years, but I do more balancing with visual…Every day, during the growing season, I'm walking over part of the farm.” Yet another farmer stated he relies on “trial and error out on the farm to see what works...”. This focus on the power of observation can lead some farmers to deemphasize the importance of soil testing. One farmer stated that his grandpa did not do any soil testing, but he inherited the farm, and it turned out that his “calcium to magnesium ratios are very good.” Although one farmer stated that he does soil testing, he referred to the case of one prominent Ohio organic farmer who was successful without using soil tests.

The use of multiple sources of information on soil balancing shows that **farmers are seeking and comparing diverse opinions about best soil management strategies**. As one retired farmer stated, “you can ask 1000 different people the same question you'll get 1000 different answers.” Another farmer suggested that out of “10 people in a room…you'll probably have 11 opinions on sulfur.” In our interviews, it was clear that most farmers were not necessarily devoted to any particular approach or consultant. Rather, they merged advice from different consultants, and other sources with wisdom gleaned from their own accumulated experiences. One farmer described this process as using half of one person’s advice and half of another and ending up “somewhere in between.” Only three of the 24 farmers we interviewed deferred almost entirely to their consultants to decide on soil balancing amendments (and actually referred us to their consultants to answer our questions about what was being done on their fields).

C. The Prevalence of Soil Balancing

1. Farmers who self-identify as soil balancers

Based on anecdotal observations and the sheer quantity of soil consultants and published materials focused on the approach, soil balancing appears to be a relatively prevalent practice among farmers (particularly organic growers) in the Midwest and Northeastern U.S. To date, however, no systematic data has been collected to quantify the extent of use and characterize the types of farmers who utilize soil balancing. To address this gap, we implemented a mail survey of certified organic corn farmers in four states (Ohio, Indiana, Michigan, and Pennsylvania) in the spring of 2018. One goal of the survey was to estimate the prevalence and ways soil balancing was practiced on organic cornfields during the 2017 growing season. A total of 859 farmers returned useable surveys (a response rate of over 57%).

The results provide an empirical basis for estimating the relative prevalence of soil balancing in this region. Based on the interview results presented above, we also recognized multiple ways that soil balancing is defined and practiced in the region. Therefore, we asked a number of different questions to capture the diverse ways that soil balancing might be measured. The core section of the survey on this topic began with the following text:

> *“Some farmers follow a practice often referred to as soil balancing. Soil balancing usually focuses on balancing the saturation ratios of base cations (e.g., calcium, magnesium, potassium) to improve soil qualities and the availability of other nutrients. Common target base cation saturation ratios are calcium (65-75%), magnesium (10-15%), and potassium (3-5%). Soil balancing is often achieved through application of high calcium and low-magnesium forms of lime or gypsum. The next section asks you about your experiences with soil balancing (if any). Given this definition, do you use a version of this soil balancing approach on your farm?”*

In response to this question, **a little over half (55%) of organic corn growers farmers self-identified as practicing soil balancing** (see Table 1). Respondents who answered yes to the first question were then invited to write out a short description of "*what you do and what you are trying to accomplish" through soil balancing?*" Answers to this open-ended question were qualitatively coded to capture mention of key phrases or concepts.

Table 1: Frequency of Self-Reported Use of Soil Balancing (SB)

Description	Frequency	Percent of all Farmers
Not a self-identified soil balancer	364	45.0
Self-identified soil balancer	444	55.0
Written Descriptions of Soil Balancing Practices/Goals		
Discusses BCSR, SB amendments, and/or using SB consultant	*164*	*20.3*
Describes using soil tests to balance soil nutrient levels (but no explicit mention of BCSR/SB products)	*149*	*18.4*
Other types of descriptions (general soil health, cultural practices, etc.)	*96*	*11.9*
Identified as SB, but did not provide written description	*35*	*4.3*
Total[1]	808	

Notes: [1] = excludes 51 farms where respondent did not answer the question about being a soil balancer

We used the written comments provided by farmers to classify three subgroups. Subgroup one consisted of self-identified soil balancers who explicitly used BCSR words: e.g., they wrote about managing base cation exchange ratios, applying amendments to raise or lower Ca and Mg levels, used Hi-Cal lime or gypsum, or made reference to using recommendations from a consultant or advising service that has a prominent focus on soil balancing. This subgroup comprised roughly 20% of the overall organic farmer sample or 37% of self-identified soil balancers (Table 1). About half of this subgroup of farmers referenced base cations or Ca:Mg ratios/percentages explicitly. Examples include:

- "We use gypsum to raise calcium and lower magnesium. Our goal 80% cal/15% magnesium/5% potassium with boron at 1.5 to 2%
- "Add gypsum yearly. Try to attain base saturation of 75% Cal."
- "Using Hi-Cal lime and/or gypsum…to flush Mg."
- "I took soil samples and plan to apply Hi-Cal Lime and/or gypsum to balance cal/mag ratio to help drainage and biology."
- "We monitor base saturation ratios and use this as a guide when applying lime, manure, or other amendments. Our goal is to be in the ranges described above."
- "We soil test every 2 years and completely balance prior to rotation to corn. We balance at least all cations and 7-8 anions."
- "High calcium lime is used to maintain calcium levels. Gypsum is used to supply sulfate and lower magnesium, and a variety of manures are used according to NPK requirements. The goal is to set the stage for all forms of biology to thrive."
- "I am trying to balance base saturation according to the values stated above, using Hi-Cal lime or gypsum for Ca, and broiler manure to raise K. However, I am also attempting to raise phosphorus levels with Tennessee Brown phosphate and broiler manure, per Agri Energy's recommendations. Also applied for N needs and micronutrients for that year's crop needs."

- "I hire an agronomist (Homestead Nutrition). I have high Mag soils = tightness, so we are trying to loosen soil and increase microbial activities."

Others in this subgroup mentioned calcium or magnesium, applied hi-cal amendments, or referred to using a soil balancing consultant but did not discuss BCSR chemistry explicitly. Typical examples included:

- "Add Hi-Cal Lime, Boron, Copper. Try to get the soil looser and more balanced for better plant health--more yield & less weeds."
- "I do a lot of cover crops the year prior to where I plant the next year. I do a soil test every year. I have a program with Green Field farm. They give me a recommendation. I apply the soil amendment before planting my produce. I do not raise corn to sell, so that kind of gets the back seat."
- "Soil test field every 3 years. Go by MBA [Midwest Bio Ag] recommendation to balance soil for crop fertility and soil improvements."
- "I do soil tests with Kinsey Ag and follow their recommendations. I am trying to build soil health and organic matter so that I get better yields and test weights with less input dollars, and I also believe better balance soil has less weeds."
- "Apply gypsum annually (goal) 500lbs acre - bring up calcium and sulfur levels - take soil tests every 3 years - limit poultry litter on fields where potassium levels are high."
- "Agri energy agronomist gives recommendations according to soil test results."
- "We consulted Midwestern Bio-Ag and follow their recommendations."

As is clear from these selected comments, farmers who described BCSR approaches often highlighted the impacts on soil physical properties. They also frequently include consideration of other (non-BCSR) soil management considerations (e.g., rotating crops, using manure, and balancing levels of N and P) as part of their description of their soil balancing approach.

We used written comments from the remaining self-identified soil balancers to identify a <u>second subgroup</u> that generally relies on soil tests to determine what amendments to apply, but who did not specifically mention base cations, soil balancing-related forms of calcium, or specific soil balancing consultants in their written comments.[9] This group comprised another 18% of all farmer respondents (Table 1). Typical examples of descriptions included in this group were:

- "Soil test and sap tests."
- "I take soil tests every 3 years and apply nutrients as recommended to achieve nutrient levels for crops production."
- "Take soil test, read soil test, and analyze primary needs, buy nutrients in greatest needs, apply nutrients to balance in soil test."
- "I test the soil every 3-4 years and add the necessary amendment for a balanced soil. I am also trying to get organic matter up by plowing down cover crops."
- "Soil test, apply lime, manure, and micronutrient as recommended for optimum yield and soil health."
- "We soil test every 3 years then add soil amendment as we can afford. My goal is to get the soil balance to maximize soil health and yield potential."
- "Take soil sample and use a consultant to keep soil balanced."
- "Do soil testing every 3 years and try to put on trace minerals as needed to get soil balanced to what I'm learning is good."

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[9] It is important to note that some respondents may not have included BSCR concepts or amendments explicitly in their written description since these were included in the wording of the introduction to this block of questions; to the extent that this occurred, our results may underestimate the proportion who use BCSR approaches.

- “We soil test every 3 years. We add nutrients where deficient to try to balance soil for maximum feed quality is our goal.”
- “I have an agronomist that makes recommendations according to my soil sample.”

A final subgroup consisted of farmers who self-identified as soil balancers and provided another type of description of their practices (12% of all farms, Table 1).[10] The most common answers simply referenced using soil amendments and cultural management practices to improve soil health and crop outcomes. Examples include:

- “To get the nutrients all in balance.”
- “Balance soil to improve crop quality and yield and decrease weed pressure.”
- “Balance nutrients - use some compost to bring organic matter up and cover crop.”
- “My soil has enough nutrients, but they are not available...trying to loosen the elements up to make available to crop.”
- “Raise the pH and other minerals along with organic matter.”
- “Soil amendments to grow healthy crops for my cows.”
- “As per consultant to improve soil tilth and health which in turn produces more and healthier crops.”
- “I try to maintain and feed the soil as one would the human or an animal. I find both very similar.”
- “I am try to get mainly the potash and phosphorus rates up and get some nitrogen in. My pH is good been liming for years. Have used legumes and cover crops my whole life.”
- “I use my farm manure and buy some chicken manure, then add fertilizer as needed.”
- “Crop rotation, soil amendments, healthier soils, better drought tolerance.”
- “I plant cover crop to try and raise my organic matter.”
- “Lime, fertilizer as needed. Grass in alfalfa fields cover crops after corn, most often wheat, rye.”
- “Rotate all my fields with alfalfa/grass – hay and pasture haul manure then plow for corn. (2 years corn. 3 years hay, 1 year pasture then corn). Increase organic matter, keep all microorganisms living and thriving.”

Overall, the proportion of self-identified soil balancers who mentioned different key concepts in their description are listed in Table 2 below. It is important to note that these categories are not mutually exclusive, but they highlight the prevalence of different overlapping key concepts that appeared in the written descriptions of their soil balancing practices and goals. By far, the most common theme in the written descriptions is the use of soil tests to achieve some kind of nutrient management plan. Forty-four percent of self-identified soil balancers mentioned testing and managing nutrients in their explanation of how they practice soil balancing. This finding is similar to the prominence given to this topic in the interviews discussed earlier. A large fraction of comments (23%) suggested that the farmer relied heavily on advice from a consultant to implement soil balancing. The use of Hi-Cal lime and gypsum was only explicitly mentioned in 14% of the written comments. This is interesting since the application of these amendments is one of the primary ways base cation percentages are typically achieved or maintained. The application of micronutrients was mentioned in 13% of the comments, which parallels comments made in the consultant and farmer interviews and literature. Eleven percent of comments described the use of compost and manures as a key part of their approach to soil balancing. Nine percent mentioned using a specific consultant or agency that we identified to be using soil balancing practices. Roughly eight percent wrote fairly generally about balancing nutrients using amendments without specific reference to soil balancing products. While managing soil biology was a prominent theme in the farmer interviews, only

[10] Another 4% of respondents said they were followed soil balancing approaches, but did not provide a written description.

about 4% of the written comments on the surveys mentioned adding inoculants and mycorrhizal fungi as part of their soil balancing approach. The diversity in goals and practices confirms the multiple complex ways that soil balancing is conceived and practiced.

Table 2: Frequency of key themes expressed in written descriptions of soil balancing.

Concept	Percent of written descriptions that mentioned each concept
Use of soil tests	43.9
Generic reference to follow advice of consultant	22.5
Use of gypsum, Hi-Cal lime, low Mg lime	13.5
Application of micronutrients	13.1
Use of composts and manures	11.0
Use of consultant known for soil balancing	9.0
Balancing nutrients and minerals in general	8.1
Use of biologicals (inoculants, etc.)	3.8

The survey also asked all self-identified soil balancers how many years they have been using soil balancing approaches (Figure 4). We found that over half of the soil balancers had been practicing this approach for over ten years. This suggests that soil balancing ideas are not a particularly new phenomenon among organic corn growers in this 4-state region.

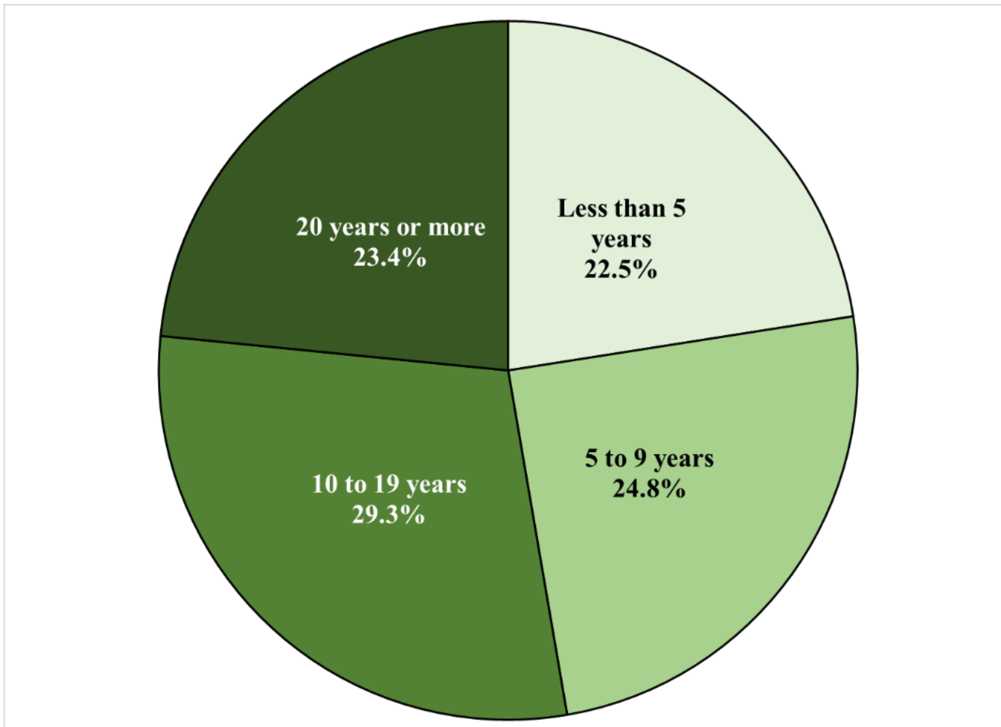


Figure 4: Percent of Self-Identified Soil Balancers by Years Using This Approach

2. Importance of Attaining BCSR Cation Saturation Ratios

On a separate page on the survey, we asked farmers to rank various considerations by their importance to their soil management approach. For each principle, respondents were given four choices: "not at all important," "somewhat important," "important," or "very important." Among a list of 14 possible considerations,[11] we included one option that was designed to capture the soil balancing philosophy: "I try to keep soil calcium saturation at roughly 65-75% and magnesium at roughly 10-15%." Because it was asked of all farmers in our sample, this question provides an independent estimate of the importance of BCSR soil balancing in this region. Responses are shown in Table 3 below. The results suggest most organic corn growers think that attaining a recommended target level of Ca:Mg is important. About 20% said this was very important to them, and nearly two-thirds said it was either important or very important.

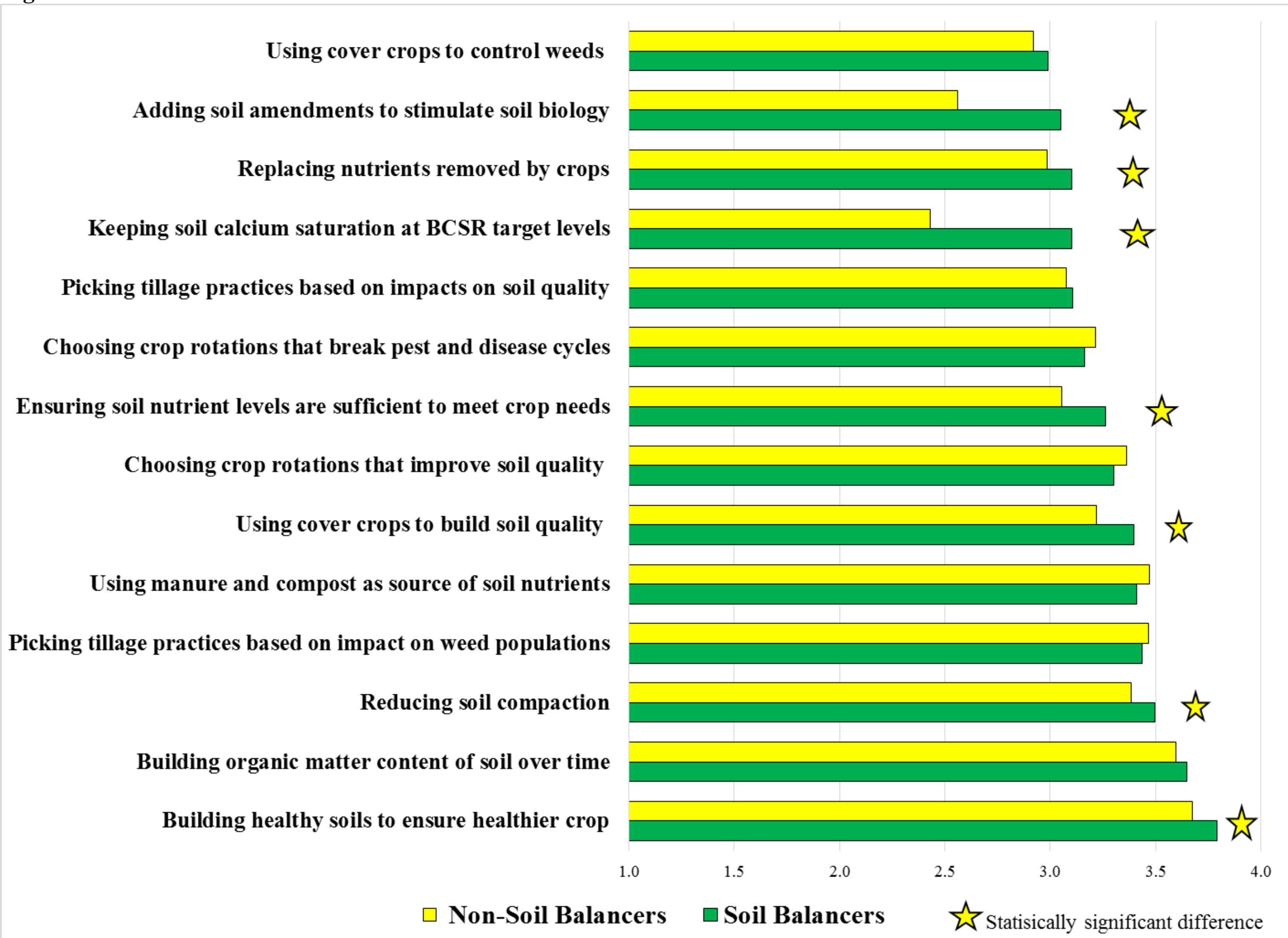
[11] Other examples of principles included statements like: "I ensure that soil nutrient levels are sufficient to meet crop needs," "I seek to build the organic matter content of my soils over time," "I use cover crops based on their ability build soil quality," and "It is very important to me to reduce soil compaction."

Table 3. Importance of Attaining BCSR target Ca and Mg Ratios to Farmers

Statement: *I try to keep soil calcium saturation at roughly 65-75% and magnesium at roughly 10-15%*	Frequency	Valid %
Not at all important	40	5.3
Somewhat important	221	29.2
Important	345	45.5
Very important	152	20.1

For comparison, Figure 5 shows the average importance placed by farmers on each of the 14 considerations included in the survey. We also break out results separately for those who did and did not self-identify as a soil balancer. The results offer several important take-home messages. First, the goal of keeping soil Ca and Mg levels in a BCSR range is clearly more important for soil balancers than non-soil balancers. Second, the BCSR goal appears to be less important than most other considerations when making soil management decisions regardless of soil balancing status (even among soil balancers, it received the third lowest rating). This suggests that most soil balancers are integrating multiple considerations when managing their soils (not just BCSR). Finally, self-identified soil balancers did rate a number of other considerations as more important than non-soil balancers did, including using amendments to stimulate soil biology, building soil quality, and reducing soil compaction. Interestingly, they also were *more* likely to say that traditional SLAN/B&M goals were important than non-soil balancers (e.g., replacing nutrients removed by crops and ensuring soil nutrient levels are sufficient to meet crop needs).

Figure 5: Average Importance of Different Soil Management Considerations among Organic Corn Growers, by Self-Identified Use of Soil Balancing



3. Comparing Indicators of Soil Balancing Status

A comparison of responses to the two questions "do you use a soil balancing approach" and "how important is this principle to you" reveals some level of inconsistency in farmer responses. For example, some farmers may not have identified as someone who practices soil balancing but in fact, gave importance to managing toward BCSR ratios when making soil management decisions (and vice versa). Table 4 presents information about the proportion of self-identified soil balancers and non-soil balancers, who rated the BCSR goal with different levels of importance. The findings illustrate that 30% of the self-identified soil balancers (or 124 farms) indicated that achieving ideal Ca:Mg percentages was a very important priority, and another 52% thought it was important. Meanwhile, 7% of farmers (23 farms) who did *not* identify as soil balancers indicated that achieving a BCSR cation level is very important to them. Interestingly, roughly 18% of self-identified soil balancers (76 farms) rated achieving BCSR target cation saturation levels as either not important or only somewhat important. These results suggest that each type of question elicited slightly different groups of farmers to indicate that they use BCSR or soil balancing.

Table 4. Importance of managing ideal BCSR ratios by self-identified soil balancing status

	Importance of goal: *"I try to keep soil calcium saturation at roughly 65-75% and magnesium at roughly 10-15%"*				
Self-identified Soil Balancing Status	Not at all important	Somewhat important	Important	Very important	Total
	Percent (number) of farms in each category				
Soil Balancers	1.2 (5)	17.2 (71)	51.6 (213)	30.0 (124)	100.0 (315)
Non-Soil Balancers	10.2 (32)	43.5 (137)	39.0 (123)	7.3 (23)	100.0 (413)
All farms in sample	5.1 (37)	28.6 (208)	46.2 (336)	20.2 (147)	100.0 (728)

4. Farm Management Practices used by Soil Balancers

Before asking farmers whether or not they used a version of the BCSR soil balancing method, the survey gathered detailed information about the management practices and soil amendments they had used on a specific organic corn field in 2017. This allowed us to compare the frequency of use of different farm inputs and management practices between self-identified soil balancers and non-soil balancers. Not surprisingly, results suggest that **farmers who self-identify as soil balancers consistently use more calcium amendments** than other organic corn growers (Table 7). Self-identified soil balancers were roughly twice as likely to use BCSR recommended calcium inputs like Hi-Cal lime and gypsum on their cornfield in 2017 than non-soil balancers. This pattern is even more striking when looking at whether they had made any applications of Hi-Cal lime and gypsum over the last four years. While the use of BCSR forms of calcium is higher among soil balancers, they are no more likely to use agricultural lime than non-soil balancers.

With the exception of manure and compost, which did not differ across the groups, the **self-identified soil balancers were more likely to use most other forms of soil amendments or fertility inputs compared to non-soil balancers**. For example, over half of soil balancers used an input containing N, P, or K[12] in 2017, compared to roughly 30% of non-soil balancers. Soil balancers were also three times more likely to apply sulfur, boron, and other micronutrients. While the increased use of boron and sulfur by soil balancers is consistent with the information we gained from our farmer interviews, the heightened tendency to use products containing N, P, and K was not expected. It appears that soil balancers are more likely to apply biological inoculants and stimulants on their organic corn fields than non-soil balancers. This is particularly interesting considering that biologicals were rarely mentioned in open-ended questions explaining soil balancing. Farmer practice suggests that adherence to a soil balancing philosophy often correlates with a greater interest in and use of products designed to boost soil microbiology.

Finally, at the bottom of Table 7, we compare the use of various cultural agronomic management practices between the soil balancing and non-soil balancing subgroups. Organic farmers typically manage weeds through tillage, so it is not surprising that conservation tillage adoption overall was rather low (compared to regional averages for conventional non-organic farms). In our interviews, soil balancing consultants often stressed the importance of some strategic use of deep tillage, so we expected soil balancing farmers to use conservation tillage less frequently. However, we did not find any statistically significant differences in the use of conservation tillage based on soil balancing status. Similarly, while the use of cover cropping for building soil health was emphasized in both consultant and farmer interviews, results suggest no significant differences across our two subgroups. Finally, we used information about crop rotations over the previous four years to highlight the frequency of incorporating small grains and hay in the rotation for fields planted to corn. Again, soil balancers and non-soil balancers appear to have a similar pattern of crop rotations.

[12] Not including any manure or compost products.

Table 7: Use of Various Soil Amendments and Inputs by Soil Balancing Status

	Practices of Self-Identified Soil Balancers			
	Not a Self-Described Soil Balancer	**Self-Described Soil Balancer**	***Combined Full Sample***	*Statistically Significant Difference*
	n=364	*n=444*	*n=859*	
Use of calcium soil amendments on corn field at any time over the last 4 years				
Any Ca input	37.9%	60.4%	*50.6%*	***
Lime	10.7%	11.9%	*11.4%*	
Hi-Cal	18.7%	30.4%	*25.5%*	***
Gypsum	15.7%	33.1%	*25.3%*	***
Use of soil Amendments and inputs on corn field in 2017				
Any Ca input	19.2%	35.8%	*28.7%*	***
Lime	3.8%	4.1%	*3.8%*	
Hi-Cal	8.2%	15.3%	*12.3%*	**
Gypsum	10.2%	17.8%	*14.8%*	**
Any manure	88.5%	90.5%	*89.2%*	
Any compost	9.9%	12.4%		
Any NPK input[1]	30.5%	53.2%	*42.1%*	***
Any N input	26.1%	43.7%	*34.4%*	***
Fish fertilizer products	7.1%	12.4%	*9.5%*	*
Any P input	13.7%	26.8%	*20.2%*	***
Any K input	13.2%	27.3%	*20.2%*	***
Sulfur	6.3%	17.8%	*12.2%*	***
Any Micronutrients	11.8%	35.4%	*24.7%*	***
Boron	6.0%	19.4%	*13.1%*	***
Microbial Stimulants & Inoculants	12.9%	25.9%	*20.0%*	***
Foliar applied inputs	11.5%	16.0%	*13.7%*	
Use of Farm Cultural Management Practices				
Reduced or No-Till	14.0%	11.5%	*12.7%*	
Cover Crops	40.4%	47.7%	*44.4%*	
Diverse Crop Rotations[2]	53.4%	50.5%	*48.7%*	

Notes: [1] = Includes any amendments that included N, P, and/or K.

[2] = Includes only non-corn and soybeans in rotation over previous 3 years prior to planting corn.

As noted above, the survey also asked all farmers (regardless of whether they self-identified as a soil balancer) how important the goal of achieving a BCSR-like level of soil cations was to their approach to soil management. In Table 8, we disaggregate the frequency with which farmers reported using soil amendments by their answer to this question. The findings suggest that farmers who **assigned higher levels of importance to keeping "soil calcium saturation at roughly 65-75% and magnesium at 10-15%" were much more likely to use calcium inputs (except for ag-lime)** than respondents who did not think that this was important. Moreover, the use of BCSR-oriented calcium inputs (Hi-Cal lime and gypsum) increased with each category as the importance given to BCSR goals increased. Similar patterns were seen for the application of NPK amendments, sulfur, boron and other micronutrients, and microbial stimulants. The consistency of the patterns observed in Tables 7 and 8 reinforce the idea that regardless of how we operationalize the concept of soil balancing using the survey data, the soil balancers are more likely to use a wide range of soil amendments on their organic corn fields.

The use of conservation tillage, cover crops, and diverse crop rotations continue to be unrelated to the extent to which farmers place importance on achieving BCSR ratios despite the interviews that emphasize their importance in the context of soil balancing (bottom of Table 8). While not statistically significant, use of conservation tillage tended to be lower, and use of cover crops tended to be higher among farmers who placed more emphasis on BCSR ratios. These results suggest that these cultural practices may not be distinctly soil balancing practices but rather practices that are emphasized in the context of organic farming.

Table 8. Use of Soil Amendments and Inputs, by Importance of BCSR Goals to Farmer

	How important is "trying to keep soil calcium saturation at roughly 65-75% and magnesium at roughly 10-15%."				
	Not at all important	**Somewhat important**	**Important**	**Very Important**	*Statistically Significant Difference*
	n=40	*n=221*	*n=345*	*n=152*	
Use of calcium soil amendments on corn field at any time over the last 4 years					
Any calcium input	25.0%	43.9%	52.8%	65.1%	***
Lime	5.0%	13.1%	11.0%	13.2%	
Hi-Cal	17.5%	18.1%	28.4%	33.6%	**
Gypsum	7.5%	22.2%	25.5%	35.5%	***
Use of soil amendments and inputs on corn field in 2017					
Any calcium input	12.5%	25.8%	29.0%	38.8%	**
Lime	2.5%	5.4%	2.3%	5.9%	
Hi-Cal	7.5%	7.7%	15.7%	15.1%	*
Gypsum	2.5%	15.4%	11.6%	23.0%	***
Any manure	85.0%	89.6%	92.2%	85.5%	
Any compost	7.5%	9.5%	13.3%	11.8%	
Any NPK input[1]	17.5%	34.8%	45.2%	58.6%	***
Any N input	17.5%	28.1%	38.3%	46.7%	***
Fish fertilizer products	2.5%	7.7%	9.9%	17.8%	**
Any P input	12.5%	12.7%	23.8%	27.0%	***
Any K input	7.5%	14.0%	23.5%	28.3%	***
Sulfur	5.0%	5.4%	13.6%	23.0%	***
Any Micronutrients	5.0%	17.2%	26.7%	38.8%	***
Boron	5.0%	7.7%	14.8%	20.4%	***
Microbial Stimulants & Inoculants	5.0%	18.6%	20.6%	30.9%	***
Foliar applied inputs	7.5%	11.8%	15.7%	17.1%	
Use of Farm Cultural Management Practices					
Conservation Tillage	14.6%	14.6%	12.2%	11.9%	
Cover Crops	29.3%	43.3%	44.7%	50.0%	
Diverse Crop Rotations[2]	58.5%	49.1%	49.1%	50.0%	

Notes: [1] = Includes any amendments that included N, P, and/or K. [2] = Includes only non-corn and soybeans in rotation over previous 3 years prior to planting corn.

5. *What types of farms are more likely to practice soil balancing?*

While the survey sample was limited to certified organic farms who grew corn in 2017, the respondents represented diverse types of farming operations. We were interested in whether or not farmers with different farming enterprises were equally likely to use soil balancing methods. To explore this question, we used information about the most important sources of farm income to classify farms into five categories based on crop and livestock enterprises. In Table 9, we explore the frequency of soil balancing and the use of BSCR amendments across these five farm types. The findings suggest that vegetable operations who grow corn were much more likely than other farm types to identify as soil balancers and to use Hi-Cal lime frequently. Dairy farms were the next most likely to identify as soil balancers and to use Hi-Cal lime. Since both vegetable and dairy farms produce relatively high-value products, this suggests a possible link between the intensity of farm sales and use of soil balancing approaches. It could also be related to concerns about calcium removal on dairy farms discussed by early proponents (Albrecht 2011). Interestingly, there were no significant differences across the farm types related to the percent who report BCSR saturation levels as 'very important' to their management approach. Similarly, there were no significant differences in the use of gypsum.

Table 9: Percent of farmers identifying as soil balancer or using inputs, by farm type.

	Most Important Source of Farm Income					
	Cash Grain (n=214)	Vegetables (n=46)	Other Crops (n=37)	Dairy (N=443)	Other livestock (n=67)	*statistical significance*
	Percent of farms in each category					
Self-Identified Soil Balancer	45.3%	76.1%	43.2%	59.4%	49.3%	***
BCSR target ratio 'very important'	18.5%	25.0%	24.2%	21.2%	12.3%	
Used Hi-Cal Lime in 2017	10.7%	24.5%	2.6%	13.8%	5.5%	**
Used Hi-Cal Lime over last 4 years	20.6%	28.6%	21.1%	30.1%	12.3%	**
Used Gypsum in 2017	16.7%	16.3%	15.8%	13.3%	13.7%	
Used Gypsum over last 4 years	24.5%	22.4%	21.1%	26.5%	23.3%	

As noted in the methods section above, a large fraction of the farmers who grow organic corn in this region are members of Amish, Mennonite, or other Plain communities. Among the respondents to the survey, nearly two thirds (63.5%) relied primarily on horses to carry out fieldwork on their organic corn fields. Based on our knowledge of the study area, the vast majority of survey respondents who use horse-drawn equipment in their corn fields are likely to be Old Order Amish (the dominant group who uses horse-drawn group) with a few New Order Amish farmers particularly in a few settlements in Ohio. Some farmers may be Swartzentruber Amish which is a more conservative subgroup in terms of church rules than the Old Order Amish.

The use of soil balancing differs between farms that used horses versus tractors to pull field equipment in 2017 (Table 10). Organic corn growers who rely on horse-drawn equipment are more likely to self-identify as soil balancers (though they were not more likely to say that BCSR saturation targets were very important to them). Farmers who farm with horses were more likely to use Hi-Cal lime, but not more likely to use gypsum.

Table 10: Frequency of soil balancing, by use of horses vs. tractors to pull field equipment.

	Horses (N=508)	Tractors (n=297)	*statistical significance*
	Percent of farms in category		
Self-Identified Soil Balancer	58.9%	48.5%	**
BCSR target ratio very important	20.2%	19.7%	
Used Hi-Cal Lime in 2017	14.8%	8.4%	**
Used Hi-Cal Lime over last 4 years	29.4%	18.3%	***
Used Gypsum in 2017	13.3%	17.0%	
Used Gypsum over last 4 years	24.4%	27.0%	

D. How Well does Soil Balancing Work?

As noted in the introduction to this report, **farmers and consultants have long argued that soil balancing has generated positive results under working farm conditions**. The private soil balancing literature (i.e., Acres, U.S.A. books, and newsletter) is full of stories where BCSR principles have transformed relatively poorly producing soils into dynamic and productive agricultural fields. Our research sought to capture more systematic information about the observed outcomes associated with the practice of soil balancing from practitioners in this region.

1. Changes in soil and crop outcomes reported in interviews

In our interviews, **nearly all of the farmers and consultants reported observing changes in soil chemistry, physics, and biology** that they associated at least to some degree with their use of soil balancing practices. Improvements in soil physical properties and soil quality were among the most common outcomes mentioned in our interviews (discussed in 17 of the interviews). Many of the farmers used adjectives describing positive physical changes in the soil that occurred after applying soil balancing amendments. Ten of the farmer interviewees described previously unbalanced soils using negative adjectives associated with physical properties, including "tight," "tied up," and/or "locked up." For example, one farmer stated that if the Ca:Mg ratio is off, then soil "is real tight and can't absorb the air and water." Another farmer stated that when the ratio of calcium and magnesium is correct, there is "less compaction or locking it [i.e., the soil] up." Others used descriptions that sounded more like chemical interference. The same farmer explained that when the Ca:Mg ratio is off, the "calcium is in the soil, but it can't get in the plant," and that his soil balancing tactics are "trying to get it more in balance, so it's more available for plant uptake." Another farmer stated if you have your soil balanced, "then the various nutrients then can be released, and they're not tied up in the soil."

Similarly, a balanced soil was described with **positive physical qualities**. Three farmers talked about their soil being "mellow" to indicate a positive state of soil tilth. Two farmers used the word "flocculate" to indicate a state of balance. One stated their goal to "move that calcium into those high 60s first, flocculate that soil to where you can get some leachability with it." Another farmer stated that the sulfur in gypsum helped to "loosen" soil. One consultant discussed how soil balancing improves resilience, saying the soil is "basically softer, and it holds up better to adverse conditions."

These positive physical properties were often connected with reduced weed pressures. About two-thirds of those interviewed mentioned reductions in weed pressure from soil balancing. Seven interviewees described how overall weed pressure declined with soil balancing and ten specifically discussed how grasses such as foxtail, in particular, were less common. Of those interviewees who felt there was a connection between weeds and soil balancing, they generally associated soil balancing with reduced compaction, which provided a less desirable environment for weed seeds. One farmer claimed to have significantly reduced a quackgrass problem by correcting the "high magnesium levels, tighter soils" and using "a lot of cover crops over the years." It is worth noting that most respondents did not volunteer information about the impacts of soil balancing on weeds until we prompted them by asking about this topic directly.

Finally, only a few interviewees specifically reported improvements in plant health and reduced insect pressures linked to soil balancing practices. However, for those interviewees who did discuss plant health and reduced insect pressures, the issues tended to be connected to each other and to improved physical and biological properties of the soil. A consultant observed that improved soil health could improve plant health in that they have "less bug pressure than we did the first year that we were farming." He also felt that he had seen improvements in "the soil structure, the soil microbes" and therefore he has seen improvements in plant health and improved "immunity towards pests and diseases." Another farmer echoed this integrated sentiment by saying, "you get the soil balancing right; you get the biology right," and then "you can have less weeds, less insects, less disease."

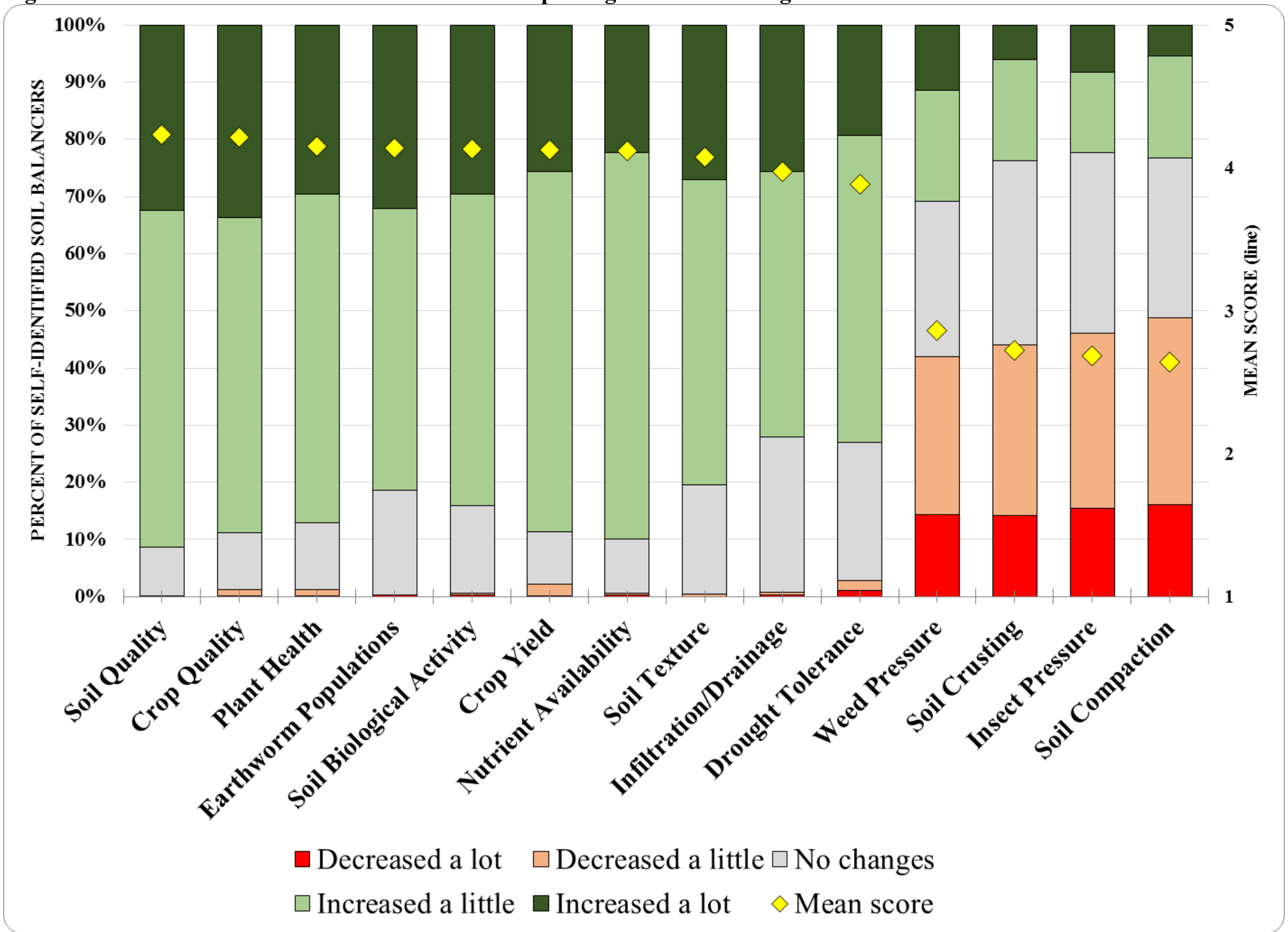
2. Changes in soil and crop outcomes reported in surveys

The experiences shared in interviews are consistent with the results of the survey. Specifically, we asked all self-identified soil balancers to describe whether the use of soil balancing has increased or decreased various types of outcomes on their farms. The proportion of farmers reporting increases, no change, or decreases for each outcome are illustrated in Figure 6.

Results suggest that farmers associate their use of soil balancing with a wide range of positive outcomes. The **most common improvements were seen for soil quality and plant health** (including crop quality, soil biological activity, and earthworm populations). Slightly fewer farmers (but still an overwhelming majority) saw improvements in yield, nutrient availability, and soil texture. While most farmers reported improved infiltration and drought tolerance, some farmers said that these did not change on their farms when they switched to soil balancing approaches.

We included four items on the survey that reflect negative outcomes (weed pressure, insect pressure, soil crusting, and soil compaction) that might be affected by soil balancing. Most soil balancers report that these four negative conditions declined after balancing their soils (suggesting a benefit), but a minority reported increases in these problems. A close examination of the surveys suggest that a very small group of respondents (n=15) may have patterned their answers (e.g., ranking every type of outcome with the same score), but these patterned responses may not explain the negative reports, especially in weed pressure.

Figure 6: Percent of Self-Identified Soil Balancers Reporting Positive and Negative Outcomes



3. Economics of Soil Balancing (interview results)

Interview data illustrate complexities in how **practitioners evaluate the economic returns from soil balancing**. In general, farmers and consultants were more likely to highlight the biophysical impacts of soil balancing on soils and crops, and less likely to emphasize economic outcomes. Positive economic benefits from the use of soil balancing practices were mentioned in 15 farmer interviews, but this was most commonly discussed only after respondents were specifically prodded about the topic.

Consultants generally report positive economic returns for their clients and shared the sentiment that "if we're not making [farmers] money, then they're not going to pay me…" as indicated by a "very very good retention on customers... Once we get those soils in…the proper relationship of calcium to magnesium." Most consultants acknowledged that additional upfront costs are required during the transition toward a more balanced soil. In general, consultants argued that farmers would need fewer inputs after their soils are balanced because it will generate "consistency of yield and efficiency of nutrients…and bottom line." Another consultant said that their clients eventually "wouldn't have to buy as many inputs."

While both **farmers and consultants acknowledged that the process of soil balancing might require significant outlays of capital at the beginning, farmers expressed more concern about the extent of these costs** and were skeptical about whether the benefits justified the extra costs. One farmer noted that "you need to balance what you can make and what you can afford." In another case, a farmer noted how he sought to find a local source for his Hi-Cal lime and gypsum to reduce trucking costs and make soil balancing less expensive.

Concerns about costs were not necessarily limited to soil balancing amendments, per se. When one farmer was asked to elaborate on his statements regarding the high cost of gypsum, he responded by stating that it "is all expensive," while another referenced the cost of phosphorus and potash products in the context of soil balancing. A few farmers expressed general skepticism about the cost-effectiveness of many soil additives on the market. One said that if the consultant "can consistently drive a better truck than I do, I think maybe I'm buying too much of it." While he stated that soil consultants are "in it for the soil health," they are also "in it to make money." Another farmer described asking his consultant, "what's the difference between fish oil and snake oil?" and said, "It usually gets a pretty good response." While the farmer seemed to think that fish oil is a useful additive, the snake oil comment indicated skepticism. Some farmers felt that a heavy focus on purchased soil additives is not compatible with the core philosophy of organic farming. One said that too much reliance on additives is "basically the same thing as chemical farming." Another expressed concerns about how using some soil management additives "totally missed the point of the holistic management of understanding that nature has a way of balancing some of that out."

A few farmers talked about how managing their fertility budget was more important than achieving high yields. In other words, they were fine if their yields were not as high as their potential if it made more sense financially. One farmer admitted he was not achieving top yields, but felt he has a handle on his "fertility budget," stating, "We don't just spend everything the soil has asked for, you know?" Another farmer echoed that view when he asked rhetorically, "If you make $500 an acre on something, and you spend $500 getting it, what did you make?"

Compared to purchasing soil amendments, **cultural field management practices were considered by some to be a more economically efficient way to improve soil quality**. One farmer stated, "Cover crops are cheap" as compared to "soil amendments." He goes on to explain how the cover crop enriches the soil directly, whereas soil amendments need time to break down and become usable. Another farmer talked about the different amendments he had been applying which included gypsum, sulfur, and foliars; but now, due to finances, he is trying to "grow my organic matter, and hopefully, nature can balance some of that out...".

It is worth noting that the months in which the interviews took place were characterized by persistent low prices for soybeans, corn, and milk (which were the core commodities produced by most of our interviewed farmers). One farmer referring to his consultant stated, "right now he's probably going to suffer a lot of sales because of the dairy situation." Poor economic conditions led some farmers to say that they cannot afford gypsum. One consultant hoped that farm economics would "get turned around" so that one of his clients could afford more amendments "but that's one of the challenges." Another consultant discussed how the state of the farm economy meant that "farms are pushing me to show change in one year…" and "if I don't show them some kinda change in year one, they're not interested."

4. Profitability of Corn Production (survey results)

Based on self-reported data on soil amendments and crop yields, we were able to estimate the net returns to labor and management for most survey respondents' corn enterprises. Results suggest that self-identified soil balancers had statistically higher yields when corn was harvested as grain (138 vs. 129 bushels per acre), but no significant difference when corn was harvested as silage (20 vs. 19 tons per acre). While higher yields led to greater total revenue per acre for soil balancers, consistent with the results noted in Table 7 above, soil balancers spent more on most types of soil amendments (except for manure and compost). They also had estimated expenditures on seeds and land costs that were higher than non-soil balancers (most likely because they planted at higher densities and lived in areas with higher land rental rates). As a result, net returns to labor, and management for soil balancers were not statistically better than on farms where soil balancing is not practiced. [13]

[13] Further analysis is needed to tease out the influence of hi-cal lime and gypsum versus the other inputs if one were to try to analyze the influence of BCSR in particular.

Table 11. Expenses and Net Returns for Soil Balancers vs Non-Soil Balancers

Characteristic	TOTAL SAMPLE (n=715)	Self Identified Soil Balancer NO (n=319)	YES (n=396)	*sign. diff.*
		average/acre		
Corn Yield				
Corn harvested as grain (bu)	133.7	129.1	137.7	*
Corn harvested as silage (tons)	20.1	19.4	20.5	
		average $/acre		
Soil Amendment Expenses				
Manure & Compost	$79	$80	$79	
NPK fertilizers	$26	$17	$34	***
Calcium products	$14	$10	$17	**
Micronutrients	$9	$4	$13	***
Microbiologicals	$4	$3	$6	*
Fish products and Foliar Applications	$6	$4	$8	**
Other expenses	$11	$7	$14	*
Estimated Corn Expenses/Acre				
Combined Soil Amendment Expenses	$150	$124	$171	***
Estimated Seed Expenses	$98	$96	$100	**
Estimated Land Rental Expenses	$155	$146	$162	**
Estimated Fieldwork Expenses	$95	$96	$94	
TOTAL EXPENSES	$154	$461	$527	***
TOTAL REVENUE	$1,307	$1,255	$1,348	**
NET RETURNS TO LABOR & MGT	$809	$794	$821	

5. Complex system dynamics

Farmers and consultants struggled in the interviews to identify the *most important* benefit associated with soil balancing. For those who did respond to the question, responses were wide-ranging: yield, quality, soil structure, profitability, and plant health. **Outcomes associated with soil balancing practices were often described by farmers and consultants as a set of interlocking and related effects**. Discussing one outcome in isolation ignores the complex and integrated way in which many of the practitioners think about the dynamics of their farming systems. When asked to list some of the benefits of soil balancing, eight respondents chose to focus on the importance of system integration (either because the benefits were clearly intertwined and related to other management practices, or because they listed multiple benefits in the same sentence). One consultant stated that with soil balancing, you get "Better aeration, I see less weed control problems, especially in the grasses when we get better soil balance." Another talked about how improvement in "the soil structure" and "the soil microbes" was connected to the health of that plant. He went on to say that improved health of the plant helped provide immunity toward pests and diseases. Another farmer stated how soil balancing promotes "a more resilient soil. It's basically softer, and it holds up better to adverse conditions." This may be why farmers rated most outcomes from soil balancing in the survey very positively (see Figure 6 above).

The **interconnected nature of soil balancing benefits may help explain why many respondents chose not to talk about crop yields**. As one farmer stated, a balanced soil gives him "more consistent stands, less stress, and it ends up being better yields." A consultant claimed that their "focus is not necessary yield…We don't make that a… goal post…" Rather he went on to say, "Our goal post is the quality of the crop and so, as we achieve that, the yield takes care of itself." One interviewed farmer who also responded to the mail survey expressed frustration by the economic focus of the survey instrument as he felt that farmer motivations around soil health were more than just monetary. It was also not clear that all the mentioned benefits were derived solely from achieving the ideal chemical soil balancing ratio. One of the interviewees stated that he does not think that positive outcomes on his farm were necessarily all attributable to some "magical calcium product."

IV. Summary

For decades, **soil balancing has been recommended by a large group of crop consultants and advisors and practiced by a significant number of farmers (particularly in the organic sector).** This study represents a pioneering effort to collect systematic data on the extent of soil balancing, how it is practiced, and the types of outcomes experienced by soil balancing consultants and farmers. We used interviews with 33 farmers and crop consultants and survey responses from over 850 organic farmers to benchmark the behaviors and self-reported experiences with soil balancing among organic corn farmers in Indiana, Michigan, Ohio, and Pennsylvania.

It is worth noting that the **university scientific community has largely dismissed the value of soil balancing**. The limited scientific studies in the peer-reviewed literature on soil balancing have consisted of formal agronomic experiments that look for crop yield effects associated with the use of calcium amendments to achieve recommended BCSR ratios. These studies have not been able to reproduce statistically significant benefits from following a BCSR program. Land grant extension and other advisers place greater trust in an approach known as sufficiency level of available nutrients (SLAN), where soil amendments are recommended at levels that meet the annual nutrient requirements of common field crops.

To measure the prevalence of soil balancing, we first sought to capture information about how farmers and consultants define that term. Our interviews and surveys confirmed that the use of **Hi-Cal lime and gypsum amendments is a core component of most soil balancing programs**. Manipulation of base cation saturation ratios in the soil was linked by consultants and practicing farmers to visible improvements in crop and soil quality, particularly when "tight" soils had prevented adequate drainage and limited nutrient availability. Soil balancing consultants emphasized how calcium interacts with other nutrients and reported that when ideal BCSRs are achieved in soils on farms where they have worked, the availability and resulting plant uptake of other macro and micronutrients can improve. They also argued that while levels of soil nutrients may look adequate in standard soil tests, these nutrients may not be in a plant-available state (either due to an imbalance in base cations or because of interactions with other macro and micronutrients, such as boron). Many consultants indicated the effectiveness of BCSR approaches depends on having adequate cation exchange capacity (CEC) in the soil.

While **BCSR is at the core of most soil balancing programs, most consultants and farmers cautioned that a narrow focus on BCSR chemistry could ignore the importance of the physical and biological legs of soil balancing**. As a result, most recommend a range of complementary soil fertility (e.g., manure/composts, SLAN, micronutrients) and field cultural practices (e.g., cover crops, crop rotations, and tillage) to balance soils and improve overall soil health.

Over half of surveyed organic farmers in this 4-state region say they use soil balancing. However, their descriptions of what they do when they use the practice were diverse. While references to BCSR levels and ratios were common, written comments on the surveys suggest that using high-calcium amendments is only one of several overlapping practices farmers associate with soil balancing. Farmer descriptions frequently referenced using soil tests to "balance" a wide range of nutrients (not only base cations), and many soil balancers integrated ideas from both BCSR and SLAN approaches. Self-identified soil balancers reported greater use of a wide range of soil amendments (e.g., NPK, micronutrients, microbial stimulants, and inoculants) in addition to higher levels of Hi-Cal lime and gypsum, reflecting their emphasis on soil testing and soil fertility management. Self-described soil balancers were three times as likely to apply micronutrients (especially boron) and spent three times as much on them. These results mirror the emphasis on boron and sulfur uncovered in our interviews. Perhaps more importantly, many farmers emphasized how their approach to soil balancing involved the use of cultural management practices such as manure/compost, diverse crop rotations, and cover crops designed to build soil health.

Survey and interview results indicated that self-described soil balancers **experience improvements across a number of indicators of soil health and crop quality and performance**. Most common were improvements in soil physical and biological quality, plant nutrient availability, and improved crop health and quality. Crop and soil performance indicators were rarely mentioned in isolation of each other. Survey results also suggest that self-described soil balancers had higher yields and revenues from their corn fields but spent more on soil amendments, and thus experienced similar net returns. While consultants were confident that soil balancing would improve long-term soil quality and farm profits, many farmers expressed concern about spending money on soil amendments (particularly during difficult farm financial conditions).

Several limitations to our work could be addressed in future studies. While our interviews included a variety of different farm types, the mail survey sample only included farms with certified organic corn acreage. Given that corn farmers who also grew vegetables were more likely to be soil balancers, there may be more to be learned about how soil balancing is practiced by vegetable farmers. This study was also limited to organic farmers in the eastern corn belt/northeast region. Anecdotal evidence suggests that soil balancing is also common among conventional farmers in this area, and it would be interesting to explore whether the diversity of soil management practices deployed by certified organic soil balancers is duplicated among conventional farmers.

Future research should build on important concepts that were gleaned from this research to bridge the gap between previous scientific studies and practitioners. The complex character of soil balancing practices among farmers and consultants suggests a need for more scientific research designed to capture the interactions among BCSR and related soil management practices. This might require studying soil balancing outcomes under working farm conditions. Since our survey gathered data on only one year of corn production, future economic research would benefit from incorporating data from multiple years to account for more biophysical and market factors that affect crop yield and net farm returns.

Important issues to address in future scientific research include: (a) comparing systems vs. single factor analysis, (b) exploring ways that base cations interact with other macro and micronutrients and the role of calcium, magnesium and potassium on plant availability of nutrients throughout the growing season, and (c) observations of the long-term effects of soil balancing practices, and how these are mediated by soil CEC. This research captured some of the expertise and experience of soil balancing consultants and farmers. Future work would benefit from engaging the experiential knowledge of these practitioners to more accurately capture the complexity and diversity of actual soil balancing behaviors.

V. Appendix: Mapping the Soil Balancing Consultant World

Notable relationships and connections exist between key soil balancing organizations and soil testing labs. As discussed earlier, William Albrecht is considered the forefather of soil balancing. His ideas have been mainly disseminated most recently via the organization Acres, U.S.A., which was founded by Charles Walters. Brookside, a prominent soil testing lab in Ohio which emphasizes soil balancing, is also connected to Dr. Albrecht. One of the leaders of the lab, Dr. Kuck, started to work with Dr. Albrecht in 1950 and adopted his methods. Albrecht worked there post-retirement until his death in 1974, leaving his research records with them. According to Brookside Lab's website, they are the oldest soil testing lab in North America. Brookside holds training sessions on soil balancing and employs more than 200 independent consultants who are knowledgeable in BCSR theory. Another prominent soil balancing consultant and author, Neal Kinsey, received a certificate from Brookside labs and served as a consultant there before establishing his own organization, Kinsey Agriculture Services, in 1973 in Missouri. After he retired from the University of Missouri, Kinsey took a private course Albrecht taught at Brookside Lab. Kinsey wrote *Hands-On Agronomy* an important resource for this paper and for many consultants, particularly around the chemical components of soil balancing.

Bill McKibben is another Ohio-based independent consultant who was affiliated with Brookside Labs for many years. He is now affiliated with Logan Labs and wrote the book *The Art of Balancing Soil Nutrients* which is also more focused on the chemical part of soil balancing. Logan Labs started in 2002. The soil balancing approach is not obvious from their materials aside from the link to Bill McKibben's book. Bill McKibben has the most clearly presented outline of appropriate contexts for using BCSR. His book has a unique emphasis on an alternative soil test which he feels can detect nutrients more effectively in high CEC soils.

Gary Zimmer founded Midwestern BioAg in Wisconsin in 1983 and was partly schooled on Albrecht papers and Brookside consulting in the 1970s. While the independent consultants highlighted above also emphasize soil biology, Gary Zimmer emphasizes it more concretely in the recommendations and reframes soil balancing within the concept of biological farming. According to the Midwestern BioAg website, he is considered by many to be the father of "biological farming." He wrote a number of books, including the recent *The Biological Farmer*. Gary Zimmer starts this book with the idea of testing and balancing but then builds from there with five other core principles for managing soil which includes, "utilizing fertilizers that are life promoting, minimizing pesticides, maximizing diversity, strategic tillage, and feeding life." Midwestern BioAg is expanding and now has consultants in many other states besides Wisconsin. Midwestern BioAg has been using Midwest Labs in Nebraska as their headquarters "for 30 or 40 years."

Jerry Brunetti, the founder of Agri-Dynamics in Pennsylvania, drew from and interacted with Neil Kinsey and Gary Zimmer and also cites the Albrecht papers and the Rodale Institute. Brunetti attempts to "bridge natural and scientific understandings of plant and animal 'ecosystems.'" Like Gary Zimmer, he is very focused on the biological components of soil balancing but stresses additional concepts such as Brix as a measure of crop quality, using foliar fertilizers, and thinking of food as medicine. A number of independent consultants sell Agri-Dynamics products. One such consultant who worked closely with Jerry Brunetti is Jonathan Zeiset. Jonathan Zeiset operates Zeiset Ag Consulting & Sales and farms organically in Central Pennsylvania. Jonathan Zeiset also sells Midwestern BioAg products and studied under Neal Kinsey.

The Ohio-based consulting firm, Advancing Eco Agriculture (AEA), was founded by John Kempf in 2006 to promote "regenerative agriculture." He worked with Jerry Brunetti and was also trained by Gary Zimmer. While AEA focuses primarily on vegetables and fruits, they also work with agronomic crops. AEA's website states that their focus is not just about yield but also about quality and having a functioning immune response. They indicate that higher yields will follow after quality is increased.

Overall, there is some geographic segmentation between the different organizations and cross-fertilization between the groups given how interconnected they are, but there is also a friendly competition despite their intertwined relationships and geographic differences. In addition to these groups and others not mentioned, smaller locally based groups may offer consulting services and sell products for one or more of the organizations discussed above. Additional groups such as Soil Biotics may recommend high calcium amendments while not affiliating strongly with soil balancing theory.

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