HOW VARIABLE IS VARIABLE FOR PRODUCTION FIELDS IN SOUTHERN IDAHO

L. Schott[1], E. Brooks[2], C. Robison[1], A. Chapagain[1], K. Nouwakpo[3], and D. Bjorneberg[3]
[1]University of Idaho, Twin Falls Research and Extension Center
[2]University of Idaho, Moscow, Idaho
[3]USDA ARS, Kimberly, Idaho

ABSTRACT

Agricultural producers in Southern Idaho, just like many other regions, are tasked with managing irrigation water and soil fertility on large fields with spatial heterogeneity in a way that results in homogeneous crop production. Management practices implemented to the 'average' of the field limit the ability to attain maximum efficiencies of inputs, such as fertilizer and water. To better advise agricultural producers on precision agricultural practices, first spatial variability of typical production fields must be assessed and quantified. To this end, two 130-acre fields in Southern Idaho were sampled at a high spatial resolution for soil physical, chemical, and biological properties at multiple depths in fall 2019 and spring 2020. Initial results showed the presence of spatial variation in the soil properties like cation exchange capacity, pH, organic matter, total inorganic nitrogen, and phosphorus. However, the degree of the variation was different for each soil property. The presence of spatial variation in soil properties will serve as the basis for site-specific management to attain higher nutrient use efficiency and optimum crop productivity as supported by the potato yield and fall soil fertility data presented.

INTRODUCTION

Generally, agricultural research is conducted on small plots to reduce soil variability. While this is important for research purposes, scaling up of the results of research by producers can be a challenge in the presence of soil heterogeneity. With the increase in acreage from plot to field, the variability within the field also increases. Implementation of management practices, like fertilizer application and irrigation, tend to target the field average and do not necessarily account for field variability. Commercial crop production systems tend to adhere to homogeneous management of large acreage fields due to the efficiency of application of inputs. However, homogenous management practices applied over these large production fields does not necessarily result in the optimum use of inputs. Reduced input efficiency can be caused by the loss of applied input through leaching, runoff, volatilization, and evaporation, depending on the type of input. These input losses also incur economic losses. When crop inputs are optimized, the profitability from the agricultural commodity grown can be maximized.

In this regard, evaluating the variability of soil fertility and crop productivity is important. When the variability in the field is known, it can be better managed, such as dividing it into sections where each section has a similar response when subjected to optimized inputs. Site-specific crop management comes with advantages like better efficiency of inputs, reduced costs of inputs, and optimized crop productivity. There are many ways management zones can be defined, like based on individual soil properties or crop production properties.

The objective of this research is to evaluate the spatial and temporal variability of soil and crop properties of two Southern Idaho fields used for commercial crop production by evaluating soil nutrients and crop characteristics.

METHODS

The research was carried out at the Idaho Center for Agriculture, Food, and the Environment (Idaho CAFE) Sustainable Water and Soil Health Demonstration and Research site near Rupert, Idaho. The site extended from 42°48’28’’ N to 42°48’54’’ N and 113°40’5” W to 113°41’15” W. Site elevation ranged from 1309 m (4297ft) to 1331 m (4370 ft). The region is semi-arid with annual precipitation of approximately 24.2 cm (9.53 in).

Idaho CAFE was established as a new research and demonstration farm in 2019. As such, the initiation of research included site characterization. Historically, the cropping system of the southern fields was a four-year barley-sugar beet-barley-potato rotation. In 2019 and 2020, the fields were in barley and sugar beets, respectively, with the rotation continuing in 2021 and 2022. Each field was approximately 130 acres and irrigated with a center pivot using groundwater. Both fields are managed exactly the same, including the timing and amount of water application. The southwest field within the section (SW) was characterized after barley harvest in 2019 whereas the southeast field (SE) was sampled for characterization before planting in the spring of 2020; the large number of samples collected from each field inhibited the ability to characterize both fields at the same time. Between sampling events, fields were vertically tilled in fall and roller harrowed in the spring. Fertilizer was also applied at rates of 220 lb N ac^{-1}, 220 lb P ac^{-1}, and 165 lb K ac^{-1}. Each field was divided into 170 ft by 170 ft (0.66 acre) grids having a density of 180 points and 187 points for the SW and SE fields, respectively. At each location, the soil was sampled using a bucket auger at depths of 0-10 cm (0-4 in), 10-20 cm (4-8 in), 20-30 cm (8-12 in), 30-60 cm (12-24 in) and 60-90 cm (24-36 in), and depth to bedrock was recorded. All soil samples were air-dried and sieved (2 mm) before they were analyzed for soil chemical properties by a commercial laboratory.

Beginning in fall 2020, crop yield and quality were evaluated in 21 locations per field. The locations were selected to capture the crop variability of each field. Using 2018 satellite crop evapotranspiration (ET) data, each 2019/2020 sampling location was characterized as high (>34.6 inches), medium (31.0 – 34.6 inches), and low (<31.0 inches) ET. In 2018, temperatures were slightly above average in July, August, and September. Precipitation was well above average from January to early July and below average for the rest of the cropping year. For each ET zone, seven locations were chosen for temporal sampling. Soil fertility samples were taken in the spring before planting and in the fall after harvest. Crops were hand harvested for yield and quality analyses a few days before bulk harvest every year. Only a subset of data will be presented in this paper.

RESULTS AND DISCUSSION

Initially, descriptive statistics were used to describe soil properties (Table 1). Means for organic matter, pH, cation exchange capacity (CEC), and excess lime were similar for both fields while means of total inorganic N, total P, and total K were greater in the SE field due to fertilization between sampling the SW and SE fields. However, results seem to indicate that the SE field had higher P and K values prior to fertilization. Inorganic N also could have been higher in the SE field in the fall, but it’s impossible to say due to potential N leaching over winter. For total inorganic N, P, and K, there were wide ranges of values for both fields.

Table 1. Descriptive statistics of soil properties in total soil profile (0- 36 in) for both fields.

Property	mean	median	min	max	CV
SE Field					
OM (%)	1.51	1.48	1.03	2.21	12.54
pH	8.12	8.17	7.31	8.44	2.16
CEC (meq per 100 g soil)	19.4	19.44	14.8	23.39	7.38
Excess Lime (%)	9.41	9.91	0.36	17.02	43.78
Total Inorganic N (lb ac^{-1})	232.2	215.5	71.3	1066.5	47.14
Olsen P (lb ac^{-1})	668.2	666.6	93.5	2282.8	50.83
K (lb ac^{-1})	1306.6	1184.7	496.2	3707.5	39.16
SW Field					
OM (%)	1.6	1.58	1.17	2.29	12.21
pH	8.2	8.22	7.74	8.48	1.31
CEC (meq per 100 g soil)	17.62	18.33	8.33	24.54	17.73
Excess Lime (%)	10.75	11.66	1.49	16.38	32.69
Total Inorganic N (lb ac^{-1})	96.4	93.3	37.5	230.6	30.61
Olsen P (lb ac^{-1})	103.2	93.4	43.4	520.0	42.84
K (lb ac^{-1})	789.1	728.6	268.0	2592.5	46.02

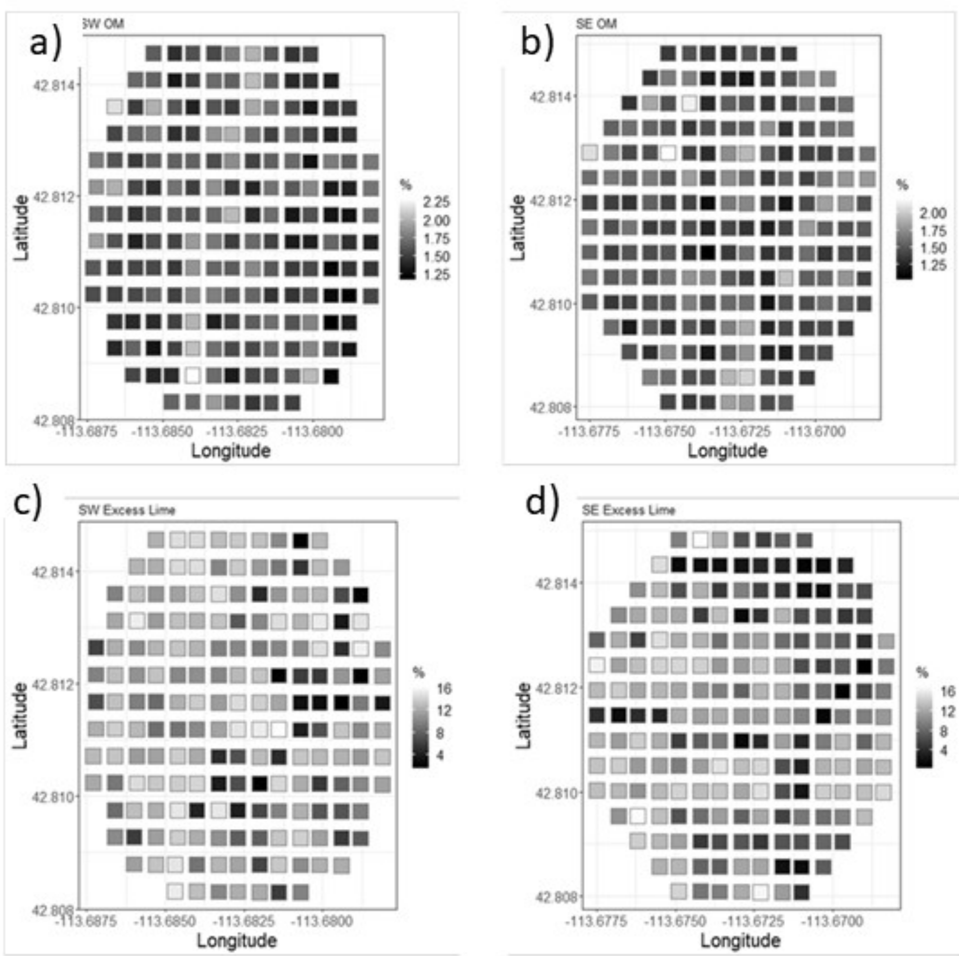

Figure 1. Total soil profile for organic matter (OM) (a,b) and excess lime (c,d) in southwest (SW) and southeast (SE) fields

A CV of 0-15% is generally considered minimally variable, 15-35 % moderately variable, and more than 35% is highly variable. The analyses show that even for the same soil properties in adjacent fields there was a difference in variability. For example, CEC was minimally variable in the SE field but moderately variable in the SW. Excess lime and total inorganic N were moderately variable in the SW field but highly variable in the SE. For the SW field, which was sampled prior to fertilization after barley harvest, soil P and K were highly variable while total inorganic N was moderately variable. All three properties were highly variable in the SE field when it was sampled the following spring after fertilization.

Figure 1 shows the variation of one of the least variable properties (OM) and one of the most variable properties (excess lime) across the sampled fields. The locations of the high and low OM values are somewhat random across both fields. For the excess lime, most of the locations have high values with a prominent area of lower values in the N and NW corner of the SW field.

Table 2 shows correlation coefficients between some selected soil properties. There was variable soil depth in the fields due to the presence of $CaCO_3$ layer as well as shallow bedrock in some areas. Thus, the major soil chemical properties were correlated with soil depth. For both fields, OM was negatively associated with soil depth (i.e. the shallower the soil the higher the OM) while inorganic N, P, and K were all positively correlated. For the SW field, elevation was negatively correlated with soil depth where the higher elevation areas had shallower soils. In the SE field, OM was not correlated with elevation but in the SW field, higher elevations had statistically higher OM. For the SE field, OM was negatively correlated with P while it was negatively correlated with K in the SW field. For both fields, higher concentrations of inorganic N were correlated with higher concentrations of P and K.

Table 2. Correlation coefficient (r) between the major soil properties with elevation and soil depth to impenetrable layer in the SE and SW fields. Negative (-) before r indicates negative correlation. Presence of '*' (0 '*' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1) indicates statistically significant correlation.**

	pH	CEC	Excess Lime	OM	Total IN	P	K	elevation
SE Field								
CEC	0.13							
Excess Lime	0.82***	-0.01						
OM	-0.84	-0.07	0.07					
Total IN	0.13	0.19***	0.14	0.01				
P	-0.37***	-0.22*	-0.38***	-0.19**	0.40***			
K	-0.62***	0.02	-0.60***	-0.02	0.23***	0.71***		
elevation	0.20**	0.02	0.20**	0.01	0.23***	-0.10	-0.1	
depth	−0.10	0.13	-0.03	-0.39***	0.27***	0.65***	0.31***	-0.1
SW Field								
CEC	0.00							
Excess Lime	0.41***	-0.21**						
OM	-0.05	0.07	-0.03					
Total IN	-0.13	0.13	0.18*	-0.07				
P	-0.13	0.01	-0.11	-0.11	0.24***			
K	-0.21***	0.44***	-0.46***	-0.17*	0.32***	0.44***		
elevation	0.00	-0.36***	0.31***	0.34***	0.17*	0.04	-0.34***	
depth	0.13	-0.01	0.14	-0.51***	0.48***	0.36***	0.47***	-0.16*

Burbank russet yields in 2022 ranged from 49 to 534 cwt acre^{-1} in the SE field and from 149 to 480 cwt acre^{-1} in the SW field (figure). The SE field averaged 352 cwt acre^{-1} and the SW averaged 330 cwt acre^{-1}. Both fields fell short of their 400 cwt acre^{-1} yield goals.

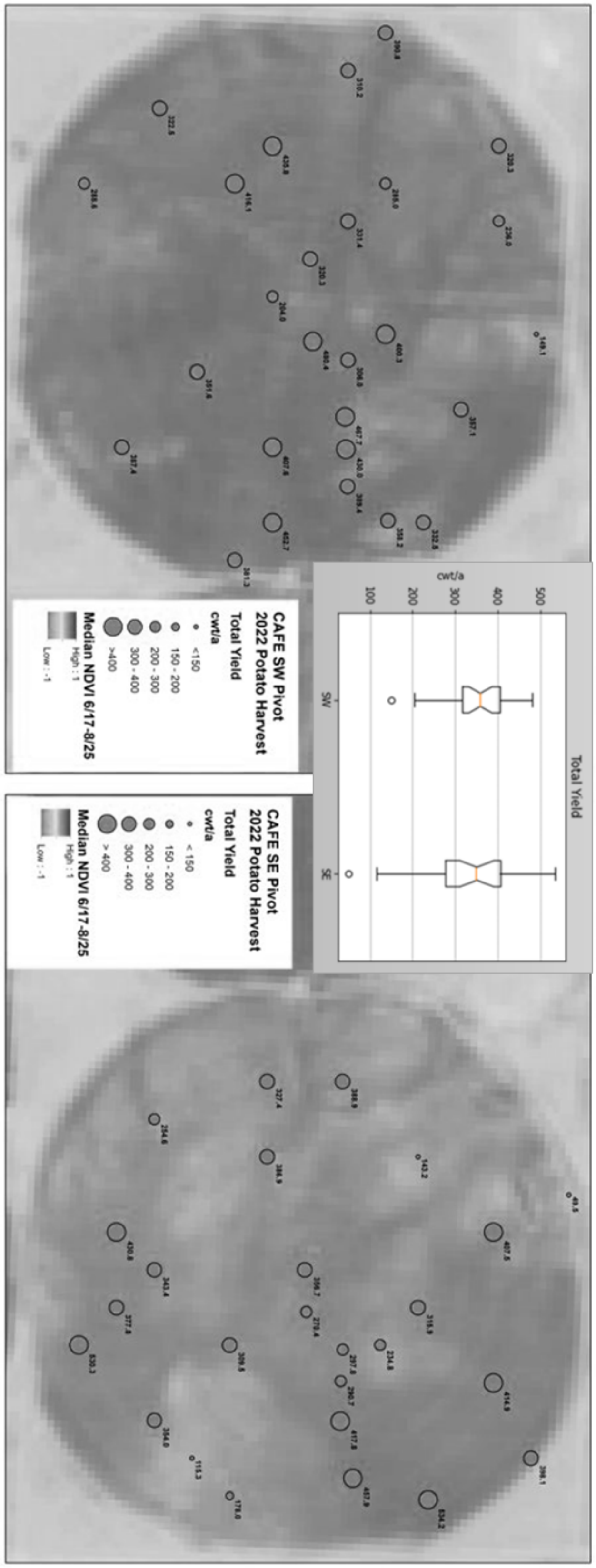

Figure 2. Spatial variability of potato yields (cwt acre^{-1}) in 2022.

Residual fall inorganic nitrogen was also variable both within field and between fields (Figure 3). Average N within the soil profile was slightly higher for the SE field compared to the SW field. However, the SW field had higher soil inorganic N in the upper 12 inches compared to the SE field. Much of this residual N will likely be lost over winter to leaching or other processes.

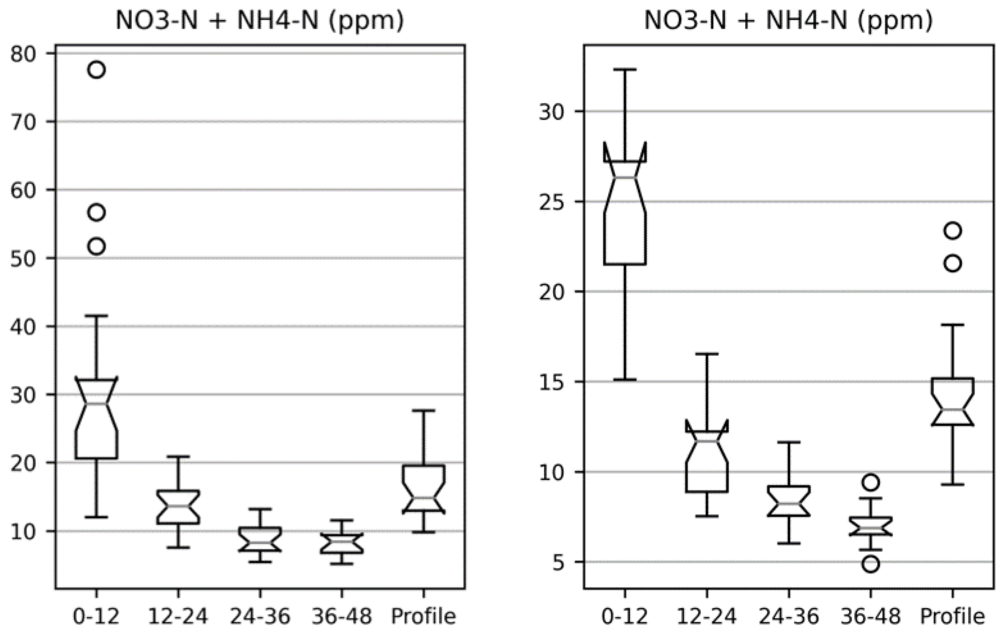

Figure 3. Box plots representing residual fall total inorganic nitrogen in 2022 after potato harvest for 0-48 inches of soil depth for the SW (left) and SE (right) fields.

In summary, while the two fields were managed the same by a commercial farmer, there are notable differences in soil variability among properties. Most notably, the SE field has a higher excess lime content variability and lower variability of CEC. Unfortunately, due to logistical challenges, both fields were not characterized at the same time. However, even with fertilization of the SE field prior to sampling, it is apparent that there is high persistent variability in this field. The CV values support this. There were also differences in correlation coefficients between the two fields. The presence of spatial variation in soil properties will serve as the basis for site-specific management to attain higher nutrient use efficiency and optimum crop productivity as supported by the potato yield and fall soil fertility data presented. These fields would be good candidates for variable rate application of fertilizers and further investigation into the drivers of variability as well as the impact on crop variability.