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Cameron Chemicals, Suffolk, Virginia, U.S.A.
Ultra Yield Micronutrients, Moxee, Washington, U.S.A.

Micronutrient Manufacturing Market Drivers

Micronutrient Fertilizers

- How do we determine the requirements and market potential?
  - Published data
  - Nutrient removal charts
  - Soil Test
  - Tissue Test
  - Crop scouting
  - Nutrient Balance

Micronutrient Fertilizers

- A look at the past:
- Manual on Fertilizer Manufacture, Vincent Sauchelli, Industry Publications, Inc. Caldwell, New Jersey, 1963.
  - 2 pages out of 478 are dedicated to Micronutrients. The the most notable quote:
    - “From casual recognition as trace elements, they are now considered quantitatively as agricultural chemical of commercial importance.”

Micronutrient Fertilizers

- A look at the past:
  - EPA, National Service Center for Environmental Publication, Source Assessment: Fertilizer Mixing Plants, March 1976 reports in Table 7, the “Quantities of Secondary and Micronutrient Fertilizer Materials Consumed in the U.S. in 1972.”

Material	Quantity in metric tons
Copper compounds	513
Boron compounds	4,495
Manganese compounds	3,137
Iron compounds	9,300
Zinc compounds	20,681

Copper in Plant, Animal and Human Nutrition

- Copper in Plant, Animal and Human Nutrition
  - Page 8: “Key Points”
    - Soil parent materials can vary considerably in copper content, with black shales normally having high and sandstones having low total copper concentrations.
    - The availability of copper for uptake by plants is determined mainly by soil pH, organic matter content and absorptive capacity.
    - **The main types of copper deficient soils are: sandy (coarse textured) soils, peats and soils with more than 7-10% organic matter and calcareous soils.**
    - The total and available copper contents of soils show considerable spatial variation and therefore samples for diagnostic soil testing should comprise a large number of subsamples bulked together.

Copper Deficiency

- Copper in Plant, Animal and Human Nutrition
  - Page 17: “Key Points”
    - Copper deficiency has been reported in over 50 crops and in 51 countries
    - Wheat has been found to respond to copper in at least 23 countries, Oats, Maize and Barley each in 12 countries, and Rice in 9 countries.
    - Table 3.1: “Estimated Areas (‘000 acres) of Soils Potentially Low in Available copper

Countries	Total land (‘000)	Cultivated (‘000)
Canada	725,328	31,914
United States	510,124	101,869
All other countries	398,717	34,385
Total	1,634,169	168,168

U.S. Crop Acre Statistics as reported to the USDA Farm Services Agency

2017 Planting	Acres
Corn	87,301,251
Soybeans	88,712,003
Wheat	43,188,817
Cotton	12,397,997
Sorghum	5,043,792
Barley	2,418,374
Rice	2,443,135
Oats	1,950,081
Sugar Beets	1,122,989
Sugar Cane	887,917
Total	245,466,358

2017 Planting	Acres
Top 10 Crops	308,085,519
Other 246 Crops	392,172,290
Total Planting	700,257,809

Top 10 Crops represent 44% of Total

Supplying sectors including:

- Food
- Feed
- Fuel
- Fiber

Copper Fertilizer Market

- Our research has shown us so far that the United States and Canada represent 79.8% of the worlds estimated market for copper fertilizers.
- Of the 700 million acres planted in the U.S., 101 million or 14% are estimated to be deficient in copper.
- We are looking for coarse textured soils, high organic matter soils and calcareous soils
- Cereal grains including wheat, oats, barley, maize “corn” and rice are the most responsive.
- Of those, we know that corn represents the highest number of acres with all five representing over 137 million acres in the United States in 2017.
- Based upon this limited data we can estimate the market potential.

Nutrient Removal Charts

Maize “Corn” Nutrient Uptake
Crop Physiology Laboratory at University of Illinois
Corn in 2010 at 230 bu/a = 14,400 kg/ha

Nutrient	Total Nutrient Uptake	Nutrient Removed with the grain	Harvest Index %
N (lbs.) [kgs.]	(256) [287]	(148) [166]	58
P_2O_5 (lbs.) [kgs]	(101) [113]	(80) [90]	79
K_2O (lbs.) [kgs]	(180) [202]	(59) [66]	32
S (lbs.) [kgs]	(23) [26]	(13) [15]	57
Mg (lbs.) [kgs]	(52) [58]	(15) [17]	29
Zn (oz.) [g]	(7.1) [225]	(4.4) [140]	62
B (oz.) [g]	(1.2) [38]	(0.3) [10]	23
Mn (oz.) [g]	(8.1) [257]	(1.0) [32]	13
Fe (oz.) [g]	(18.8) [597]	(3.5) [111]	19
Cu (oz.) [g]	(2.0) [64]	(0.6) [19]	29

Nutrient Removal Charts

- We will use the data for corn and the other sensitive crops to determine a total market potential.
- Let's continue to look at copper removed by the harvested portion

Crop	Ounces/bushel	Yield in bushels	Copper ounces
Corn	0.0026	176.6	0.459
Wheat	0.0048	46.3	0.222
Rice	0.0064	166.8	1.067
Oat	0.0015	61.7	0.092
Barley	0.0023	72.6	0.167
Average	0.003		0.401

Nutrient Removal Charts

- 0.401 ounces of elemental copper or 1.6 ounces of copper sulfate x 101 million cultivated acres that are estimated to be deficient equals 5,050 tons.
- 0.401 ounces of copper or 1.6 ounces of copper sulfate x 137 million acres of sensitive crops equals 6,850 tons.
- If the nutrient removal where the same on all US crop acres then the requirement increases to 35,012 tons.
- We are only talking about replacing what the crop removes. We haven't accounted for other reasons that would affect the application rate. These include providing for the total uptake requirements or for building soil reserves.

Finding the Market

- We can mine data already published in order to tell us that there are significant acres that are potentially suffering from a copper deficiency and we should look for those deficiencies in the most likely places by one or all of the following methods:
- Soil Sampling
- Tissue Sampling
- Crop Scouting

Boron Market

- The US Geological Survey identified in 2014 that “boron is the most widely used fertilizer micronutrient, applied primarily to promote fruit and seed production.”
- “In the United States, crops with boron deficiencies are often found in the Atlantic Coastal Plain, Great Lakes region, and the Coastal Pacific Northwest.”
- The last estimate of consumption in agriculture was published for 2002, 2003 and 2004 at 10,943 metric tons of B_2O_3 content for an estimated domestic market of 30,000 short tons.

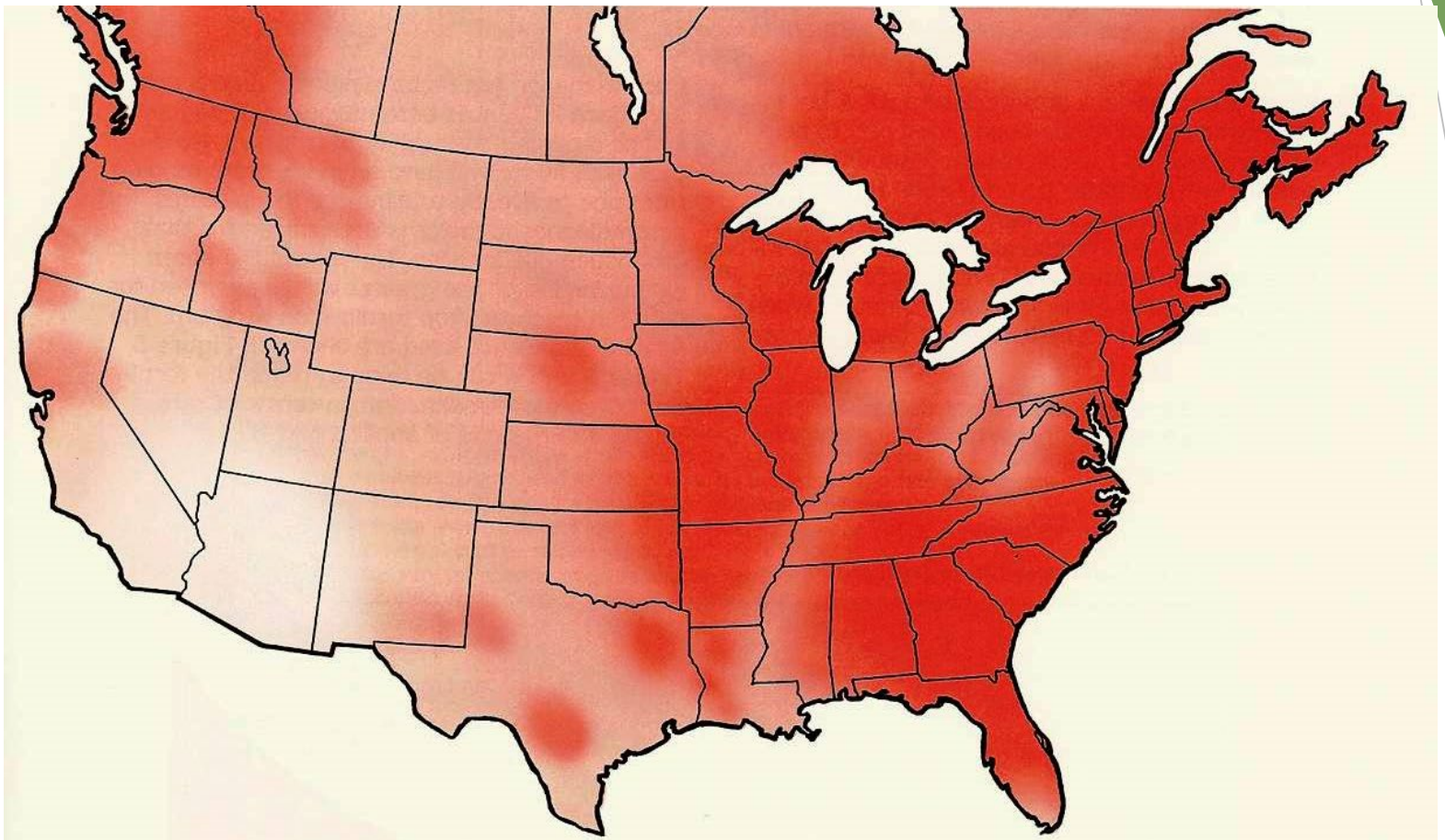


Figure 4. Shaded portions of this map indicate areas where boron may be deficient in soils.

Boron Market

- So now we have an estimated Boron market of 30,000 short tons for all crops based upon published data.
- Let's calculate based upon the nutrient removal number for the weighted average of the top 4 crops; corn, soybeans, wheat and cotton, and apply to all acres.
- 0.7 oz at 12.5%B = 5.6 ounces per acre x 700,257,809 acres
- = 122,545 tons.
- 30,000 ton boron market vs. 122,545 ton potential.
- Which means that 24.4% of the acres are receiving the boron that they need to replace what the crop is removing.

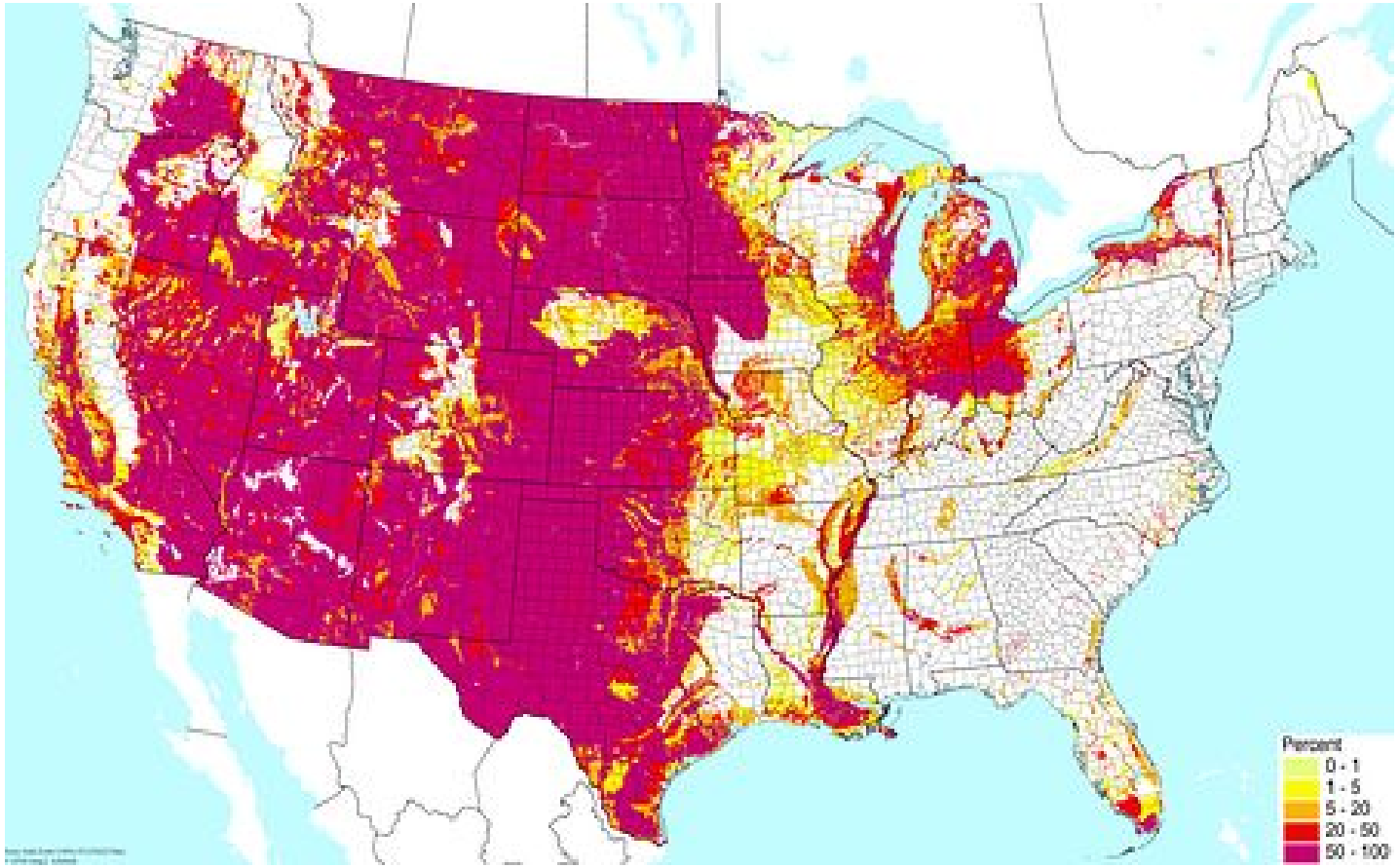
Boron and Copper Market Determination

- We have looked at a couple of different ways. One is based on an estimate of acres that are deficient while the other is based on what the crop removes from the soil.
- Neither are perfect,
- Each could benefit from more data and more analysis.
- Boron market potential is estimated at 122,545 tons at 12.5% B equivalent.
- Copper market potential is estimated at 35,012 tons at 25% Cu equivalent.

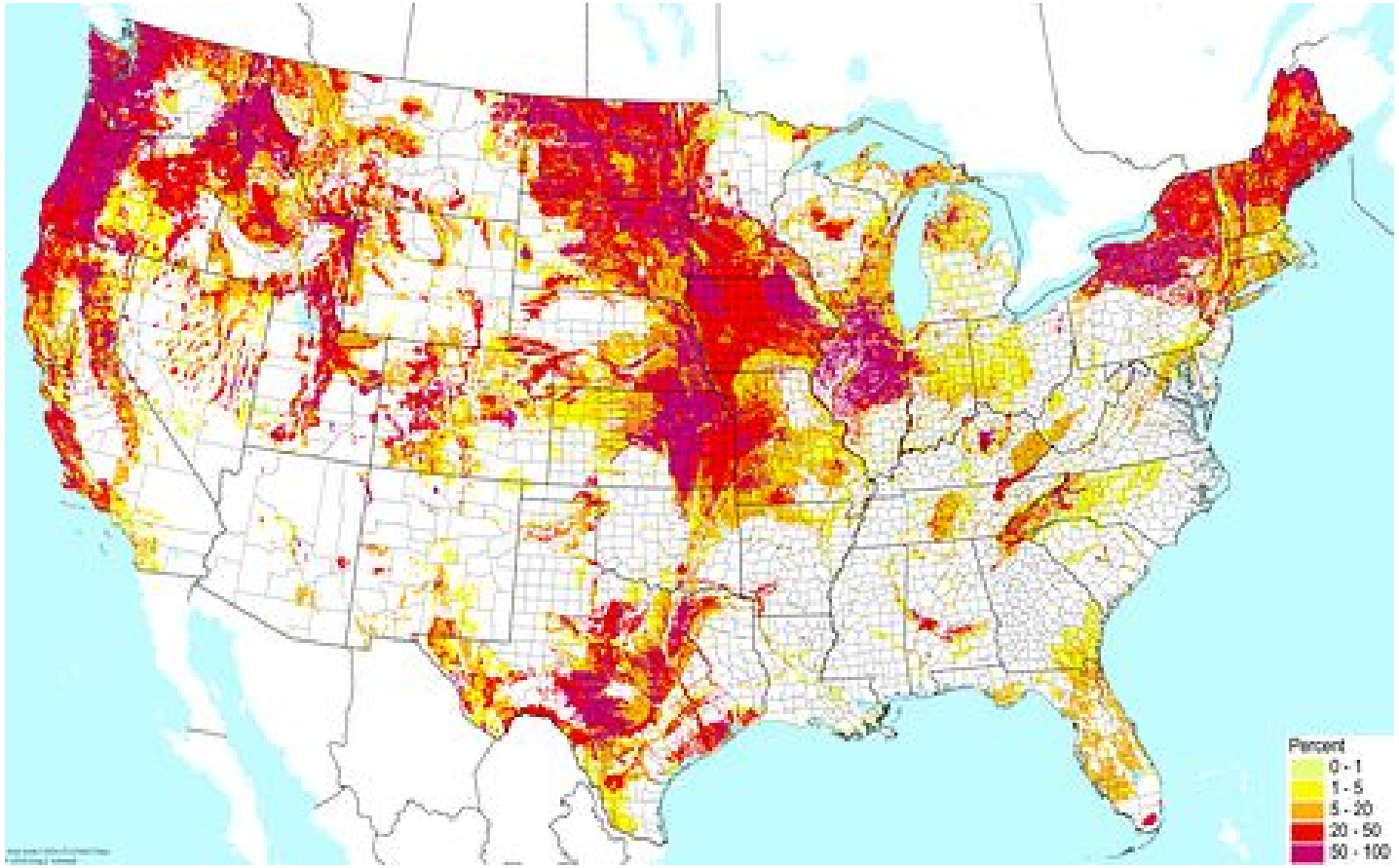
Manganese

- If we look at a statement made in Copper in Plant, Animal and Human Nutrition; “The availability of copper for uptake by plants is determined mainly by soil pH, organic matter content and absorptive capacity.” “The main types of copper deficient soils are: sandy (coarse textured) soils, peats and soils with more than 7-10% organic matter and calcareous soils.”
- If we simply substitute the word manganese for copper, we can narrow our search for markets considerably.

Soil pH greater than 7.0



Organic matter affects availability



Manganese

- I'll do a quick estimate in the same manner as for boron and copper.
- If 101 million acres are copper deficient and this deficiency occurs on similar soil types then perhaps it is reasonable to assume that 101 million acres are deficient in manganese.
  - 101 million acres x 3.1 ounces of manganese sulfate equivalent = 9,863 tons
  - If 700 million acres where to receive a manganese replacement application, then the volume equals 68,384 tons of manganese sulfate equivalent

Iron

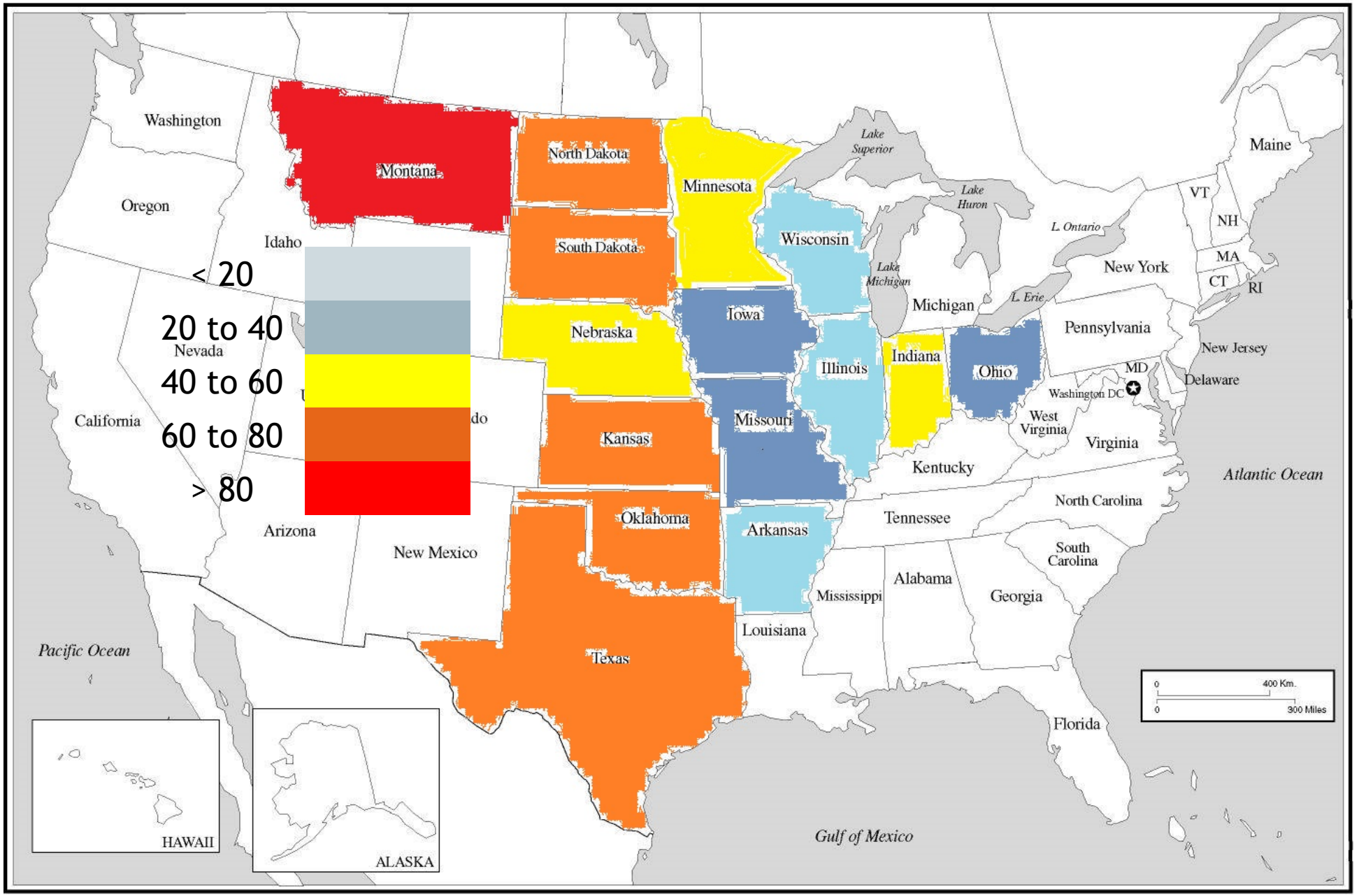
- Iron is the 4th most abundant element in the earths crust and yet, can be deficient or unavailable when crops need it.
- Conditions leading to deficiency are closely related to those of manganese. The symptoms of one deficiency can be mistaken for the other.
  - If 700 million acres where to receive an iron replacement application, then the volume equals 363,259 tons of iron sulfate equivalent.

Zinc Fertilizer Demand

- In 2010, the International Plant Nutrition Institute (IPNI) began collecting information from North American soil testing labs on the relative availability of zinc in soils.
- The following map shows the Top Producing States for the Top 10 Crops.
- The colors represent the following legend.

% of Soils Samples Testing Low in Zinc	Color
< 20	
20 to 40	
40 to 60	
60 to 80	
> 80	

The United States



Produced by the Dept. of Geography
The University of Alabama

Zinc deficiencies

- Of all States and Provinces reporting, 42% of the samples are below the critical level for zinc.
- The estimated zinc replacement requirements on those 295 million acres are 64,900 tons of zinc sulfate equivalent.
- If all 700 million acres where to receive a crop removal application the estimate increases to 154,057 tons.
- If we widen the scope of to provide for the projected uptake by all crops the requirement equals 289,512 tons.

Micronutrient Market Potential (tons)

Element	Uptake	Removal	Critical Deficiency
Copper	87,532	35,012	5,050
Boron	350,129	122,545	30,000
Manganese	334,811	68,384	7,575
Iron	1,100,718	363,259	52,393
Zinc	289,513	154,057	87,815
Total	2,162,703	743,257	182,833

Insights

- There are naturally occurring excesses and deficiencies as well as man made ones.
- Each can only be discovered by testing the soil, testing the crop and testing the food produced.
- A balanced fertility program is just as important as a balanced diet.

Insights

- The United Nations Food and Agriculture Organization estimated in 2016 that 815 million people, or 10.7% of the world's population suffers from chronic undernourishment.
- Zinc and Iron deficiency are among the most common nutritional deficiencies' leading to morbidity and mortality in at risk children.
- 450,000 children are at risk of dying every year due to diarrhea, pneumonia and infectious disease caused by zinc deficiency.
- Studies show that zinc supplied through healthy foods can improve the health of the at risk population.
- I propose that the same can be said for other micronutrients.
- Healthy soils make healthy foods and in turn support healthy people.

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