Data Intensive Adaptive Management in Organic Agriculture
Montana View Scholarship Report – April 30th 2021

Sasha Loewen – PhD Student – Montana State University
Dr. Bruce Maxwell – PI – Montana State University

Farmers are facing rising demands for both increased food production and increased ecosystem services produced from their land (Foley et al., 2011). To accomplish both these goals farmers must pursue a strategy of agroecological intensification. Precision agriculture (PA) has been shown to be an effective tool to increase both yield and ecosystem services in the pursuit of agroecological intensification (Garbach et al., 2017). PA offers a chance for organic farmers to take advantage of new technologies to increase the level of sustainability of their farms. Technological advances in the realm of satellite imagery, GIS applications, variable rate technology, and open-source software, can be used to build on traditional knowledge with data sets to improve soil health, reduce weed pressure, increase yields, and maximize net returns across every acre of farms (Weersink et al., 2018). To accomplish this, we sought to determine the validity of using varied seeding rates of both nitrogen-fixing green manure cover crops (GM), and following season cash crops like wheat, to maximize farmer net return. Beyond this, farmers have also been keen to deploy these technologies with other organically approved inputs such as nitrogen rich bloodmeal as a wheat amendment, and so we explored this technique as well. By using freely available web and machine-based data, and open-source software already in various stages of development, we sought to optimize PA in organic agriculture.

Experiments of the proposed methods are currently being tested on four stakeholders' organic farms in Montana: Bob Quinn / Seth Goodman (Big Sandy), Casey Bailey (Fort Benton), Ole Norgaard (Shonkin), and Ty OConnor (Broadus), and one farmer in Canada: Roy Loewen's farm near Steinbach, Manitoba . On the Quinn, Bailey, and Norgaard farms, GM seeding rate was site-specifically varied and subsequent year wheat seeding rate factorially varied to determine the influence of seeding rates of successive crops on wheat yield and grain protein content. These experiments are all producing yield results this season (2021). On the OConnor farm, bloodmeal was used as a nitrogen source for wheat and was varied as a topdress across the crop. In Manitoba simply the wheat cash crop was varied across the field to find optimums for wheat seed. Annual and perennial weed presence was mapped the fields to determine seed rate treatment effects on their abundance. These experiments are all ongoing and in progress however I will highlight three examples below of what we have learned so far.

In figure 1 we see results from the wheat seeding rate experiment in Manitoba. Wheat was varied at five planting densities across the field and we aimed to find the spatially optimized rate of wheat across the field for maximized net return for the farmer. In panel one we see the elevation of the field, this is a major contributor to field variation and affects and is typically correlated with other important agronomic traits such as water and nutrient availability and soil type. In panel two are the rates of the seed placed across the field; also pictured are orange circles, showing where weed presence was sampled and their corresponding presence measured in volume. From these data I produced a random forest model which optimized future seeding rates for minimized weed presence. The output of this model is shown in the third panel. These results indicate that most low areas require higher seeding rates to provide maximum competition with weeds, and in high places the opposite is true. Though other spatial factors contribute to the layout of the new seeding map as well. The next step in the process will be to produce a yield optimized map and compare it to the weed optimized map, then a meeting with the farmer to compare these results with their own rich understanding of the field. The next time the farmer plants wheat in this field they can use this data to develop a more sophisticated seeding rate prescription.

In figure 2 we see the ongoing experiment on Bob Quinn / Seth Goodman's field in north central Montana. In this figure we see the seeding rates of a nitrogen fixing green manure (pea) in the first panel planted in 2019. In the second panel we find the seeding rates of the following season's cash crop of barley planted at varied rates across the field. Patches of thistle are presented on top of these seeding rates, showing how varied seeding rates of either crop can affect the growth of these perennial weeds over time. Unfortunately the 2020 crop was hailed out, and the farmer has replanted the barley crop this spring, in the same fashion, to attempt to produce a yield result from which to build a net return model. Initial analysis showed no reduction of perennial weed patches at greater seeding densities, and it will be interesting to continue measuring this parameter this year and next. This figure is an example of a typical organic two-year rotation which we hope to optimize for green manure seeding rate, cash crop seeding rate, to minimize long term weed presence, and maximize net return for the farmer.

Finally, figure 3 and 4 show the results of the bloodmeal experiment in south east Montana on the OConnor farm. In Figure 3 we see the field elevation, experimental bloodmeal rates, and response variables of yield and protein. In this instance the farmer is using the nitrogen rich organically approved bloodmeal as their input variable to optimize for net return. Here the farmer has both a yield and protein monitor on their combine and we can see the initial results of the experiment in figure 4. Figure 4a shows that there was not very much difference overall in yield response to increased bloodmeal levels, and in fact the highest levels on average were found for 20 lbs/acre, the middle application rate. Figure 4b shows the average results for protein and demonstrates that here the highest rate does indeed contribute to the highest protein response in the wheat crop. However, figures 4c and 4d show us that when we look at the response on the spatial scale of elevation it is only in select areas of the field that the bloodmeal is having an effect. In fact in some areas of the field, bloodmeal appeared to reduce yields and protein levels. In discussing the results of this experiment with the farmer, the farmer was not impressed and has decided to cease using the product. Our methodology allows for fine tuning inputs spatially across fields, but in some cases larger more obvious trends can be found. Here onesuch instance occurred, which demonstrated the impracticality of the use of bloodmeal in organic dryland wheat production, for this farmer.

There are many more results of experiments forthcoming from this exciting project. Farmers already have a great deal of understanding about how their fields function as agroecyosystems, and our aim is to give them yet more knowledge, spatial statistical knowledge, of how their farms and fields perform under specific circumstances. We are in the process of developing a software application to model optimal site-specific seeding rates to maximize producer profitability in organic fields by applying on field precision experiments. This software app is open source for use by both farmers and researchers, and a package is already available in R (OFPE). These findings have already been shared collectively with farming communities such as the Precision Agriculture Research Association, the Montana Organic Association, and recently at BigSkyGeoCon. This research will provide farmers with new on-farm experimentation methodologies largely based in GIS, and access to modern data sources to increase understanding of what factors cause variation in crop response across their fields. Results are being used to implement management practices that increase farm profitability and sustainability.

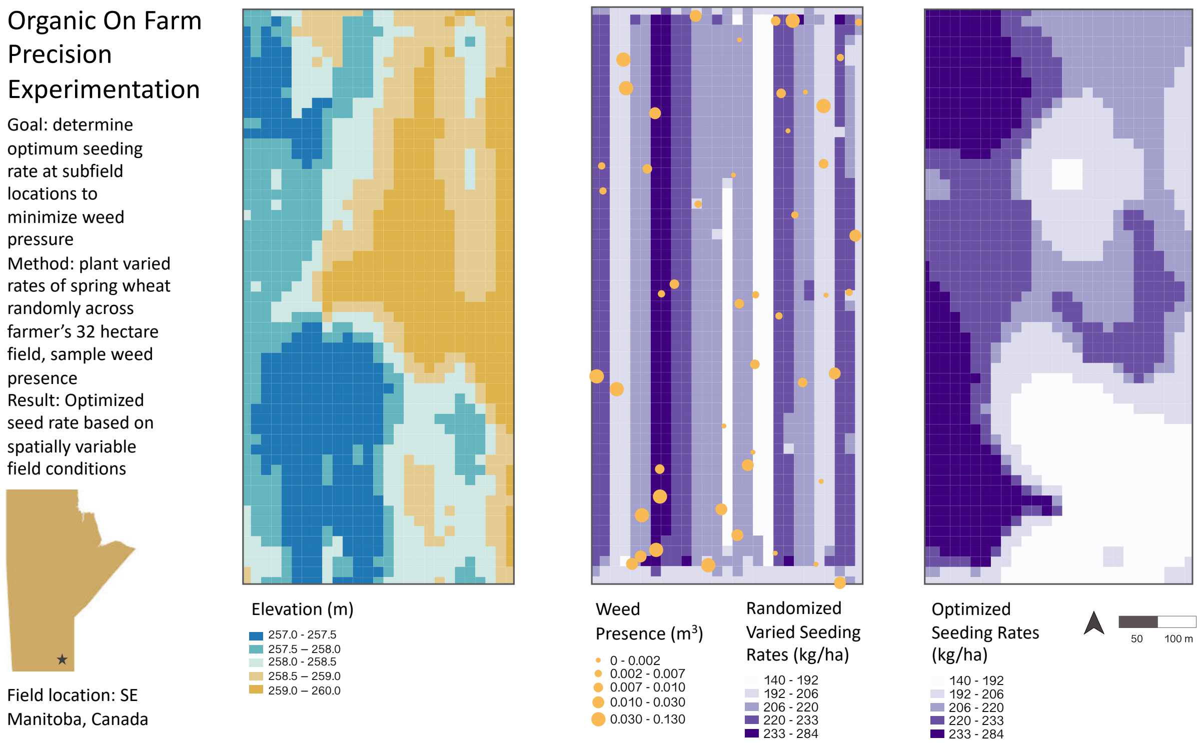

Figure 1 – Organically managed field in south east Manitoba where varied seeding rates contributed to increased understanding of weed management due to spatial factors. *This map was presented at the 2021 BigSkyGeoCon and was awarded 2nd place in the mapping contest.*

Seeding Rate Experiment

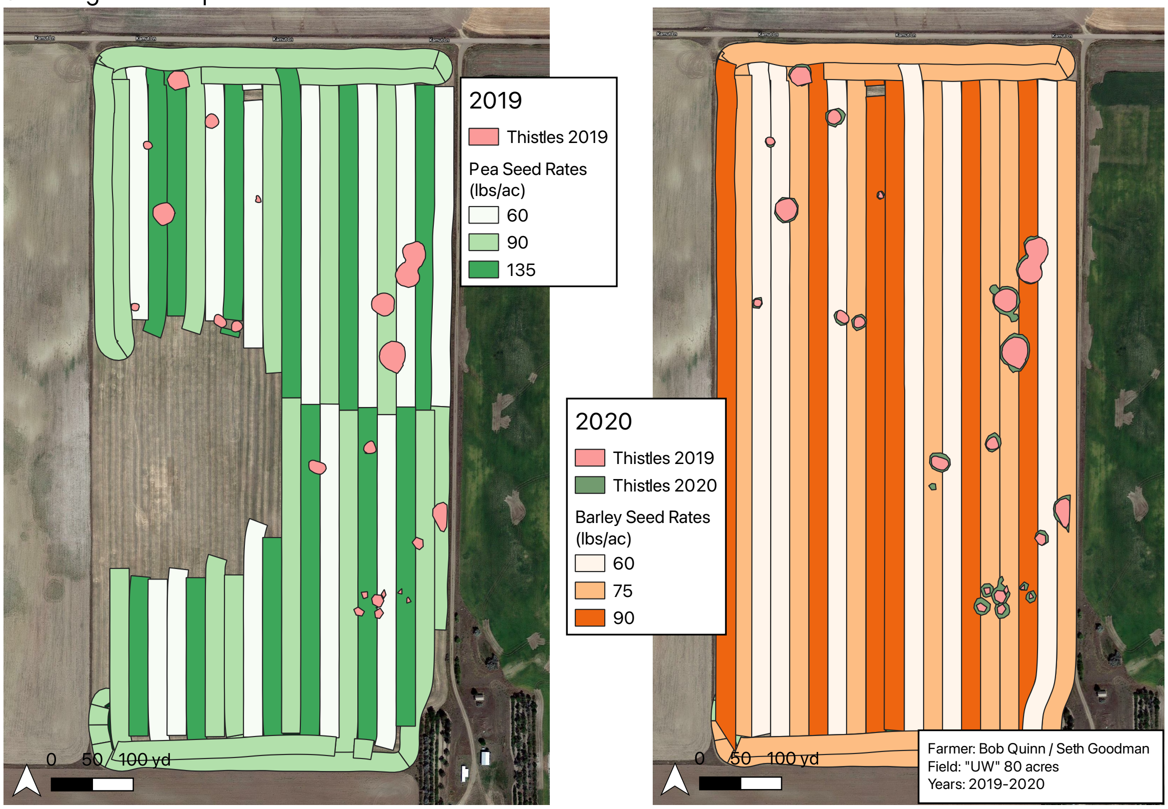

Figure 2 – Seeding rates across an organically managed field in north central Montana. A) Green manure (GM) rates are varied across a field (overly wet area prevented seeding in skipped portion) which includes thistle patches. B) A cash crop of barley is sown across the same field the following season to attempt to determine site specific optimum rates of GM for yield production and perennial weed (thistle) reduction – unfortunately this crop was hailed out and yield results for this experiment are delayed until harvest 2021.

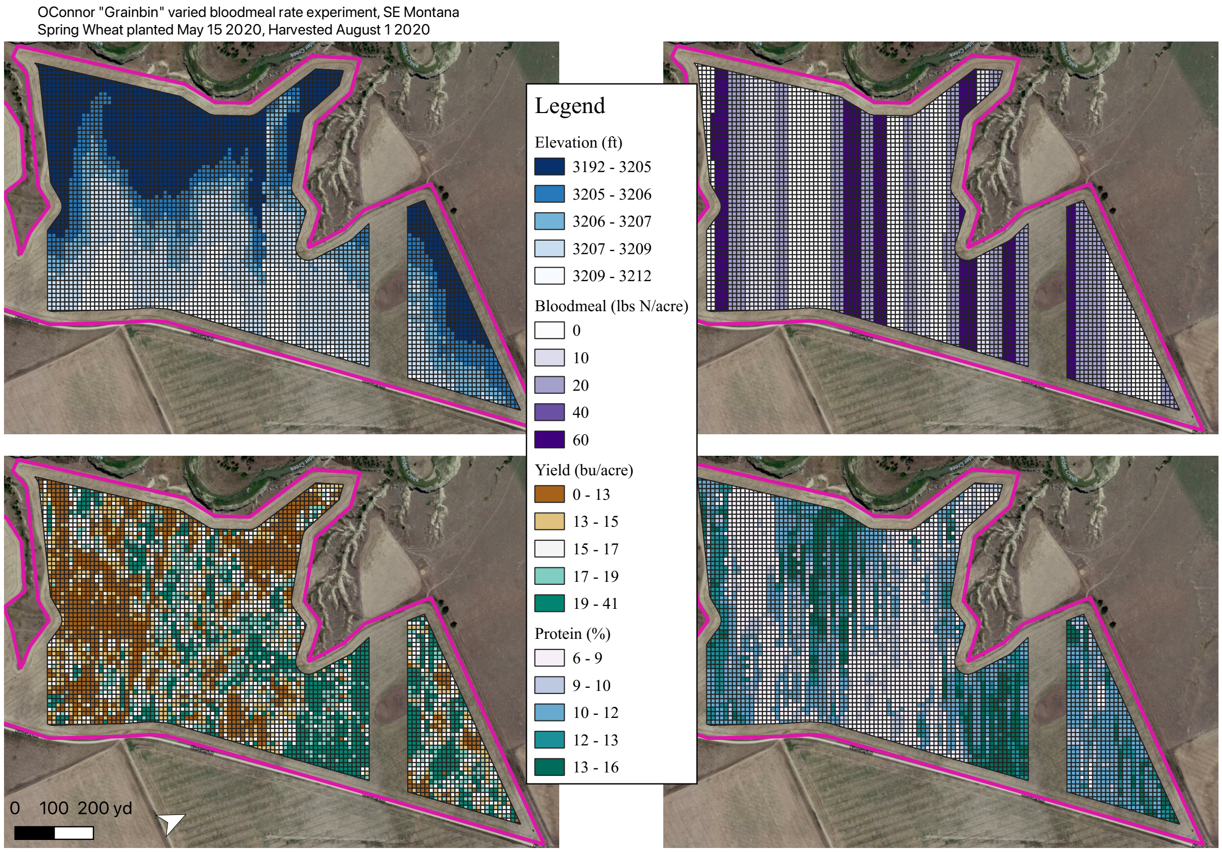

Figure 3 – Not all organic farmers rely on green manure for nitrogen. This farmer in south east Montana experimented with varied rates of organically approved blood meal across a field of spring wheat to determine site specific optimums for that product based on yield and protein of the crop.

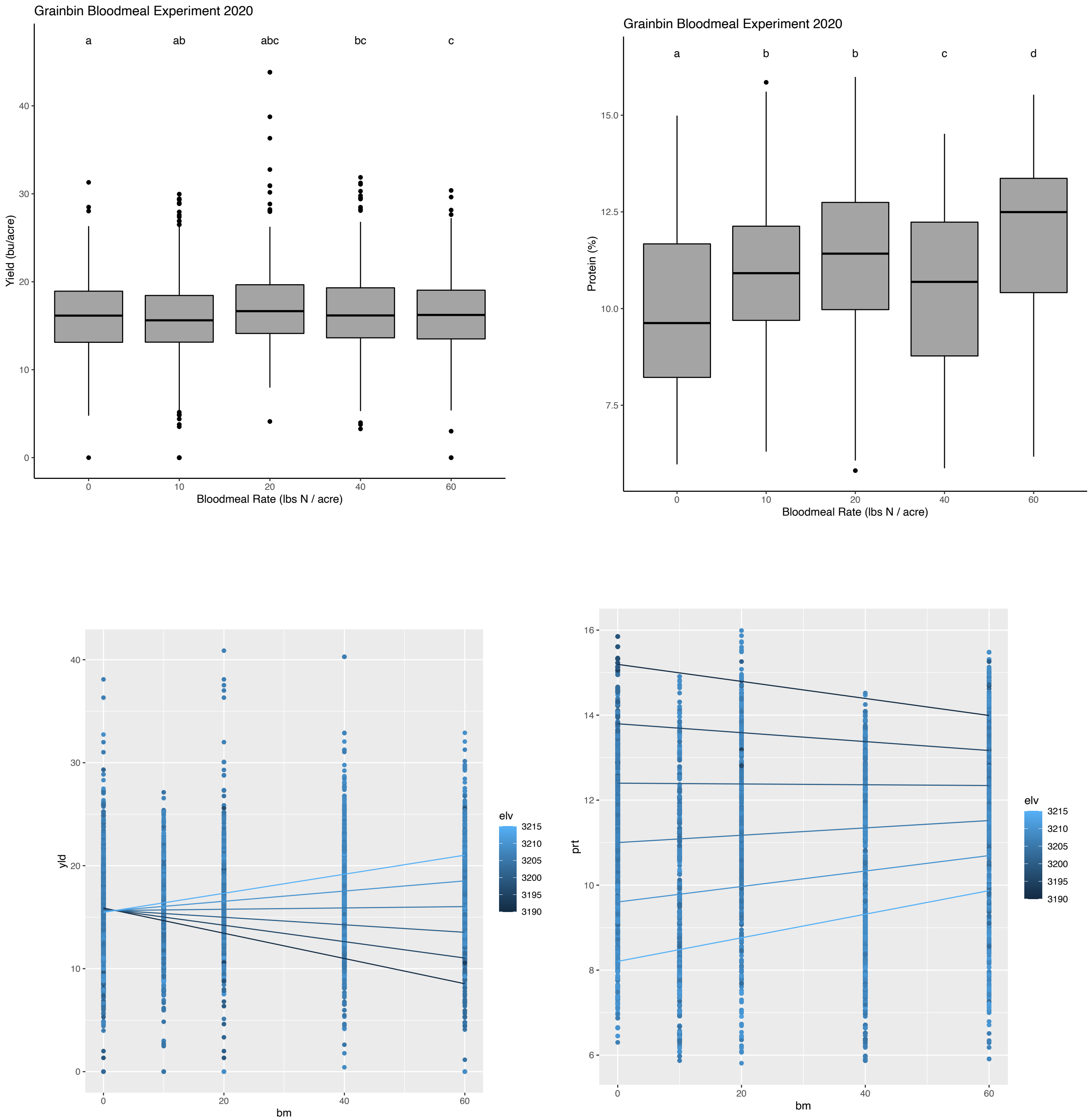

Figure 4 – Results of bloodmeal (bm) experiment indicate bloodmeal was a poor nitrogen supply for the crop. A) Yield (yld) as a function of five rates of applied bloodmeal; B) Protein (prt) as a function of five rates of applied bloodmeal; C) Yield as a function of bloodmeal rates by varying elevation levels across the field; D) Protein as a function of bloodmeal rates by varying elevation levels across the field.

Citations

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., Mueller, N. D., O'Connell, C., Ray, D. K., West, P. C., Balzer, C., Bennett, E. M., Carpenter, S. R., Hill, J., Monfreda, C., Polasky, S., Rockström, J., Sheehan, J., Siebert, S., … Zaks, D. P. M. (2011). Solutions for a cultivated planet. *Nature*, *478*(7369), 337–342. https://doi.org/10.1038/nature10452

Garbach, K., Milder, J. C., DeClerck, F. A. J., Montenegro de Wit, M., Driscoll, L., & Gemmill-Herren, B. (2017). Examining multi-functionality for crop yield and ecosystem services in five systems of agroecological intensification. *International Journal of Agricultural Sustainability*, *15*(1), 11–28. https://doi.org/10.1080/14735903.2016.1174810

Weersink, A., Fraser, E., Pannell, D., Duncan, E., & Rotz, S. (2018). Opportunities and Challenges for Big Data in Agricultural and Environmental Analysis. *Annual Review of Resource Economics*, *10*, 19–37.