SURVEY ON FUTURE CHANGES IN CROP PRODUCTION ON PRAIRIE FARMS AND IMPLICATIONS FOR RESEARCH

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Table of Contents

Section 1 - Executive Summary

Sixty interviews were completed with WGRF member organizations (18), Applied Research Organizations or Agri-ARM sites (7), scientists, private sector companies (10) and individual farmers (12). A total of 187 people participated and responded to five questions designed by WGRF to assess how western field crop production would change in the short (5 years) and longer term (10-20 years). Respondents represented all regions of the prairies including the BC Peace. The main objective was to identify cross cutting production issues of greatest concern to farmers.

There was general agreement that farms would likely continue to get bigger. Autonomous equipment was seen as a natural development for farm equipment and would help to address labour shortages. The area of precision agriculture was regarded as a disruptive technology that would change the way farming was practiced. More accurate weather forecasting was considered by many to be an important need to aid better crop management decisions. Variable rate nutrient application and spot spraying of crops for weed, disease and insect control would continue to be developed but the biggest change would be in the very large amount of data that would be collected on every aspect of each farm operation, analyzed by artificial intelligence and provided to farmers to improve their overall efficiency and profitability. Farmers thought that independent work to ground truth vegetation, soil and nutrient maps would be needed to verify the accuracy and cost effectiveness of precision agriculture techniques along with a better understanding for all farmers on data ownership and sharing. Without stable internet in all corners of the Prairies farmers crop production management from precision farming practices is at great risk.

Cereals, canola and pulses would continue to be the major acreage crops grown but there was considerable divergence of opinion on which crops would have expansion opportunities and those that would decline in popularity. Many thought that pulse acreage would increase due to increasing global demand for plant protein and others thought there was considerable potential for corn and soybeans and for winter crops with longer and warmer growing seasons. Some suggested minor or niche crops such as flax, oats, fababean and canaryseed could grow in acreage. Respondents also suggested that more work needed to be done on crops that could be grown profitably in rotations that would allow more crop diversification and longer rotations and reduced disease pressures. Plant diseases such as Aphanomyces in peas and lentils, clubroot and blackleg in canola and fusarium head blight in wheat were frequently cited as needing continued or enhanced research investment.

Most considered that crop inputs would become subject to increasing regulation with some pesticides being deregistered and increased controls implemented on the application of pesticides and fertilizers to farmlands. More efficient fertilizer use was a common theme with some suggesting more independent field scale trials to update fertilizer recommendations.

Many farmers were concerned that glyphosate or seed treatments would be more highly restricted or banned in the future and this would lead to major challenges for no-till farming unless alternative weed and insect control practices were developed. Alternate weed control methods such as intercropping, cover crops, weed clipping and mechanical weed seed destruction were all areas needing research.

Biotechnology was thought to be the future to problem-solving on the farm. Products of biotechnology for crop production and protection developed from techniques like gene editing and RNAi were regarded as essential to be included in research programs, although there were risks that regulation or consumer acceptance could prevent future commercialization. Many cited the growing number of biological products that had various claims, including increased yields and improvements to soil quality, but lacked independent studies that verified efficacy. Respondents were generally highly in support of public research and had concerns that government would reduce services in future years due to large fiscal deficits. Of special note was the loss of government extension positions across the prairies and the need to study more effective ways of knowledge transfer with products aimed at the new generation of farmers who were technically savvy.

In the area of sustainability, farmers considered it would be important to review some of the potential problem areas that might deter or reduce the effectiveness of conservation tillage systems as tillage equipment was often being promoted as a new technology. Regenerative agriculture, organic agriculture and low input agriculture were discussed as a farming practice that was associated with sustainability, but the former was considered to lack definition and more work was thought to be needed to assess the impacts of these practices on profitability and soil quality. The Carbon levy was a big concern for farmers and a rapid low-cost way of demonstrating changes in soil organic matter and accumulation of C in the soil was needed so that farmers could qualify for C credits.

In the near to far future, a generational change of farmers, declining rural quality of life, new models for marketing crops, continued consumer surveillance and changing government policies will all have indirect effects on research implications.

Section 2 - Background/Purpose

As part of their 40th Anniversary, WGRF requested Drs. George Clayton and Stephen Morgan Jones to lead a study to identify and confirm cross cutting production issues of greatest concern to farmers. The focus was on WGRF's fifteen priority crops that include: barley, canaryseed, canola, chickpea, corn, fababean, flax, lentil, mustard, oats, pea, soybean, sunflower, wheat and winter cereals.

The study was conducted by interviewing groups and individuals using 5 questions that were developed by WGRF. The questions were designed to better understand what western field crop production could look like in the short (5 year) and longer term (10-20 years) by asking for responses to the following:

Q1 What changes do you see in western Canadian field crop production in the short (5 year) and longer term (10-20 years)?

Q2 What crops do you expect farmers to be growing more of (or less of)?

Q3 What crop production opportunities and threats will grain farmers face?

Q4 What new technologies do you expect to be available/needed by farmers?

Q5 What current technologies do you expect may not be available (or may have more restrictions) to farmers?

The interview process commenced with a brief overview of the study and its main objective of identifying and confirming issues of importance to western Canadian farmers. It was also stated to be the second step of a 4-step process that would be followed up with workshops later in the year with the last step being the priorities for WGRF investment in crop production research. No prompting of interviewees was conducted during the interviews.

During January and February 2021, we conducted 60 interviews with a total of 187 people. The groups included 112 farmer representatives from 18 WGRF member organizations and 7 Applied Research Associations or Agri ARM sites, 12 individual farmers, 35 scientists and 40 from private sector companies. The farmer interviewees covered the main farming areas in western Canada with representation covering the northern, central and southern areas of the three prairie provinces and also the BC Peace. The scientists included agronomists, geneticists, pathologists, entomologists and soil specialists. The private sector company people were mainly from farm input companies (seeds, fertilizer, crop protection) and one processor.

Interviews were structured to allow all respondents to comment on the questions and the main points were noted. There was considerable overlap in the answers to the five questions. Some provided answers to question 1 that covered all five questions and others had responses for each question.

We took the raw interview data and organized this into one section that provides a summary of what we heard for each question. We also organized the responses to the interviews in a summary form by thematic area. Finally, we provided an analysis and the research implications of what we heard. To be clear this was solely based on what we heard from the interviews and was not a literature review of the research areas covered during the interviews.

Section 3 - Summary of what was heard by question

Question 1 - What changes do you see in western Canadian field crop production in the short (5 year) and longer term (10-20 years)?

SHORT TERM

There was a pretty strong agreement that the current trend towards larger farms (> 10,000 acres) would continue, while small farms would tend to specialize, grow more diverse crops and get engaged in identity preservation and traceability endeavors with processors or local markets. Fewer but larger farms will result in less farmers farming more land and the possibility of more marginal land being farmed. Farm labour shortages will increasingly continue.

Two large and connected issues that face agriculture are the increasing price of land and the generational turnover as older farmers retire. The increasing price of land and equipment will make it very difficult for new entrants to get a start in farming. The access to capital will exacerbate these issues. Some saw that the current price of land would drive more land rental for farming or more foreign ownership, and this could result in less attention paid to long term sustainable management and declines in soil quality.

Survey respondents consistently indicated that farming in the short term would become increasingly dependent on technology. Technology in the broad sense included autonomous equipment, tools such as sensors that provided increased data for better management decisions and an overall focus on increasing efficiency of farm input utilization, whether this be through new cultivars or agronomic management. More automated equipment would be driven by labour shortages in rural areas and the continuing trend for farms to get larger although some thought that farm size was maybe getting close to a plateau. Managing these larger farms will require more external support such as crop consultants, management consultants and diverse skill sets to manage technical equipment and big data. At the same time there were concerns expressed about the costs of new equipment and the thoughts that large farms would be the ones in the best position to invest in new equipment and be the early adopters. Manufacturers might revert to smaller sized automated equipment on the premise that large farms would have multiple units and thus allow more flexibility for managing breakdowns. A diverging opinion was that small farms will not need expensive complex equipment to manage their crop and soils.

Precision or digital agriculture was seen as being a key technological change for prairie farming that was still in the early stages of development. Responses indicated that many farmers are using variable fertilizer rate application. Some farmers are looking at variable spray technology and variable rate seeding that is often combined with soil moisture measurements, drone scouting and on-farm weather data. This digital revolution that is happening in the farm sector will provide for micromanagement of fields for crop inputs, maximize yield and result in an important increase in farm efficiency and productivity. With the trends towards more automation and precision agriculture, an often-repeated concern was the availability of internet service in rural areas that has many areas without service and those areas currently with service with limited broadband capacity.

While precision agriculture was seen as a key technological change, respondents often commented that the big data era that was coming to farming still had a long way to go on the data management and analysis side so that the best decisions could be made for crop production in real time. Farmers need and want a much better understanding of their returns from precision agriculture. In the same vein, there were comments made about readiness of older farmers to adopt the new data collection methodology that comes with precision agriculture and the need for new technical skills to manage digital information. Precision agriculture will increase in scope. Variable management of all inputs in sections of a field were seen to be the wave of the future.

The whole area of training in a world of automated equipment and artificial intelligence was mentioned by some as an area needing more attention. Young farmers and new entrants to farming may be more adept at managing in the digital age than the retiring generation but may also be more susceptible to using inputs and practices that are not particularly effective or needed. Autonomous or automated farm equipment and the data collection tools (drones, weather stations, sensors) that will be common on the farm will need different skill sets for both maintenance and data management.

The overall responses indicated that there would not be large changes in the way the land is farmed in the next 5 years. Respondents did not see large changes in types of crops that will be grown and the fluctuations in different crop acreages would largely be driven by commodity prices. Farmers would tend to focus on increased yield per acre. Weather extremes were also considered to impact crop choice with examples provided of reduced acreage of peas following a wet season and soybeans following a dry season.

There was considerable diversity of opinion about crop rotation and the types of rotations that would be popular in the different growing regions of the prairies. Three-year rotations of a cereal, oilseed and pulse crop are common. Some suggested that large farms (>10,000 acres) needed simple rotations to function efficiently, but lots of concerns expressed about the potential to increase disease pressures such as clubroot in canola and Aphanomyces in peas and lentils. Some suggested that rotations needed to be much longer in the 7–8-year range with a greater diversity of crops grown. Some also suggested that the newer or niche crops such as quinoa, fababeans, hemp, canary seed may need to be tested in rotations. However, the opposing view was that some farmers would chase price and shorten up or abandon rotations due to large, short term financial pressures. Demand for vegetable oil is increasing globally so canola acreage will stay the same or increase slightly.

Intercropping and cover crops were mentioned by many respondents as a mechanism to reduce risk from weather or disease by having more than one crop to harvest in the same field. Farmers are experimenting with intercropping across the prairies, but there needs to be a better understanding of the crop combinations that work the best and the impacts on diseases, weed control, soil fertility and quality. Cover crops were also mentioned as a means to prevent bare soil being exposed to the elements without crop cover for a portion of the year and the positive effect on soil fertility and quality. While some suggested that cover crop acreage was trending upwards, there was no consensus on which cover crops were the best choice and their overall benefits in relation to their input costs.

The planned expansion of irrigation in both Alberta and Saskatchewan would result in higher valued crops being grown and potentially more grain and silage corn. Corn production with improved shorter season varieties may become more profitable than other cereals in the southern parts of the prairies and displace wheat and barley acreage. Any expansion in corn production could result in a renewed interest in the use of heavy tillage to address corn residue concerns. Corn producing areas in Manitoba tend to use more tillage practices versus conservation tillage and this could result in more challenges for environmental sustainability. More soybeans are also a possibility with climate change and an assured water supply.

As farm size increases, it is possible that more prescription/calendar-type cropping systems that rely on external inputs (e.g., fungicides, insecticides, etc.) will develop. Management of the crop will reflect more routine inputs with potentially less activity related to assessing risk. For example, at a specified crop growth stage fungicide would be applied to manage leaf spots, regardless of the actual risk in the field. More routine prophylactic spraying may lead to issues with pesticide resistance in pest populations as well as off-target effects.

The major crops in rotations all have significant challenges that need to be managed. Respondents expressed that rotations would get tighter (shorter) and this will increase disease pressures. The changing climate with warmer winters and wetter summers in some regions of the prairies will also tend to increase disease pressures on crops. Diseases like clubroot and blackleg will be managed by genetics but shifts in pathotypes continue to occur and may outpace the development of crop resistance. Some thought canola disease issues would result in decreased acres of canola planted. Cereals will have continued issues with fusarium head blight and leaf spots/rust that will increase reliance on the use of fungicides. With more pulse crops, foliar diseases are managed with fungicides and pulses are most likely to have the second most frequent use for prairie crops and risks of fungicide resistance will increase. Respondents felt a need to move to longer rotations and have crops to grow that make farmers money. Also, a strong need to have automated scouting (automated insect traps) to allow early and sectional application of insecticides. Virulence shifts in pathogens will occur and cause breakdown in genetic resistance for diseases like clubroot.

Weed resistance to herbicides was a general issue of concern raised by many. As there are not a lot of new herbicides being developed, increasing weed resistance may result in more tillage for weed control with negative effects on soil organic carbon. Harvest weed seed management may become important with the use of equipment that destroys weed seeds (Harrington Seed Destructor). It can result in less chemical usage but no consensus on whether this technology was a good solution for the future control of weeds. A changing climate will also result in new invasive weeds and insects that will need new control methodology.

The overall outlook by farmers concerning the future use of chemicals to control weeds, diseases and insects was bleak. Most believe that there will be increasing regulation and accountability required by farmers to use them with a worst-case scenario being deregistration of existing products (e.g., glyphosate and seed treatments) and no effective replacement chemistries. Glyphosate is currently under a lot of scrutiny. Direct processor sales of oats and peas generally do not allow the preharvest application of glyphosate and the processor monitors batches to ensure compliance.

There was general consensus that fertilizer prices will continue to increase, and farmers will become increasingly vigilant to maximize their use of this expensive input. Variable fertilizer rates in combination with soil probes are now being used to optimize fertilizer placement in a section of a field. Some areas will be found to be unproductive and not cropped. There has been less fertilizer research conducted in the last 10-15 years and as new varieties are developed the fertilizer recommendations have become outdated. Crops like canola and wheat have generally seen a 1% / year yield increase so need to focus on nutrient management. Concerns expressed that there has been nutrient drawdown on soils with high yielding crops and not replacing nutrients like P that may impact rooting of crops. More advancement needed in predicting N usage and needs. Fertilizer efficiency needs to be increased and better understanding of effectiveness of stabilizers that control the breakdown of urea. Placement of fertilizer was mentioned by some as needing more work. Large farms may choose to broadcast fertilizer for convenience reasons rather than its efficient placement in soil.

Regenerative agriculture has no clear definition but is thought by some to be a way to improve soil quality and reduce inputs. On the other hand, some mentioned that there needs to be a clear understanding of the value of these practices before launching new research.

Most respondents saw little change over the present conditions that farmers grow crops across the prairies. The biggest issue mentioned facing all farmers except those with irrigation was the degree of uncertainty in predicting moisture for a growing season. There was agreement that weather forecasting both short and longer term needs to improve.

Several reported that the extreme weather events with lots of rain falling in a short period of time has resulted in a lot of erosion on land that had been in zero till for 20 years. There is interest in under seeding and in-season seeding to provide a cover crop that mitigates the exposure of bare soil to weather elements following harvest.

Most respondents considered that abiotic stresses were intimately linked with weather and climate change. Increased frequency of extreme weather events could impact production in any one or more regions of the prairies. Expansion of irrigation in Southern Alberta and Saskatchewan would help reduce risk around very low moisture conditions and there will be ongoing issues with water use and storage. Increasing day and night temperatures were also seen as a challenge along with wet Spring and Fall seasons.

Research was often cited as a key part of future producer success. A high level of recognition was given to continued efforts in breeding with a focus on yield and disease resistance. However, a diverging opinion was that much more effort needed to be made to make plants drought and saline soil resistant, flood resistant and earlier maturity. Others commented on the need to have more research on using less pesticides and better use of fertilizers. Some concerns were expressed that public research was declining and the research funding models with many players acting provincially needed more integration.

One issue that was stated multiple times in the interviews was the future investment in research from public sources could be threatened with governments dealing with large fiscal deficits and looking for areas to cut expenditures. Others saw a lesser overall government contribution in the future for agricultural research and this was seen as a reality as governments attempt to manage ballooning budget deficits. Some respondents indicated a concern with the loss of crop scientists with field-based experience. In recent years the replacement of retiring scientists (Universities and Federal Government) has often been with those who have strong laboratory and molecular skills. This has resulted in a lack of field-based training of students.

Many considered with the increasing world population there would be a continued increase in the demand for plant protein. Protein crop processing has recently expanded in western Canada with plants that fractionate crops like peas into protein concentrates and isolates that are then used for a variety of protein products including beverages, bars, cheezes and texturized meat analogues. In the short term this trend will likely drive some modest acreage increase in pulse crops particularly in the eastern prairies. Others suggested that plant-based plastics could offer some value-added opportunities.

Market access was a concern expressed by many during these interviews that could impact crop production in the short term. Respondents also recognized the fragile state of market access for international trade managed by the Federal Government. The retaliatory loss of the canola seed market in China, the temporary loss of the durum market in Italy and pulse markets to India were given as examples where producers were vulnerable to changes in export markets. These were issues out of a farmer’s control but did impact on crop production decisions.

Being more closely connected with consumer needs was also reported as an increased trend. Some suggested more organic or low input crop production would be demanded particularly for more local markets, but others suggested that organic production was at a plateau. Example given was that the Verdient Foods pea plant in Vanscoy Saskatchewan was built to process only organic peas but as production ramped up nonorganic peas have become the main supply crop. Others suggested an increased acreage of crops that would be grown under contract to companies where the crop management would be dictated by a processor.

The whole area of consumer trust was also raised and the fact that many consumers relied on social media to find out information that was often biased or even pure misinformation (often termed “fake science”). Few people outside of farming understand the high level of science and technology that is used in the production of food that ensure its safety and quality.

The Grain Farmers Voluntary Code of Practice that is under development to document sustainable practices and improve processor and consumer confidence was regarded by some as a big future change that would also be costly for the sector. Others suggested that the draft document in circulation was very prescriptive over fertilizer and pesticide usage and could have been written in a more positive manner. Many also saw this process as a forerunner to a producer license to operate along with approved plans for chemical and fertilizer inputs.

While governments (both Provincial and Federal) may be forced to cut research expenditures there was a strong sentiment that more resources would be found to increase government regulation on climate change and environmental issues. Many cited the changes that have taken place in Europe as an early indication of what might happen in Canada. The Federal Government will be increasingly focused on increased environmental regulations for the use of pesticides and fertilizers and reducing the Carbon footprint of farming. Some thought there would be a huge pushback on the future use of nitrogen fertilizers due to the release of NO_2 as a greenhouse gas and suggested that a broader range of N-fixing crops would be useful along with N sources that did not leach and had much lower volatile losses of N.

Canadian Government policies such as the Carbon levy were also perceived to have a short-term impact on crop production as farms need a reliable supply of fuel and inputs to produce crops. Some respondents indicated that an increasing Carbon levy and loss of exemptions would put a lot of pressure to be more efficient with fuel usage and would make farmers look more carefully at input costs and consider lower input crops particularly for smaller farms. The Carbon levy received a lot of comments from the majority of the interviewees with the general conclusions being that a significant tax that directly increased input costs for farmers would potentially reduce producer returns over time. Some even thought that the Carbon levy could result in a restructuring of the industry towards much lower production inputs.

LONG TERM

Over the next 20 years technology will change a lot and will represent an ongoing evolution from the changes expected in the shorter term. The transition from fossil fuels that currently power farming to green fuels like hydrogen or electricity will be well underway. A diverging opinion was the thought that there could be on-farm production of biodiesel that would prolong the use of diesel engines and avoid any future Carbon levyes on fossil fuels that would become a significant piece of farm input costs.

Automation may develop to the stage that general farming operations such as seeding, fertilizing, spraying and harvesting will be done by robots. The majority of prairie farmers use GPS and would not want to farm without access to autosteer. The low orbit satellite project (Starlink) is well underway and will potentially provide broadband access to all of Western

Canada along with improvements in internet access announced by the Federal Government that automation will depend on.

Respondents were in general consensus that digital agriculture would be mainstream in the longer term. Many cited autonomous equipment linked with arrays of sensors that measured weather, its forecasting for the farm, sensor measurement of moisture and nutrient requirements down to the micromanagement of each field, the spot spraying of weeds and the advanced control of disease or pest outbreaks. The result will be better precision in fertilizer application rates, reduced pesticide usage and more precise knowledge systems. Some concern was expressed that agronomic decisions could be downloaded from the farmer to companies where in such cases farmers become service providers to the supply chain.

Many responses suggested that biotechnology would play an increasing role in crop improvement in response to more challenging growing conditions and emerging diseases and pests. Technologies like CRISPR and other gene editing tools could be used to incorporate new traits that would allow plants to better respond to biotic and abiotic stresses and possibly see N-fixation capabilities added to crops like wheat.

Diverging opinions appeared where some prefer the status quo of the public breeding programs releasing varieties in cereals and pulses. Some thought as plant breeding advances become more dynamic (vs slow and incremental), certified seed sales will substantially increase. The piloting of seed sales connected to an SVUA agreement creates another administrative load with a lack of tools to monitor compliance. The risk is having an inflexible regulatory model in place for seed sales.

Climate change will have a significant impact on crop production over a 20-year period and result in more extreme weather events and increased variability of crop yields. Consumer demand will also play a strong role on crops grown in western Canada. Some of the longer-term changes in crop production could include more diverse crop rotations including more corn and soybeans, more intercropping, more pulse crops and a switch to winter crops that in addition to cereals, might also include canola and peas. New crops such as sorghum and lupins might become possibilities and growth in niche crops (flax, sunflowers, canary seed, hemp etc.) are also possibilities. Flax was considered by some as an underutilized crop and had the large challenge of straw management. Farmers need more diverse rotations and the crops to fit into these longer rotations that they can make money on. The length of the growing season will continue to be an issue for the more northern part of the prairie under cultivation and continued efforts to produce more adapted varieties will be necessary to increase crop choices. Also, shorter season crops may be more important to reduce drying costs.

A longer growing season would be expected if current trends continue and apply to all crop producing regions of the prairies. This would offer up more possibilities when combined with adapted varieties for the longer season crops like soybeans and corn to be grown on the prairies. Adapting to climate change will mean being able to better understand changing moisture and temperature conditions so that crops can make best use of available water.

There was an opposing viewpoint expressed such that the weather cycle was starting to move into a longer-term cooling period for the next 30-40 years. Shorter growing seasons could make many of the crop varieties less adapted for prairie crop production systems and act against any large increase in corn and soybean acreages.

Logistical problems would become more complex on large farms particularly if crop diversity increased. This would likely drive automation and more data analysis to have more timely management decisions. Emphasis on efficiency of input use will be mainstream with reduced usage of N fertilizers and less use of pesticides.

Some respondent thought that crop production would have a much more biological focus with less dependence on inputs. Organic or regenerative agriculture are options for producers to consider. Regenerative agriculture was considered to be an area of potential expansion but really had no definitions or understanding what this term really implied.

Changes in the use of conservation versus conventional tillage may occur. This may be driven by a lack of historical knowledge and perspective related to the detrimental aspects of conventional tillage (soil erosion, soil health/quality, increased equipment costs, etc.). Also, tillage may be viewed as a "new" technology by a younger generation of farmers. They may also view tillage as a solution to seeding issues related to excessively wet soil conditions, weed management, straw management, or perhaps to nutrient stratification, etc. Unfortunately, some of these issues with conservation tillage may be based on general perceptions, or views not supported by science. Equipment manufacturers may also view tillage equipment as another revenue stream and thus promote its use to address real or perceived issues with conservation tillage. Yet, overall comments suggested that farmers need to remain vigilant about soil health and its improvement.

Overall, there was strong consensus that farmers would face significant challenges in the future in the control of insects, weeds and diseases. The use of chemicals would be much more severely restricted than was the case today and several thought that the number of new chemistries registered would be extremely limited.

Insect threats such as flea beetles, pea and soybean aphid were mentioned as longer-term threats particularly if farmer access to insecticides is restricted. Pests may overwinter more easily with warmer winters and new invasive species may move into the prairies from the United States. Several respondents considered that new approaches would be needed in the future to control insects with RNAi technology mentioned as an example.

Disease pressures will be an ongoing challenge for the major crops (cereals, canola, pulses). Some thought that plant breeders would be able to keep ahead of emerging pathogen races for diseases like clubroot and blackleg while others suggested it may force farmers to adopt longer rotations. New diseases for which there was no available genetic resistance were also stated as a potential issue with the example given of verticillium wilt in canola. Large acreage crops like canola will have the major disease challenges of clubroot and blackleg to contend with that will threaten acreage seeded if the genetic resistance breaks down. Farmers would then tend to move away from canola or look at longer rotation intervals. Blackleg may be controlled with seed treatments and fungicides. For cereals improved genetics and even new breeding techniques (gene editing if it is deployed) will help manage the fusarium head blight issue. Leaf spot and rust diseases may become more prevalent if some of the public work on incorporating resistance is reduced and result in more fungicide usage and potential fungicide resistance. Reintroduction of pulse acres to farms, once genetic resistance to root rots is developed, may take 10 years but not well understood.

Weed resistance to crop protection chemicals and greater numbers of invasive weed species were thought to be a problem that would continue to increase in the next 20 years. Some suggested that this would push the movement towards cultural control with greater seeding rates, more tillage and more diverse cropping and others called for new chemistries that met environmental concerns. Others saw an increase in the number of biological crop protection products for both weed and pest control. Seed destructor technology was also mentioned as something that might become an important weed control technology.

Consumers in the future will buy and choose products based on the perceived environmental impacts. Demonstrating soil health is maintained and improved by farming practices that increase soil organic C will be important. Cargill and General Mills are moving towards regenerative agriculture with their crop specifications. Early regenerative pioneers were a little extreme but has more recently morphed into sustainability, where rotations are more diverse, crop inputs like fertilizers are reduced and forages/livestock are often brought in as part of the rotation.

There was also a general feeling that quality and safety assurance requirements for producing crops will increase over time. Respondents mentioned traceability and the increasing power of processors and export markets in setting standards that would require more accountability at the farm level.

Reducing fuel usage and adopting robotic practices to counter shortage of labour were cited as issues that would become more important over time. Fuel and fertilizer production could become more farm based. There is the potential to produce biodiesel on the farm to counter expensive retail purchase of farm fuel. It may also be possible to produce ammonia in relatively small fuel cells that would be more cost effective than a nitrogen source from a manufacturer.

Many interviewees indicated that the most significant challenge for farmers would be their future adaption to changing government policies to successfully mitigate the effects of climate change. Farmers consistently stated that they had widely adopted cultural practices like minimum tillage that stored Carbon in the soil, but famers were not being rewarded for these Carbon capture activities. At the same time the Federal Government has introduced a Carbon levy that will keep on escalating and will result in major cost increases for farm input costs like grain drying, fuel, fertilizer and seed. These cost increases may drive some to move to low input farming methods with corresponding reduced yields.

Nutrient management will become increasingly regulated and similar to those for application of manure. Respondents talked about prescriptions for crop inputs in the same way a livestock farmer would have to get an antibiotic prescription to access drugs for the control of livestock health.

In summary, more of the same from the issues identified in the short term. Farming will become more regulated with less use of chemicals and energy from fossil fuels. Level of accountability on what goes on at the farm to consumers will substantially increase so they are assured their food supply is both safe, inexpensive and of high quality. Farmers will provide the elevator or processor a list of the production practices for each load of delivered grain and auditing of these practices by independent sources may also be a reality.

Question 2 - What crops do you expect farmers to be growing more of (or less of)?

While many diverse opinions were proposed on the changes in crop acreages now and in the future, there was overall agreement that cereals and canola would remain the dominant crops on the prairies for the foreseeable future. Most supported pulse acreage remaining the same until some of the disease issues are addressed or showing a slight increase depending on how demand for plant protein develops in the next 5-10 years. The other major reason for pulses trending upwards is the benefit they bring of added N to the soil for subsequent crops. Fababeans are also regarded as a crop with potential for growth and as a pulse option to replace peas in areas where disease prevents profitable pea production but need concerted work on maturity to reduce length of growing season. After the major three crop types (wheat/canola/pulse) there are as many opinions about future crop growth as crop choices.

Barley has seen some resurgence for malting types with the expansion of craft breweries, but the general opinion was that this market has now plateaued. Oats are regarded as having some potential for growth for human consumption with new products (oat milk) driving some demand. Flax has some interest as an oilseed but has issues of weed control and straw management that make it a potential problematic choice for large farms. Although there may be more or less of these crops on individual farms the consensus was these crops acreages would be relatively stable.

There were some that see increased growing season or frost-free days will provide opportunities for warm season crops like corn and soybeans, but it was really the variation in weather and availability of moisture that impacted crop choices. Examples were given of producers who grew soybeans but then got a dry year and a poor crop and decided the risks were too high to continue with the crop.

Corn and soybeans have a future particularly in areas of the prairies where there is sufficient moisture during the growing season (both irrigated and natural moisture areas). Many thought that corn and soybeans would see increased acreages over the next 20 years. More emphasis on breeding would be required from the private sector over the next 10 years to have varieties that were adapted to the large variations in growing conditions across the prairies. An opposing thought was that corn and soybeans acreage will not change much as the costs and returns for these longer season crops are much greater than south of the border.

The future expansion of irrigation in southern Alberta and Saskatchewan was thought to be an opportunity for more corn, soybeans and possibly fababeans. However, the overall impact would be more local to the areas of irrigation rather than to a huge change in overall prairie acreage of these crops. Specialty crops may see a slight increase with the irrigation investments in these two provinces.

Fall seeded crops were also considered by some to have opportunities for growth particularly if moisture patterns trend to earlier in the spring. Large opportunities are seen for winter crops.

Winter cereals (durum, wheat), winter peas and winter canola and camelina may see some growth in future years but need much greater investment as presently much of the work is in the public sector.

Niche crops like quinoa, hemp, sunflowers, canary seed, buckwheat, lupins, poppies and kernza were all mentioned as having some potential to expand in acres but the overall contribution in acreage would not be large even in the longer term.

There was a general concern expressed that while rotations need to be more diverse, profitability will be the main factor influencing crop choice. Cereals, canola and pulses would continue to be the main crops grown. Larger farms needed a simple rotation to maximize economies of scale and reduce the complexities of management with a greater diversity of crops. On the other hand, small farms would have more opportunity to have greater rotation diversity.

There was a clear and consistent message provided by a large number of the groups interviewed that disease pressures would have important impacts on crop choice for farmers. Aphanomyces in peas and lentils and Clubroot in canola were both recognized as huge issues for many farmers and the presence of these diseases would put a brake on any future acreage expansion. At the same time respondents thought that farmers would have to move to more diverse rotations without pulses in the case of Aphanomyces infection for 6-8 years until effective treatments (e.g., resistance varieties) are developed. Fababeans were seen by some as offering a pulse crop with some resistance to root rots but the market needs to be better developed and the days to harvest need to be reduced.

Herbicide resistant weeds were also considered by some to impact crop choice. Wild oats and Kochia were both mentioned as difficult to control weeds.

Consumers both in Canada and in our export markets will drive crop choice. Opinions varied on the future of livestock production as there is a growing number of flexitarians who choose nonmeat meals and this trend, if it continues, will fuel the demand for plant protein. At the same time there is the potential of an emerging cell-based meat and fish production market with the first lab-based chicken product being approved for sale in Singapore. If costs are competitive and there is consumer acceptance it could result in less livestock and less livestock feed being grown.

Government policy was also seen by many to influence cropping choices through its activities in trade and market access and domestic policies around farming and environmental issues. For example, the Carbon levy may result in more on farm fuel production, more nitrogen from biological sources and more pulses. Nitrogen costs are expected to increase as they are energy intensive to produce, contribute to an increased Carbon footprint and will be affected by the Carbon levy. Biofuels may also expand depending on government policy and may put pressure on growing more canola.

Regenerative agriculture was raised by some as a holistic approach to farm more sustainably with greater diversity of rotations using more niche crops (crops such as hairy canola, quinoa, hemp, lupins, mung bean) but, if adopted, would find a possible place in smaller farms. Using animal manures as natural fertilizers in a regenerative system is only possible where livestock are in close proximity to grain farms, or the farm has livestock and has forages in the crop rotation.

Gene editing (CRISPR) was mentioned frequently during the interviews as a technology that was clearly needed to aid in accelerating progress in traits that would be required by farmers such as being more resistant to variability in weather or N-fixing wheat or canola. Advances in these breeding techniques would provide more options for cropping choice. The US has indicated the gene edited plants that have the same traits as produced by conventional breeding would not be regulated, whereas in Canada gene edited plants would most likely be classed as being novel (and novel food and feed) and this may put Canada in a less competitive position to our southern neighbors.

Early adoption of hybrid wheat would be likely, particularly if the yield advantages for variable growing conditions are established and good enough to overcome the higher seed costs. Niche GM crops with novel traits are being developed and could potentially be available in next 5 years. Examples given included herbicide tolerant mustard and camelina. These new tools may support increased acreages of these smaller acreage diverse crops.

Farmers have large expectations on what science could deliver and see N-fixing wheat and apomixis as potential game changers in cereals, but they indicated the time frame is likely more than 20 years.

Consumers will also have an impact on pushing governments to adopt more regulation that controls crop production practices (spraying, fertilizing). Traceability and documenting production practices will become mainstream in the future and respondents saw that producer relationships with processors or commodity marketers would strengthen over time.

Question 3 - What crop production opportunities and threats will grain farmers face?

Opportunities:

The growing global demand for plant protein was one of the biggest new opportunities for protein crops like peas and lentils. Canola may also benefit as a human protein source as most canola meal ends up as livestock and fish feed. New processing capacity built in western Canada gives more stability for crop prices that would otherwise depend on the commodity export market.

Many saw value-added processing as a big opportunity for crop production and would result in less reliance on commodity export markets. Opportunities to participate as part of a supply chain to major processors were growing and could result in higher returns, although more than one of the responders indicated that the increased record-keeping requirements for the farmer did not really cover the increased returns. Biofuels were also mentioned as an opportunity both in the production of ethanol and biodiesel.

There has also been growth in local farmers markets and on-line selling of farm produce where consumers have direct contact with the producer. For small farms these trends could give opportunities for more crop diversity, more processing with examples given of snacks (bars), beverages and packaged products.

The ongoing evolution towards digital agriculture was regarded by many as bringing significant new opportunities for farmers. Many thought that autonomous equipment would be an important breakthrough with tractors, seeders, sprayers, scouting and harvesting operations being conducted with minimal operator intervention. Sensors would continue to be developed so that all aspects of crop growth and decision-making could be remotely monitored and managed to the micro-field level.

These developments would result in large volumes of data available to farmers to make better management decisions and optimize the efficiency of farm inputs. However, many considered that farmers do not effectively use the data collected on the farm presently as a central part of their decision making in crop management. Some responded that farmers needed to use open-sourced software to collect and manage the data to avoid being enrolled in company specific programs.

Research and technology development was considered by many to be a core issue for creating new opportunities for farmers. This could be through solving existing production problems that cost farmers money, through the development of new products such as varieties, equipment, fertilizers, weed and insect control methods and providing information that was credible and unbiased.

The importance of agronomy research conducted independently was also considered to be an important opportunity by many farmers for both large acreage and niche crops and would be essential to understand and get the best returns from soil and crop management and precision agriculture.

Plant breeding and the development of improved varieties has long been recognized by farmers as a core activity for improved productivity by increasing yield, disease resistance and meeting quality requirements. Respondents thought the basic work on topics like the wheat genome would lead to accelerated progress in plant breeding. However, the new breeding techniques like gene editing (CRISPR) were believed to offer emerging new opportunities for variety advancements if the technology is not over-regulated and consumers understand the benefits (e.g. less pesticide usage). Gene editing could result in more rapid progress to improve the plants ability to respond to extreme weather events (drought and excess moisture). Farmers gave examples of some of the developments they would like to see. These included, N-fixing wheat and canola, glabrous plants to protect against insects, new rotation crops, drought resistance and overall a faster rate of progress so that new varieties are clearly better than the ones they replace.

New crop protection products that had significantly lower impact on the environment or on perceived health of consumers would be a huge opportunity for crop production. Crop protection techniques such as RNAi were mentioned as control methods for pests and diseases that did not use chemicals, but regulation was an issue and effectiveness had not really been established at the field scale in Canada. The number of biological type products with various claims, such as increased yield and building soil fertility, did not have independent research information and needed more work. Some mentioned biological control of weeds, pests and diseases as an opportunity.

Some respondents mentioned that farmers were very willing to co-invest in research and others commented on the importance of having a prairie wide funding agency versus individual provincial funding agencies. Others suggested that with out-of-control government deficits, producers needed to invest and take ownership in variety development as the public programs would come under considerable financial pressure in the next 5 years.

Climate change was regarded as a potential opportunity with less predicted impact for the Canadian prairies than in some of the main crop producing areas of the United States. It was mentioned that the prairie growing season had increased by 2-4 weeks over the last 60 years and this provides for greater crop diversity that will apply to areas north of highway 1. Others perceived that higher levels of CO_2 in the atmosphere would result in elevated growth of crops and higher yields. Improved accuracy in the prediction of seasonal weather in advance of seeding would be a tremendous opportunity for farmers as climate change has increased weather variability. Winter crops were also thought to be an opportunity with climate change and would allow the possible harvesting of a forage cover crop in the same season. Intercropping was considered to be an opportunity, but lack of research information has led to farm experimentation and little independent information.

Sustainability was mentioned frequently as a big opportunity for farmers mostly in the context of regenerative agriculture and the growing interest of large companies in promoting food products that have positive environmental stories. However, many indicated that there were no commonly understood definitions of regenerative agriculture or measures that might be taken to support increased sustainability. It is assumed by some to be a farming system that uses low crop inputs, may include livestock for manure nutrients, and is somewhere between organic and conventional cropping practices. Carbon capture might also be included as part of sustainability with farmers getting paid for their eco-system services that was regarded by some as a big opportunity. There was also the opportunity in the area of Carbon credits that might offset or partially offset the rapidly increasing Carbon levy.

Public scrutiny of agriculture and crop production will increase and there will be opportunities for farmers to exploit this gap in the understanding of modern crop production practices. Some thought that traceability at the farm level will be an increasing requirement for farmers to market food and would entail additional record keeping and costs. Consumers will demand sustainable practices and will support the idea of identity preservation and farm auditing. The right to farm and documenting good farming practices that are environmentally friendly for chemical usage and soil health will be important to improve consumer understanding of farming practices.

Threats

There was general consensus that the next 10 years will see a loss in crop protection tools for agriculture and thus an urgent need to find replacement technologies. First and foremost, producers talked about increasing restrictions and use of glyphosate with preharvest application in pulses and oats not allowed by certain processors and strict MRLs in place. This restriction of use increases farm costs through having much higher drying costs that were inflated by the Carbon levy. Producers thought that glyphosate usage might be completely banned in crop production in the future with much erroneous information available on social media. A ban on the use of glyphosate would have huge implications for modern crop production and result in more tillage for weed control and potentially reverse some of the positive changes in soil quality that have taken place over the last 30-40 years with the widespread adoption of conservation tillage on the prairies.

Insects and diseases are always an issue in crop production and a reduction in the pool of available insecticides and/or fungicides will create considerable challenges for farmers unless there are replacement technologies. Farmers also discussed loss of seed treatments as being possible in the future. Respondents gave examples of a large number of insect threats that are an ongoing problem (flea beetles, wheat midge, wheat nematode, cabbage maggots). New pathotypes and new diseases such as bacterial blight in wheat and verticillium wilt in canola were also mentioned as emerging threats causing economic loss to farmers.

Weed resistance and the introduction of new invasive weeds were both regarded as long-term threats to production. Wild oats and Kochia were cited by many respondents as causing significant problems for producers. Changes in management and rotations may be necessary to control these problem weeds. Invasive weeds are thought to be moving north from the United States and those with significant herbicide resistance will be significant future problems. Responses indicated that weeds like water hemp, Palmer amaranth and Canada fleabane were all threats that would need attention.

Several mentioned an increasing concern over the availability of Phosphate as it was becoming scarce and mined in countries with unstable governments. Phosphate dynamics in the soil would give a better understanding of how much of this element was removed under different crops and new ways to extract P may be required to reuse this core element in plant nutrition.

With the trend towards digital agriculture and ongoing need for high-capacity internet, many considered that the lack of stable and reliable internet service in rural areas could be an ongoing threat that would limit uptake of this technology.

Respondents also were of the opinion that the corporate data management systems represented a threat in that a company accessing farm data could very easily set up their price point for crop inputs supplied by the same company. Concerns were also expressed about the ownership of a farm’s data, the cost benefit of company programs and the fact that Companies having access to farm data would allow them to better target price point for farm inputs.

Global market policies are incredibly unpredictable, yet prairie agriculture depends on the rest of the world to market our crops and food. Markets can be shut down overnight as has been seen for canola exports to China, durum exports to Italy and pulse exports to India.

Transportation of crops out of Western Canada to world markets is also an ongoing challenge with road and rail infrastructure needing improvements and the competition with other commodities like oil for space in rail transport.

Many respondents placed a high value of public research conducted by Universities and Government research facilities and the research undertaken by farmer driven applied research associations. There was a general feeling that declines in public research would lead to less independent research and reduce the availability of unbiased data for farmers.

Government deficits at all levels of government leading to cuts or discontinuation of services over time threaten market development, extension and research. A repeated example was public plant breeding and, if not maintained, it would be a significant threat to the future release of varieties. The recent pilot testing of SVUAs by seed companies, particularly if it involved public varieties that had been partly funded by producers was regarded as a threat, whereas others saw it as an opportunity.

Other threats mentioned in the area of public research included no short-term solutions to counter significant diseases in canola (rapidly changing pathotypes in clubroot) and pulses (Aphanomyces in peas and lentils) and the potential loss of pest surveillance networks.

Many regarded the Federal Government as one of the biggest threats to the viability of farming on the prairies through increased regulation of farm practices. The Carbon levy will have an impact on the cost of production and this tax will continue to increase in future years. This threat is exacerbated if farmers are not recognized for the Carbon they sequester.

The often-negative consumer perception of agriculture is an ongoing threat that will drive increased environmental regulation. Some thought that the Government may subsidize low input, low technology agriculture or stimulate organic production of food that would fuel more distrust of farming practices. Lab grown meat, if it gains commercial acceptance and can be done at a competitive cost, could result in less livestock and demand for feed grains.

Changing government priorities can also be a big threat with a switch towards environmental issues in government innovation programming and corresponding reduced research to improve production efficiencies. Farmers believed that regulations around nutrient use and application would continue to be developed as nutrient pollution through run off and contamination of waterways continues to exist. A concern was expressed that this may result in nutrients only being allowed with a prescription from a certified agronomist or governments imposing regulations on farmers. A BC Peace example was stated where the Province requires a nutrient plan every three years with the requirements being largely related to intensive production systems in the Fraser Valley than the grain farming area of NE British Columbia.

Migration of people from the city to rural areas was also regarded as a threat. COVID has resulted in many more people working from home and this major trend has been also linked with people moving to lower cost areas in the country. The perceived threat is that the movement of people to the country will create increased pressure on environmental issues (pesticide usage), noise abatement and not being able to work fields after dusk.

Loss of experience and advocacy towards minimum/zero tillage was perceived as a threat. With weed resistance as a growing problem and herbicides being less effective in weed control, there is a trend toward a greater use of tillage and manufacturers have been advertising the benefits of various kinds of disc rippers, vertical tillage tools and chisel ploughs. Greater soil disturbance will lead to loss of soil organic matter and potential soil erosion.

The current Code of Practice that was under development was cited by some as people in Ottawa trying to control the way farmers managed their land and crops. Others saw it as an opportunity. There was varied opinion about who is driving the Code of Practice, but the majority were concerned with the uncertainty of what it would mean to farm practices.

Farmers not recognizing themselves as food producers and understanding that accountability and transparency is becoming much more important in food production is an ongoing threat to farming. There is a portion of the consuming population that want to know how their food is produced and handled.

Question 4 - What new technologies do you expect to be available/needed by farmers?

There was a consistent message from the majority of the respondents that technologies in the area of farm equipment and the tools to collect the data or information, that could aid in making better farm management decisions throughout the growing season, would continue to evolve and be adopted to various degrees by farmers across the prairies.

Automation of farm equipment was perceived by many as the wave of the future driven by the ongoing difficulty of getting reliable farm labour in rural areas. Operations like seeding, spaying, application of fertilizers and combining could all be done by self-driving equipment with accuracy down or close to the nearest centimetre. Some people saw smaller equipment and an army of robots managing field operations with each piece of equipment replicated several times to work the different zones of a ¼ or ½ section. DOT technology was mentioned by several as being one good example of autonomous farm equipment development, whereby one powered platform was able to handle a large variety of farm implements. Another example given was advanced automation aspects of the John Deer X series combine that received the top award for the “Best of Innovation” at the 2021 North American Consumer Electronics Show. While farmers saw increased farm automation as being inevitable, there were frequent concerns raised about the inability of farmers to service proprietary electronic systems and the control and ownership of the data that was collected.

Farmers also considered that in time the autonomous equipment would change from diesel to electric power or an alternative low C fuel source. Alternative fuels for the farm were cited as an important future need with fossil fuels being increasingly subject to tax increases. While biofuels were believed to have application for greater farm use, newer low Carbon fuel development was a priority need for farmers in the future. Fuel costs will potentially continue to escalate with a planned increase in the Carbon levy and alternatives are needed to farm diesel. As the Federal Government continues to place increased emphasis on reducing the Carbon footprint of farms, alternative energy sources such as fuel cells, hydrogen, on farm generation of biofuels including biodigesters may need to be developed. One respondent suggested that a suitcase sized nuclear reactor could be a solution for low cost on farm power that was Carbon neutral.

The growing amount of data that could be automatically collected from equipment or from the field itself was frequently mentioned. As the data explosion builds, farmers do not manage this source of information very well or use it effectively. Farmers often relied on companies to provide data analysis and predictions, based on machine learning and artificial intelligence, to aid farm management decisions. The costs of using company driven programs in precision agriculture versus the rate of return was questioned by several as an area needing independent study since the companies generally provided optimistic figures on rate of return in using their services. At the same time, it was recognized that farmers often did not possess the expertise to collect and integrate the different sources of data that could be collected on the farm and use it to improve operational efficiency. It was also thought that the larger farms would be quick adopters of precision agriculture, while smaller farms would likely be slow to adopt precision agriculture as the land base on small farms could be micromanaged. Some postulated that in the future one crop specialist may have more than a million acres of farmland under a precision agriculture program.

There was a general feeling that the new generation coming to farming over the next 20 years would be much more comfortable with technology such as that provided by precision agriculture. In the meantime, farmers may need more training and support to help them better understand the possibilities and drawbacks of the digital agriculture age such as hackers gaining access to their farm data. Communicating new technologies to farmers such as that offered by precision agriculture was also a problem and needed new approaches to be developed as the space was dominated by company brochures that often were in need of independent verification.

Tools that collect data that aid and support better decision making by farmers throughout the growing season was also considered to be technology that was available but needed a great deal more development.

While precision agriculture through real time diagnostics was available to farmers through a number of companies, many considered that the technology was not yet affordable but would reduce in cost over time. Some considered that sectional control for variable rate application of fertilizer was not reliable and needed a lot more independent study. Farmers needed to better understand the cost effectiveness of integrated data management and the resulting predictions aimed to improve their decision making. Several talked about the need for more sophisticated sensors that could cheaply monitor soil fertility to improve the application of fertilizers and sensors for detecting disease. Others suggested they would need sensors and field image data to detect crop disease with results available on a cell phone app. Some also thought that being able to measure protein on the go at harvest would increase the accuracy of yield maps and improve future applications of fertilizers.

Farmers recognized that variable rate fertilizer application was an available technology and offered considerable advantages in making more efficient use of fertilizer through the application of fertilizer to zones in the field based on predicted nutrient requirements. Some respondents indicated that they had tried variable rate fertilizer technology but had not found it to be useful in its present form of development citing the costs of the technology in relation to the amounts of fertilizer used. Several farmers suggested that more independent work needed to be done to establish the true ROI for adopting variable rate fertilizer application.

Several commented that the field mapping and nutrient prediction needed a lot more work for variable rate fertilizer application to work effectively. Having field sensors beyond moisture probes that could assess soil fertility and pH and allow for accurate mapping of fertility would be a big step forward for precision agriculture, but this is not something that is likely in the short term.

Scouting of crops for diseases, insects and weeds was a big need although the accuracy of some of the present techniques to provide reliable data that was remotely transmitted to a smart phone was questioned. Drones have seen some early adoption by farmers and allow for field scouting for the presence of diseases and pests and potential lack of moisture, although several stated that it did not replace the human value of field scouting. It was considered that human field scouting was needed to ground truth the data collected by drones.

Respondents thought there was a need for rapid tests to identify soil pathogens and commented that it was a long way from having diagnostics that could predict pathogen race. A much quicker turnaround for pest and disease risk assessment was needed with possible molecular approaches adapted for field usage. Rapid weed resistance testing technology was seen as an important crop management need. Being able to assess a weed leaf for Group 1 and 2 resistance would lead to better decisions on herbicide selection to control grassy weeds.

Weather forecasting was an area of interest that has expanded with the availability of relatively cheap automated weather stations. Weather stations on farms that could continuously collect and transmit data on temperature, precipitation, humidity to a cell phone or iPad were becoming relatively common and were a key part of precision agriculture programs offered by private companies but using this data to predict future weather events of importance to crop growth was poorly developed.

Reliable predictions of weather during crop growth would result in better management decisions in the control of diseases and insects (most effective time to spray). Longer term reliable predictions of weather would lead to better selections of crop type, variety and management practice to ensure best producer returns. Much better prediction modeling for weather forecasting linked with disease and pest forecasting was seen as an important need for farmers. Others considered better weather forecasting could result in improved nutrient management.

Overall, most groups reported that farms would be increasingly managed on a site-specific basis for both nutrients and crop protection activities. Many commented on the need for farmers to independently collect their own data particularly for equipment data that went directly to the manufacturer. Use and development of open-sourced software to collect, integrate and analyze the data from equipment and sensors would be a need that some farmers would value. Reliable internet service in rural areas was something that was needed for farms to be truly competitive.

Variable rate spraying was also considered to be a technology available in other countries and would need more work for effective farm deployment, particularly for the in-crop control of weeds. The development of spray technology for spot spraying green on brown was available but a lot more work was needed for assessing the effectiveness of controlling weeds in a growing crop. Drones were also being developed to spray fields for weeds with development of software to allow for spot spraying of targets that would result in no actual field disturbance in applying the crop protection chemical and a lesser amount of chemical used than conventional spraying.

Some considered that weed clipping as done in Europe could be looked at whereas others thought in the longer term that robotic weeders could be a solution and there would be lots of mechanical approaches that will need to be assessed.

Improved crop varieties with higher yields and disease resistance packages were available and the investment in genomics would result in faster genetic progress in the future. While adoption of new hybrid varieties was high (e.g. canola), the adoption of new cereal varieties was correspondingly low suggesting the costs and returns of using certified seed from new varieties was not fully understood or there was insufficient improvement in the new varieties to make the purchase worthwhile.

Public breeding was considered to play an important role for improving disease resistance and yield in many crops and for looking at new traits (drought resistance; nutrient use efficiency) but there were concerns that public breeding may decline as the costs of the technology to support breeding increased. There was a need to increase the returns to breeders from new variety development with industry proceeding to pilot the SVUA process, but comments were made that if the trading of common seed stopped there would be increased sales of certified seed and no need for the SVUA. Alternatively, several comments were made about preserving the right to farm-saved seed and opposed to any sort of value capture.

Research was a common theme throughout expressing the need to continually improve upon what is available.

Several groups commented that the prairies had an advantage over other grain producing areas in that a diverse number of crops could be grown. It was also stated by some that a focus on early maturity was an ongoing need for all prairie producers.

Variety development and ongoing public investment in new and improved varieties was mentioned by several farmers as being a vital need for producers to remain competitive and to have access to affordable seeds. New traits such as a much greater resilience to weather variation and to combat moisture excesses and moisture stress and salinity were considered important needs.

More difficult new traits like N fixing wheat and canola were also mentioned as a need but considered to be very much to be a possibility in the long term. Some respondents considered that the only way to get these new traits incorporated and commercialized would be by use of gene editing (CRISPR).

Others mentioned a need for hybrid wheat that would be more resilient to variations in climate. Farmers would have an interest and need for hybrid cereals, but seed costs need to ensure farmers get a reasonable rate of return for their investment.

Changing disease pressures were also a challenge and breeding needed to keep ahead of new and emerging diseases and being ahead of the pathotype changes in diseases like clubroot in canola.

Farmers had the same need for independent and well-planned agronomic research as variety development.

Plant growth regulators and biologicals were being developed to provide alternative crop inputs that had many claims including, improvement of crop yield and soil health, and these needed to be independently verified for efficacy as often there were bold marketing claims that were not backed up with reliable research. Lots of different biological products but farmers need to know which soils, crops and areas of the prairies in which they are cost effective.

Aphanomyces was thought to be a major limiting factor for future growth in both peas and lentils along with Ascochyta and genetic and agronomy research needed to be increased to provide solutions that might take many years. While progress had been made in having spring wheat that was moderately resistant to fusarium the work needed to be continued. Some respondents also suggested that crop lodging was an ongoing problem with need for more genetic and agronomy work to provide solutions.

A replacement for roundup (and liberty link) was regarded by many of the respondents as a core future need. Roundup as presently used supports minimum tillage practices that are widespread on the prairies and the pre-harvest desiccation of crops to reduce drying costs. There was a general concern that lack of effective weed control measures would lead to a big increase in tillage with resulting impacts on soil erosion and soil quality. However, the combination of light tillage in conservation tillage systems has resulted in increased yields for some that needs further investigation. Weed control from the back of the combine using seed destructor technology needed to be fully assessed but did not work for wild oats.

New technologies to control insects and diseases such as RNAi were an important need for farmers to replace crop protection products that continually face environmental challenges and the spread of misinformation to consumers. RNAi products would face significant regulatory hurdles and costs to obtain product registration. While RNAi products would not replace the present need for the large companies to develop new chemistries, it would provide another avenue to provide a viable mechanism for crop protection. There would be an ongoing need for technologies that would reduce the current use of chemicals in crop production.

Reduced application of chemicals on crops to control weeds, insects and diseases was expressed as a strong need by many respondents. Better insecticides with less non target impacts were very much needed by farmers. Biopesticides were mentioned as an alternative crop protection strategy but products have mostly found a use only in organic agriculture.

Sustainability and regenerative agriculture were often raised as important issues, but no-one really seems to understand exactly what these terms mean and there is a need for more work in this area to validate principles.

There was a need expressed by several to conduct more work to have a better understanding of soil microbes and nutrient availability and on the impact of greater biodiversity on soil biology. Seeding tools may need to be refined as there were many different soil openers with no good understanding of what works the best in different seeding conditions and row widths. The overall need for better seed and fertilizer placement were mentioned as needing further development as well as residue management tools that will be different for the different ecozones across the prairies.

Better soil test validation was an ongoing need for farmers. Soil fertility testing presently involves taking core soil samples and having them physically analyzed at a reputable laboratory. The alternative has been to predict nutrient availability indirectly using yield monitor results and satellite imagery. Long term verification sites are needed across all soil zones with a focus on P and micronutrients (prill coated) so that recommendations made to farmers are based on up-to-date research. P reclamation studies were also cited as an area where more work needed to be done.

Many considered that there was a need to improve nutrient and water use efficiency. Improving the efficiency in the way that N was used on the farm was a very important need as much N was thought to be lost via gaseous losses as NO_2 or leached from the soil into the waterways. More independent field scale trials were needed to study slow-release type nitrogen fertilizers, P dynamics in the soil and updated research with modern equipment in zero till situations on the basics such as safe rates of seed row fertilizers and not just N (also include P, K and S).

With newer higher yielding varieties there was also a need to update research on the crop removal of nutrients. Fundamental research on the nutrient needs of new varieties and how these can be best met with stabilized fertilizers was an ongoing need.

Carbon capture and sequestration measurements for soils needed to be improved and farmers needed a rapid technique so they could verify the amount of C captured by their farming practices (and perhaps to capture loss of C as well). While farmers had not been recognized for their C sequestration performance, some thought that this might be brought into place to offset the C tax.

Chaff and straw distribution equipment needed to be improved so as to provide organic matter for the soil and not have crop residue impede seeding.

More research with smaller acreage crops was mentioned by multiple groups as an ongoing need. Crops like flax needed investment to increase yield and to manage the straw post-harvest. Agronomy work was needed in crops like fababeans with the newer low vicine/convicine varieties.

Intercropping was being experimented with, but producers really needed to better understand how to choose the best combination of crops that worked well together and the impacts of more than one crop on disease, weeds and insect build up.

Cover crops were another area that needed research and the equipment to manage cover crops such as roller crimpers so that seed beds were manageable in the spring.

Some respondents considered that more work needed to be done on cropping system and resulting crop quality with a focus on nutrient and micronutrient content. Others thought that much more accurate procedures needed to be developed to assess grain grades and quality that would match the assessment at the elevator.

Traceability was also mentioned frequently as something that farmers will need to adopt with block chain considered to be a useful technology to maintain accountability of farm practices through to delivery to the processor or elevator.

Question 5 - What current technologies do you expect may not be available (or may have more restrictions) to farmers?

Mentioned by almost all respondents was the issue that crop protection products would likely become more regulated with governments increasingly focused on environmental concerns and so decrease the number of tools in the toolbox for management of crop threats. This could mean loss of access to a crop protection product through deregistration of approved use or regulations that would place crop protection products under a prescription system where use would only be allowed if a certified specialist approved its usage. Some mentioned that the prescription approach for applying pesticides only when it was a proven necessity was already in place in Europe. Maximum Residue Limits (MRLs) would continue to be fine-tuned and the bar raised so that risks of using a crop protection product would be increased.

Many thought that it was only a matter of time until pre-harvest application of glyphosate would be banned as processors were already stipulating in contracts that this method of crop dry down was not allowed and backed up by screening delivery loads for compliance. Some respondents thought that this might be the first step in a process to completely ban the use of glyphosate on prairie farms and the huge negative impact on conservation tillage systems as a result. Yellow pea producers delivering to processors on contract already had restrictions on glyphosate usage and the same existed for oat deliveries for human food. Farmers will have to deal how to manage with zero tillage without glyphosate.

Seed treatments were also considered to be vulnerable to increased regulation or even an outright ban. The main example provided was the use of neonicotinoids to control flea beetles in canola.

The breakdown of existing disease and insect resistance was also cited as a concern. Insect resistance to the wheat midge conferred an important economic benefit for producers but was based on a single gene and to date the resistance has been maintained through stewardship agreements, but this resistance could be lost in future years. Clubroot was a disease with many pathotypes and difficult for breeders to keep ahead of emerging races. Resistant cultivars are important but need to be combined with agronomy to ensure the resistance is maintained with emphasis on an integrated approach. It was also thought that there needed to be a large focus on alternative approaches or replacements for these crop protection products that were so important for sustainable cropping practices. Some examples given by farmers in this area included, seeding rates, crop variety mixtures, intercropping, cover crops and harvest weed seed management. RNA interference (RNAi) where certain genes are silenced was regarded as a technology with huge opportunities for control of diseases and insects, but access could potentially be lost or delayed due to overregulation.

Farmers expected increased restrictions would be placed on fertilizer usage. Synthetic fertilizers were often stated as a source of greenhouse gases (NO_2) and heavy rainfall following application could lead to increased flow of the fertilizer nutrients into waterways of the ecosystem. Farmers thought it highly likely that the broadcasting of fertilizer will come under increased scrutiny and could be banned through environmental legislation, especially if N fertilizer is broadcasted without stabilizers. One respondent thought that anhydrous ammonia could be phased out as a N fertilizer. It was stated that Provinces have differing regulations concerning fertilizer application. Fertilizer could be applied on snow in Saskatchewan but not in the other Prairie Provinces. The situation concerning fertilizers is also becoming confused by those farmers pursuing regenerative agriculture where use of synthetic fertilizers is usually substituted with animal manures and this is advertised as being more environmentally friendly. Some also thought that there may be increased reliance placed on mining municipal waste for nutrients like P that was becoming increasingly in short supply. It was thought by some that fertilizer usage on the farm may be subject to a prescription by a certified agronomist who would confirm and approve the levels and types of fertilizer applied.

Most respondents considered that farmers would become increasingly dependent on technology and suggested that equipment will continue to be improved and updated. The next round of new technology would be the development fully autonomous equipment. Farmers, however, would not get increased access to service and complete repairs of this equipment and some thought this situation would only get more restrictive over time.

Integration of data outputs from equipment manufactured by different companies might also become more difficult. Several respondents expressed concerns about data ownership when equipment sent data to the cloud for company access and the escalating costs of all farm equipment. Some believed that the high prices for equipment were now beyond the reach of a lot of smaller farms or newer, young farmers. Most hoped that internet service would improve to keep up with the rapid advancements in technology.

It was also thought that governments would continue down the path of reducing extension services and resources and other groups like universities, colleges and applied research organizations may need additional support to get important information to farmers. Some saw a much greater role for organizations like WGRF to get more involved in knowledge transfer. Others saw reduced government investment in crop research leading to a general decline in research capacity with a general loss or reduction in independent public research. Unbiased research was regarded by many as being the most useful for farmers to make decisions on crop input choice and cropping system.

Advancements offered in plant breeding by gene editing could potentially be lost to prairie farmers if new gene edited varieties could not be registered due to restrictive regulation that substantially increased product development costs. In addition, our competitors may adopt less restrictive regulation for the registration of gene edited varieties and this could impact on competitiveness. Consumer understanding of gene editing was also considered to be a ripe area for misinformation that may result in enough negative reaction to cause food companies to reject the technology. N fixing in non-pulse crops may be a long and difficult problem to resolve but access to gene editing tools may allow more investment to be feasible. It was suggested that documentation on the impacts of not having access to gene edited varieties may be of value to help consumers understand the benefits.

Many considered that the use of diesel fuel and/or diesel engines would be discontinued in the not too far distant future with no ready replacements that are practical for prairie farm conditions. Others suggested that the traditional sprayer would disappear from farms and replaced by highly technical sprayers that only spot sprayed weeds and zone sprayed for insects and diseases.

Other farm practices that were mentioned that could be more restricted in the future include the burning of stubble which is often practiced with flax straw and landscaping fields to improve drainage. Tile drainage was considered to be an important mitigation for soil salinity but moving water into waterways is subject to increased rules and regulation.

Several respondents considered that the trend to larger farms would impact rural areas through loss of infrastructure such as roads, hospitals and schools. Quality of life in the country away from large cities and towns would decline.

The continued investment by governments in effective road and rail systems that allow movement of crops for further processing or export was considered essential for prairie crop production to be competitive in global markets. Huge government deficits may result in reduced spending on things like infrastructure and road maintenance.

Public trust was regarded by many as a big issue for agriculture particularly in the area of pesticide usage. The general population has limited education regarding food production and lobby groups often through social media put pressure on governments to increase regulation. Consumer opinion was thought to be of increasing importance in driving the restrictions farmers would face in future years in access to and use of crop inputs. Organic production has been promoted by environmental groups as a preferred production system, yet there is no understanding by the general public on the consequences of any widespread adoption of this practice. Yields of crops would be substantially reduced and the price of food at retail would increase.

Section 4 - Summary of the Anticipated Changes to Western Canadian Field Crop Production that were described

The responses by question identified many common thematic areas interspersed among the questions. This section brings all those responses together under Thematic Areas:

- Technology and Innovation
- Biotic Stresses
- Abiotic Stresses
- Soil and Water Management
- Crop Management
- Societal Stresses (social, consumer, economic, policy)

Technology and Innovation

The collective responses to the survey questions considered that farming in the short (next 5 years) and longer (10-20 years) term would become increasingly dependent on technology and innovation. Technology in the broad sense included developments in equipment, sensors to measure and predict crop growth, management decision tools based on machine learning and artificial intelligence, biotechnology such as new crop varieties and crop production practices and research and extension. Technology developments in these areas would allow farmers to better focus on increasing efficiency of farm input utilization, improve the long-term sustainability of their cropping practices and maximize returns on investment.

Equipment

Precision or digital agriculture was generally thought to be a key technological change for prairie farming that was still in the early stages of development. The majority of prairie farmers use GPS already to access to autosteer on seeders, sprayers and combines. The digital revolution that is happening in the farm sector will provide for micromanagement of fields for crop inputs, maximize yield and result in an important increase in farm efficiency and productivity. While precision agriculture through real time diagnostics was available to farmers through a number of companies, many considered that the technology was not yet affordable or well-developed but over time would improve with reduced cost.

Automation of farm equipment was perceived by many as the wave of the future that will drive the precision farming or digital agriculture revolution. Farm operations like seeding, spraying, application of fertilizers and combining could all be done by self-driving equipment with accuracy as close to the nearest centimetre. Some people saw smaller equipment and an army of robots managing field operations with each piece of equipment replicated several times to work the different zones of one farm, ¼ section or soil zone. DOT technology was mentioned by several as being one good example of autonomous farm equipment development, whereby one powered platform was able to handle a large variety of farm implements.

Responses indicated that some farmers are using variable fertilizer rate application already. Some considered that sectional control for variable rate application of fertilizer was not reliable and needed a lot more independent study. Some farmers also saw future developments in variable rate seeding and variable spray technology that would be combined with soil moisture measurements, drone scouting and on-farm weather data. Others suggested that the traditional sprayer would disappear from farms and replaced by highly technical sprayers by ground or by drone that only spot sprayed weeds and zone sprayed for insects and diseases.

Although there was an almost universal consensus on autonomous equipment becoming increasingly available, concerns were expressed about the costs of new equipment and the thoughts that large farms would be the ones in the best position to invest in new equipment and be the early adopters. Some were of the opinion that small farms will not need expensive complex equipment to manage their crop and soils. It was also thought that the larger farms would be quick adopters of precision agriculture due to the economies of scale, while smaller farms could be slower to adopt all aspects of precision agriculture. Others expressed a concern about the ever-increasing costs of farm equipment and the challenges of replacing equipment in the future. Many farmers also expressed a concern that technologically advanced equipment required service by specialists at dealers and some thought this situation would only get more restrictive over time. Despite this, more automated equipment would be driven by labour shortages in rural areas and the continuing trend for farms to get larger, although some thought that farm size was maybe getting close to a plateau. Managing these larger farms will require more external support such as crop consultants, management consultants and diverse skill sets to manage technical equipment and big data. Some postulated that in the future one crop specialist may have more than a million acres of farmland under a precision agriculture program.

Many thought that sensors for all types of measurements would be available with improvements occurring over time. Several talked about the need for more sophisticated sensors that could cheaply monitor soil fertility to improve the application of fertilizers. Others suggested they would need sensors and field image data to detect crop disease with results available on a cell phone app. Many saw developments of green on brown technology (pre- and post-spraying) to measure weed occurrence as available and soon progressing to green on green technology (in-crop spraying). Some also thought that being able to measure protein on the go at harvest would increase the accuracy of yield maps and improve future applications of fertilizers. Farmers needed to better understand the cost effectiveness of integrated data management and the resulting predictions aimed to improve their decision making.

Many cited the need for reliable internet service that was a vital part of rural infrastructure for effective technology adoption, knowledge transfer and farm communications. The low orbit satellite project (Starlink) is well underway and will potentially provide broadband access to all of Western Canada along with improvements in internet access announced by the Federal Government. With the trend towards digital agriculture and ongoing need for high-capacity internet, many considered that the lack of stable and reliable internet service in rural areas could be an ongoing threat that would limit uptake of this technology and precision agriculture.

The growing amount of data that could be automatically collected from equipment or from the field itself through sensor technology was frequently mentioned. Farmers will likely increasingly rely on companies to provide data analysis and predictions, based on machine learning and artificial intelligence, to aid farm management decisions. While precision agriculture was seen as a key technological change, respondents often commented that the big data era that was coming still required significant improvements in data management and analysis.

Integration of data outputs from equipment manufactured by different companies might also become more difficult. As the data explosion builds, farmers do not or cannot manage this source of information very well or use it effectively. However, it was recognized that farmers often did not possess the expertise to collect and integrate the different sources of data that could be collected on the farm and use it to improve operational efficiency. Ownership of the data transmitted to Companies and who it might be shared with was also considered to be an issue.

Farmers need and want a much better understanding of their returns from precision agriculture so that the best decisions could be made for crop production in real time. The costs of using company driven programs in precision agriculture versus the rate of return was questioned by several as an area needing independent study, since the companies generally provided optimistic figures on rate of return in using their services. Some responded that farmers needed to use open-sourced software to collect and manage the data to avoid being enrolled in company specific programs. Respondents also were of the opinion that the corporate data management systems represented a threat in that a company accessing farm data could very easily set up their price point for crop inputs supplied by the same company.

Over the next 20 years technology will change a lot and will represent an ongoing evolution from what is available in today's market. Many considered that the use of diesel fuel and/or diesel engines would be discontinued in the not too far distant future with no ready replacements that are practical for prairie farm conditions. Farmers considered that in time the autonomous equipment would change from diesel to electric power or an alternative low C fuel source.

Alternative fuels for the farm were cited as an important future need with fossil fuels being increasingly subject to tax increases. While biofuels were believed to have application for greater farm use, newer low Carbon fuel development was a priority need for farmers in the future. Fossil fuel costs will continue to escalate with a planned increase in the Carbon levy and alternatives are needed to farm diesel. As the Federal Government continues to place increased emphasis on reducing the Carbon footprint of farms, alternative energy sources such as fuel cells, hydrogen, on farm generation of biofuels including biodigesters may need to be developed. One respondent suggested that a suitcase sized nuclear reactor could be a solution for low cost on farm power that was Carbon neutral.

Biotechnology

Research and technology development was considered by many to be a core issue for creating new opportunities for farmers. This could be through solving existing production problems that cost farmer's money, through the development of new products such as varieties, equipment, fertilizers, weed and insect control methods and providing information that was credible and unbiased.

Biotechnology was expected to play an increasing role in crop improvement in response to more challenging growing conditions and emerging diseases and pests. Plant breeding and the development of improved varieties has long been recognized by farmers as a core activity for improved productivity by increasing yield, disease resistance and meeting quality requirements. Respondents thought the basic discovery research to better understand the wheat genome would lead to accelerated progress in plant breeding. The new breeding techniques like gene editing (CRISPR) were believed to offer emerging new opportunities for variety advancements. Gene editing could result in more rapid progress to improve the plants' ability to respond to extreme weather events (drought and excess moisture), N-fixing wheat and canola, glabrous plants to protect against insects, and overall a faster rate of progress so that new varieties are clearly better than the ones they replace. N-fixing in non-pulse crops may be a long and difficult problem to resolve, but access to gene editing tools may allow more investment to be feasible. Others mentioned the need to continue to lessen the days to harvest for crops like peas as being important. Early adoption of hybrid wheat would be likely, particularly if the yield advantages for variable growing conditions are established and good enough to overcome the higher seed costs.

One respondent thought the US has indicated that gene edited plants that have the same traits as produced by conventional breeding would not be regulated, whereas in Canada gene edited plants would most likely be classed as being novel (and novel food and feed) and this may put Canada in a less competitive position to our southern neighbors if the technology is over-regulated. Consumer understanding of gene editing (eg. less pesticide usage) was also considered to be a ripe area for misinformation that may result in enough negative reaction to cause food companies to reject the technology. It was suggested that documentation on the impacts of not having access to gene edited varieties may be of value to help consumers understand the benefits.

Farmers have large expectations on what science could deliver and see N-fixing wheat and apomixis as potential game changers in cereals, but the time frame is likely more than 20 years and would require a much more in depth understanding on how genes interact both within and outside of the plant. Some respondents mentioned the need for herbicide tolerant traits in niche crops and indicated potential availability for HT mustard and camelina in the next 5 years. These new tools may support increased acreages of these smaller acreage diverse crops.

There was lot of discussion on the availability of seed that farmers will grow. Several comments were made about preserving the right to farm-saved seed and opposed to any sort of value capture. Also problematic was a lack of seed availability and advances in plant breeding for organic cropping systems. Alternatively, some respondents thought there was a need to increase the returns to breeders from new variety development with support for industry proceeding to pilot the SVUA process. But comments were also made that if the trading of common seed stopped there would be increased sales of certified seed and no need for the SVUA. The piloting of seed sales connected to an SVUA agreement creates another administrative load with a lack of tools to monitor compliance. As plant breeding advances become more dynamic (vs slow and incremental), certified seed sales would likely show a substantial increase. Diverging opinions appeared where some prefer the status quo of the public breeding programs versus having plant breeding and variety development exclusively in the private sector.

Other technologies were also mentioned as replacements for pest control chemistries. New crop protection products that had significantly lower impact on the environment or on perceived health of consumers would be a huge opportunity for crop production. Crop protection techniques such as RNAi were mentioned as control methods for pests and diseases that did not use chemicals, but regulation was an issue and effectiveness had not really been established at the field scale in Canada. The number of biological type products often produced using genetic modification technology had various claims, such as increased yield and building soil fertility, did not have independent research information and needed more work. Some mentioned biological control of weeds, pests and diseases as an opportunity.

Biotic Stresses

Biotic stresses and issues, like technology and innovation, were articulated in all five questions. Disease pressures will be an ongoing challenge for the major crops (cereals, canola, pulses). The major crops in rotations all have significant challenges that need to be managed. Respondents expressed that shorter rotations would increase disease pressures. The changing climate with warmers winters and wetter summers in some regions of the prairies will also tend to increase disease pressures on crops. Diseases like clubroot and blackleg will be managed by genetics but shifts in pathotypes continue to occur and may outpace the development of crop resistance. Cereals will have continued issues with fusarium head blight and leaf spots/rust that will increase reliance on the use of fungicides. Aphanomyces and Ascochyta were thought to be a major limiting factor for future growth in both peas and lentils. Reintroduction of pulse acres to lapsed areas once genetic resistance to root rots is developed may take 10 years but not well understood. New diseases such as bacterial blight in wheat and verticillium wilt in canola were also mentioned as emerging threats causing economic loss to farmers. Genetic and agronomy research needed to be increased to provide solutions that might take many years.

Wild oats and kochia were considered by many respondents to be problem weeds that needed new approaches for effective control. Invasive weeds are thought to be moving north from the

United States and those with herbicide resistance will be significant future problems. Responses indicated that weeds like water hemp, Palmer amaranth and Canada fleabane were all threats that would need attention.

Wheat varieties resistance to the wheat midge conferred an important economic benefit for producers but was based on a single gene and to date the resistance to this insect has been maintained through stewardship agreements, but this resistance could be easily lost in future years.

The overall outlook by farmers concerning the future use of chemicals to control weeds, diseases and insects was bleak. Most believe that there will be increasing regulation and accountability required by farmers to use them with a worst-case scenario being deregistration of existing products and no effective replacement chemistries. There was general consensus that the next 10 years will see a loss in crop protection tools for agriculture and thus an urgent need to find replacement technologies with a priority on reducing the amount of chemical control products used in crop production. Glyphosate and neonicitinoids were commonly referenced in this concern.

First and foremost, producers talked about increasing restrictions and use of pre-harvest glyphosate application. More than a few respondents referenced the irresponsible use that often-caused Maximum Residue Limits (MRLs) to be exceeded on cereal grains, canola and pulses headed for export markets or local processors. Consequently, certain processors contracting pulses or oats do not allow the use of pre-harvest glyphosate on their contract production. Producers thought that glyphosate usage might be completely banned in crop production in the future with much erroneous information available on social media on its potential impacts on human health. A ban on the use of glyphosate would have huge implications for modern crop production and result in more tillage for weed control and potentially reverse some of the positive changes in soil quality that have taken place over the last 30-40 years with the widespread adoption of conservation tillage on the prairies.

Seed treatments were also considered to be vulnerable to increased regulation or even an outright ban. The main example provided was the use of neonicotinoids to control flea beetles in canola.

The majority of comments focused on the needs of farmers in technology, research and responses to consumers perceptions. As farm sizes increases, it is possible that more calendar-type cropping systems that rely on external inputs (e.g., fungicides, insecticides, etc.) will develop. Management of the crop will reflect more routine inputs with potentially less activity related to assessing risk. For example, at a specified crop growth stage fungicide would be applied to manage leaf spots, regardless of the actual risk in the field. More routine prophylactic spraying may lead to issues with pesticide resistance in pest populations as well as a greater number of off-target effects. Weed resistance to crop protection chemicals and greater numbers of invasive weed species were thought to be a problem that would continue to increase in the next 20 years. With more pulse crops, foliar diseases managed with fungicides are most likely to have the second most frequent use for prairie crops and risks of fungicide resistance will increase.

Some suggested that this would push the movement towards alternate methods of managing biotic stress. Mainly referencing weed control, cultural control with greater seeding rates, more tillage, intercropping, cover crops and more diverse cropping would likely increase. Others called for new chemistries that met environmental concerns. Mentioned more often than any other need was movement towards more targeted spraying of herbicides, driven by environmental pressure to reduce chemical use. Targeted spraying would require improved developments in weed seeking technologies like Blue River, machine vision, and precision spraying. Some suggested all these methods would be needed in an integrated weed management (IWM) approach. Others saw an increase in the number of biological crop protection products for both weed and pest control (bio-pesticides) but questioned whether these approaches would be effective. Seed destructor technology (Harrington Seed Destructor) was also mentioned as something that might become an important weed control technology. It can result in less chemical usage, but there was no consensus on whether this technology was a good solution for the future control of weeds. Some considered that weed clipping as done in Europe could be looked at, whereas others thought in the longer term that robotic weeders could be a solution and there would be lots of mechanical approaches that will need to be assessed.

Scouting of crops for diseases, insects and weeds was a big need although the accuracy of some of the present techniques to provide reliable data that was remotely transmitted to a smart phone was questioned. Drones have seen some early adoption by farmers and allow for field scouting for the presence of diseases and pests and potential lack of moisture, although several stated that it did not replace the human value of field scouting. More work needs to be done on ground truthing these techniques to ensure the data is reliable for farm decision making.

Respondents thought there was a need for rapid tests to identify soil pathogens and commented that it was a long way from having diagnostics that could predict pathogen race. A much quicker turnaround for pest and disease risk assessment was needed with possible molecular approaches adapted for field usage. Rapid weed resistance testing technology was seen as an important crop management need. Being able to assess a weed leaf for Group 1 and 2 resistance would lead to better decisions on herbicide selection to control grassy weeds.

It was quite clear that respondents identified pest issues as a significant need in light of crop and soil management needs, consumer pressure and government policy. Disease, weeds and insects all are being affected by weather patterns and will continue to be a challenge as new species arrive, pathotypes change or resistance becomes common.

Abiotic Stresses

Most respondents considered that abiotic stresses were intimately linked with weather and climate change. Increased frequency of extreme weather events, particularly recently, has impacted production in any one or more regions of the prairies. Better weather forecasting was repeatedly mentioned as a need, mostly related to making better management decisions. Increasing day and night temperatures were also seen as a challenge along with wet Spring and Fall seasons. Reliable predictions of weather during crop growth would result in better management decisions in the control of diseases and insects (most effective time to spray). Longer term reliable predictions of weather would lead to better selections of crop type, variety and management practice to ensure best producer returns. Much better prediction modeling for weather forecasting linked with disease and pest forecasting was seen as an important need for farmers. Others considered better weather forecasting could result in improved nutrient management and less losses of nutrients to the atmosphere or groundwater. Expansion of irrigation in Southern Alberta and Saskatchewan would help reduce risk around very low moisture conditions. Most respondents agreed that the biggest issue facing all farmers was the degree of uncertainty in predicting moisture for a growing season.

Several reported that the extreme weather events with lots of rain falling in a short period of time has resulted in a lot of erosion on land that had been in zero till for 20 years. There is interest in under seeding and in-season seeding to provide a cover crop that mitigates the exposure of bare soil to weather elements following harvest.

Climate change was regarded by some as a potential opportunity with less predicted impact for the Canadian prairies than in some of the main crop producing areas of the United States. It was mentioned that the prairie growing season had increased by 2-4 weeks over the last 60 years and this provides for greater crop diversity for areas north of highway 1. Others perceived that higher levels of CO_2 in the atmosphere would result in elevated growth of crops and higher yields. Improved accuracy in the prediction of seasonal weather in advance of seeding would be a tremendous opportunity for farmers as climate change has increased weather variability. Winter crops were also thought to be an opportunity with climate change and would allow the possible harvesting of a forage cover crop in the same season. Intercropping was considered to be an opportunity, but lack of research information has led to farm experimentation and little independent information. Adapting to climate change will mean being able to better understand changing moisture and temperature conditions so that crops can make best use of available water. There was an opposing viewpoint expressed such that the weather cycle was starting to move into a longer-term cooling period for the next 30-40 years. Shorter growing seasons could make many of the crop varieties less adapted for prairie crop production systems and act against any large increase in corn and soybean acreages. A changing climate will also result in new invasive weeds and insects that will need new control methodology. Pests may overwinter more easily with warmer winters and new invasive species may move into the prairies from the United States.

Weather forecasting was an area of interest that has expanded with the availability of relatively cheap automated weather stations. Weather stations on farms that could continuously collect and transmit data on temperature, precipitation, humidity to a cell phone or iPad were becoming relatively common and were a key part of precision agriculture programs offered by private companies but using this data to predict future weather events of importance to crop growth was poorly developed.

Soil and Water Management

Conservation farming is undergoing some kind of change with the seemingly increasing discussion of more tillage to solve problems. These changes may be driven by a lack of historical knowledge and perspective related to the detrimental aspects of conventional tillage (soil erosion, soil health/quality, increased equipment fuel and operating costs, etc.). Loss of experience and advocacy by farmers towards minimum/zero tillage was perceived as a concern. With a smaller potential toolbox of crop protection products, farmers thought this would result in more tillage. Also, tillage may be viewed as a “new” technology by a younger generation of farmers. They may also view tillage as a solution to seeding issues related to excessively wet soil conditions, weed management, straw management, or perhaps to nutrient stratification, etc. Some indicated that these issues with conservation tillage may be based on general perceptions, or views not supported by science. Greater soil disturbance will lead to loss of soil organic matter and potential soil erosion. Equipment manufacturers may also view tillage equipment as another revenue stream and thus promote its use to address real or perceived issues with conservation tillage.

Sustainability was mentioned frequently as a big opportunity for farmers mostly in the context of regenerative agriculture and the growing interest of large companies in promoting food products that have positive environmental stories. Early regenerative pioneers were a little extreme but has morphed into a sustainability debate where rotations are more diverse and crop inputs like fertilizers are reduced and forages/livestock are often brought in as part of the rotation. Regenerative agriculture was thought by some to be a holistic approach to farm more sustainably with greater diversity of rotations using more niche crops (crops such as hairy canola, quinoa, hemp, lupins, mung bean) but, if adopted, would find a possible place in smaller farms. It was assumed by some to be a farming system that uses low crop inputs, may include livestock for manure nutrients, and is somewhere between organic and conventional cropping practices. Using animal manures as natural fertilizers in a regenerative system is only possible where livestock are in close proximity to grain farms, or the farm has livestock and has forages in the crop rotation. General Mills has announced plans to source crops from a million acres of land farmed using regenerative agriculture. However, many indicated that there were no commonly understood definitions of regenerative agriculture or measures that might be taken to support increased sustainability. Some suggested there needs to be a clear understanding of the value of these practices before launching new research.

Overall comments suggested that farmers need to remain vigilant about soil health and its improvement. Demonstrating soil health maintenance and improvements by farming practices that increase soil organic C will be important. A very important element of conservation tillage was the ability to sequester carbon by way of increasing soil organic matter. Carbon capture and sequestration measurements for soils needed to be improved and farmers required a rapid technique so they could verify the amount of C captured by their farming practices (and perhaps to capture loss of Carbon as well). There was a need expressed by several to conduct more work to have a better understanding of soil microbes and nutrient availability and on the impact of greater biodiversity on soil biology.

While farmers had not been recognized for their Carbon sequestration, many thought that this should be recognized to offset the impending increases in the Carbon levy. Regarded by some as a big opportunity, Carbon capture could be included as part of sustainability with farmers getting paid for their eco-system services. There was also the opportunity to see Carbon credits that might offset or partially offset the rapidly increasing Carbon levy. Consumers in the future will buy and choose products based on the perceived environmental impacts.

There was general consensus that fertilizer prices will continue to increase, and farmers will become increasingly vigilant to maximize their use of this expensive input. Precision agriculture will increase and variable management of all inputs in sections of a field were seen to be the wave of the future. Farmers recognized that variable rate fertilizer application was an available technology and offered considerable advantages in making more efficient use of fertilizer through the application of fertilizer to zones in the field based on predicted nutrient requirements. Soil fertility testing presently involves taking core soil samples and having them physically analyzed at a reputable laboratory. These soil test results are then used to map a field by several different methodologies. Several commented that the field mapping and nutrient prediction needed a lot more work for variable rate fertilizer application to work effectively. Variable fertilizer rates in combination with soil probes are being used to optimize fertilizer rates in a section of a field. Some respondents indicated that they had tried variable rate fertilizer technology but had not found it to be useful in its present form of development citing the costs of the technology in relation to the amounts of fertilizer used. Having field sensors beyond moisture probes that could assess soil fertility and pH and allow for accurate mapping of fertility would be a big step forward for precision agriculture, but this is not something that is likely to be available in the short term. The alternative has been to predict nutrient availability indirectly using yield monitor results and satellite imagery. Precision agriculture companies were looking at real time measurements of crop composition (e.g., %protein) on the combine and using this data to predict the nutrient requirements of different crops for the next cropping year. Several farmers suggested that more independent work needed to be done to establish the true ROI for adopting variable rate fertilizer application.

Many considered that there was a need to improve nutrient and water use efficiency. There has been less fertilizer research conducted in the last 10-15 years and as new varieties are developed the fertilizer recommendations have become outdated. More advancement is needed in predicting the nutrient requirements of crops. Fertilizer efficiency needs to be increased along with a much better understanding of effectiveness of stabilizers that control the breakdown of urea. Placement of fertilizer was mentioned by some as needing more work. Large farms may choose to broadcast fertilizer for efficiency reasons and demonstrating the likely poor nutrient efficiency and relative costs in comparison to precision placement of fertilizer was thought to be needed. Improving the placement and efficiency in the way that N was used on the farm was a very important need as much N was thought to be lost via gaseous losses as

NO_2 or leached from the soil into the waterways. Several mentioned the 4R plan without going into further detail.

Concerns were expressed that there has been nutrient drawdown on soils with high yielding crops. Replacing nutrients like Phosphate was specifically mentioned as it is a finite supply. Several mentioned an increasing concern over the future availability of phosphate as it was becoming scarce and mined in countries with unstable governments. Phosphate dynamics in the soil would give a better understanding of how much of this element was removed under different crops. New ways to extract P (such as from human effluent) may be required to reuse this core element in plant nutrition. More independent field scale trials were needed to study slow-release type nitrogen fertilizers, P dynamics in the soil and updated research with modern equipment in zero till situations on the basics such as safe rates of seed row fertilizers and not just N (also include P, K and S). Long-term verification sites are needed across all soil zones with a focus on P and micronutrients (prill coated) so that recommendations made to farmers are based on up-to-date research.

Seeding tools may need to be refined as there were many different soil openers with no adequate understanding of what works the best in different seeding conditions and row widths. The overall need for better seed and fertilizer placement were mentioned as needing further development as well as residue management tools that will be different for the different ecozones across the prairies. Chaff and straw distribution equipment required improvements so as to provide organic matter for the soil and not have crop residue impede seeding.

Farmers expected increased restrictions would be placed on fertilizer usage. Nutrient management will become increasingly regulated and become similar to those that currently exist for application of manure. Respondents also talked about prescriptions for crop inputs in the same way a livestock farmer would have to get an antibiotic prescription to access drugs for the control of livestock health. Synthetic fertilizers were often stated as a source of greenhouse gases (NO_2) and heavy rainfall following application could lead to increased flow of the fertilizer nutrients into waterways of the ecosystem. Farmers thought it highly likely that the broadcasting of fertilizer will come under increased scrutiny and could be banned through environmental legislation, especially if N fertilizer is broadcasted without stabilizers. One respondent thought that anhydrous ammonia could be phased out as a N fertilizer.

It was stated that Provinces have differing regulations concerning fertilizer application. Fertilizer could be applied on snow in Saskatchewan but not in the other Prairie Provinces. The situation concerning fertilizers is also becoming confused by those farmers pursuing regenerative agriculture where use of synthetic fertilizers is usually substituted with animal manures and this is advertised as being more environmentally friendly.

Other farm practices that were mentioned that could be more restricted in the future include the burning of stubble which is often practiced with flax straw and landscaping fields to improve drainage. Tile drainage was considered to be an important mitigation for soil salinity but moving water is subject to increased rules and regulation.

Crop Management

While many diverse opinions were proposed on the changes in crop acreages now and in the future, there was overall agreement that cereals and canola would remain the dominant crops on the prairies for the foreseeable future. Most supported pulse acreage remaining the same until some of the disease issues are addressed or showing a slight increase depending on how demand for plant protein develops in the next 5-10 years. The other major reason for pulses trending upwards is the benefit they bring of added N to the soil for subsequent crops. Fababeans are also regarded as a crop with potential for growth and as a pulse option to replace peas in areas where disease prevents profitable pea production but need concerted work on maturity to reduce length of growing season. After the major three crop types (wheat/canola/pulse) there are as many opinions about future crop growth as crop choices.

Barley has seen some resurgence for malting types with the expansion of craft breweries, but the general opinion was that this market has now plateaued. Oats are regarded as having some potential for growth for human consumption with new products (oat milk) driving some demand. Flax has some interest as an oilseed but has issues of weed control and straw management that make it a potential problematic choice for large farms. Although there may be more or less of these crops on individual farms the consensus was these crops acreages would be relatively stable.

There were some that see increased growing season or frost-free days will provide opportunities for warm season crops like corn and soybeans, but it was really the variation in weather and availability of moisture that impacted crop choices. Examples were given of producers who grew soybeans but then got a dry year and a poor crop and decided the risks were too high to continue with the crop.

Corn and soybeans have a future particularly in areas of the prairies where there is sufficient moisture during the growing season (both irrigated and natural moisture areas). Many thought that corn and soybeans would see increased acreages over the next 20 years. More emphasis on breeding would be required from the private sector over the next 10 years to have varieties that were adapted to the large variations in growing conditions across the prairies. An opposing thought was that corn and soybeans acreage will not change much as the costs and returns for these longer season crops are much greater than south of the border. The future expansion of irrigation in southern Alberta and Saskatchewan was thought to be an opportunity for more corn, soybeans and possibly fababeans. However, the overall impact would be more local to the areas of irrigation rather than to a huge change in overall prairie acreage of these crops. Specialty crops may see a slight increase with the irrigation investments in these two provinces. Any expansion in corn production could result in a renewed interest in the use of heavy tillage to address corn residue concerns. Corn producing areas in Manitoba tend to use conventional versus conservation tillage and this could result in more challenges for environmental sustainability

Fall seeded crops were also considered by some to have opportunities for growth particularly if moisture patterns trend to earlier in the spring. Large opportunities are seen for winter crops. Winter cereals (durum, wheat), winter peas and winter canola and camelina may see some growth in future years but need much greater investment as presently much of the work is in the public sector.

Niche crops like quinoa, hemp, sunflowers, canary seed, buckwheat, lupins, poppies and kernza were all mentioned as having some potential to expand in acres but the overall contribution in acreage would not be large even in the longer term.

There was a general concern expressed that while rotations need to be more diverse, profitability will be the main factor influencing crop choice. There was considerable diversity of opinion about crop rotation and the types of rotations that would be popular in the different growing regions of the prairies. Three-year rotations of a cereal, oilseed and pulse crop are common. Some suggested that large farms (>10,000 acres) needed simple rotations to function efficiently, but lots of concerns expressed about the potential to increase disease pressures such as clubroot in canola and Aphanomyces in peas and lentils. Some suggested that rotations needed to be much longer in the 7–8-year range with a greater diversity of crops grown. Some also suggested that the newer or niche crops such as quinoa, fababeans, hemp, canary seed may need to be tested in rotations. However, the opposing view was that some farmers would chase price and shorten up or abandon rotations due to large, short term financial pressures.

Other factors mentioned that affect crop choice included disease, weeds and weather and the ability to minimize the effects of these issues. There was a clear and consistent message provided by a large number of the groups interviewed that disease pressures would have important impacts on crop choice for farmers. Aphanomyces in peas and lentils and clubroot in canola were both recognized as huge issues for many farmers and the presence of these diseases would put a brake on any future acreage expansion. Herbicide resistant weeds were also considered by some to impact crop choice. Wild oats and Kochia were both mentioned as difficult to control weeds. Weather extremes were also considered to impact crop choice with examples provided of reduced acreage of peas following a wet season and soybeans following a dry season.

Intercropping and cover crops were mentioned by many respondents as a mechanism to reduce risk by having more than one crop to harvest in the same field. Farmers are experimenting with intercropping across the prairies, but there needs to be a better understanding of the crop combinations that work the best and the impacts on diseases, weed control, soil fertility and quality. Cover crops were also mentioned as a means to prevent bare soil being exposed to the elements without crop cover for a portion of the year and the positive effect on soil fertility and quality. While some suggested that cover crop acreage was trending upwards, there was no consensus on which cover crops were the best choice and their overall benefits in relation to their input costs. Roller crimpers have been used with some success so that seed beds were manageable in the spring. The equipment and methodology to manage cover crops needed more research.

Plant growth regulators and biologicals were being developed to provide alternative crop inputs. They have had many claims including improvement of crop yield and soil health and these needed to be independently verified for efficacy as often there were bold marketing claims that were not backed up with reliable research. Lots of different biological products are being marketed but farmers need to know which soils, crops and areas of the prairies in which they are cost effective.

Some respondents considered that more work needed to be done on cropping system and resulting crop quality with a focus on nutrient and micronutrient content. Others thought that much more accurate procedures were needed to be developed to assess grain grades and quality that would match the assessment at the elevator.

Societal Stresses (social, consumer, economic, policy)

Social

Prevailing opinion for the majority of respondents was that the current trend towards larger farms (> 10,000 acres) would continue, while small farms would tend to specialize, grow more diverse crops and get engaged in identity preserved and traceability endeavors with processors or local markets. Fewer but larger farms will result in less farmers farming more land and the possibility of more marginal land being farmed. Farm labour shortages will continue to be a challenge for many areas of the prairies. Several respondents considered that the trend to larger farms would impact rural areas through loss of infrastructure such as roads, hospitals and schools and farm services. Quality of life in the country away from large cities and towns would decline.

Two large and connected issues that face agriculture are the increasing price of land and the generational turnover as older farmers retire. The increasing price of land and equipment will make it very difficult for new entrants to get a start in farming. Some saw that the current price of land would drive more land rental for farming or more foreign ownership, and this could result in less attention paid to long term sustainable management and declines in soil quality. Access to capital will become more difficult for the generational turnover as the cost of digital agriculture becomes increasingly prohibitive to some.

There was a general feeling that the new generation coming to farming over the next 20 years would be much more comfortable with technology such as that provided by digital agriculture. In the meantime, farmers may need more training and support to help them better understand the possibilities and drawbacks of the digital agriculture age such as hackers gaining access to their farm data. Young farmers and new entrants to farming may be more adept at managing in the digital age than the retiring generation but may also be more susceptible to using inputs and practices that are not particularly effective or needed. Autonomous or automated farm equipment and the data collection tools (drones, weather stations, sensors) that will be common on the farm will need different skill sets for both maintenance and data management.

Communicating new technologies to farmers such as that offered by precision agriculture was also a problem and needed new approaches to be developed as the space was dominated by company brochures that often were in need of independent verification.

Migration of people from the city to surrounding rural areas was also regarded as a threat by some respondents. COVID has resulted not only in people working from the home but also led to a movement of people to more rural areas. The perceived threat is that the movement of people to the country will create increased pressure on environmental issues (pesticide usage), noise abatement and not being able to work fields after dusk.

Economic

Many considered with the increasing world population there would be a continued increase in the demand for food crops with emphasis on protein and oil. Protein crop processing has recently expanded in western Canada with plants that fractionate crops like yellow peas into protein concentrates and isolates that are then used for a variety of plant protein products including beverages, bars, cheezes and texturized meat analogues. Canola protein may also play a bigger role in the human protein market in the future as the majority of canola protein currently is processed into animal and fish feeds.

Market access was a concern expressed by many during these interviews that could impact crop production in the short term. Global market policies are incredibly unpredictable, yet we depend on the rest of the world to market our crops and food. The retaliatory loss of the canola seed market in China, the temporary loss of the durum market in Italy and restrictions on pulse markets to India were given as examples where producers were vulnerable to changes in export markets. These were issues out of a farmer's control but did impact on crop production decisions.

Many saw value-added processing as a big opportunity for crop production and would result in less reliance on commodity export markets. Opportunities to participate as part of a supply chain to major processors were growing and could result in higher returns, although more than one of the responders indicated that the increased record-keeping requirements for the farmer did not really cover the increased returns. There has also been growth in local farmers markets and on-line selling of farm produce where consumers have direct contact with the producer. For small farms these trends could give opportunities for more crop diversity, more processing with examples given of snacks (bars), cold pressed oils, beverages and packaged products.

Transportation was cited by several respondents as an on-going issue. The continued investment by governments in effective road and rail systems that allow movement of crops for further processing or export was considered essential for prairie crop production to be competitive in global markets. Huge government deficits may result in reduced spending on things like infrastructure and road maintenance. Competition with other commodities such as oil for space in rail transport was thought by some to increase over time with limited pipeline capacity.

Reducing fuel usage and adopting robotic practices to counter shortage of labour were cited as issues that would become more important over time. Fuel and fertilizer production could become more farm based. There is the potential to produce biodiesel on the farm. It may also be possible to produce ammonia in relatively small fuel cells that would be more cost effective than a nitrogen source from a manufacturer.

Consumer

The area of consumer trust in agricultural production practices particularly in the use of pesticides was frequently raised by respondents and the fact that many consumers relied on social media to find out information that was often biased or even pure misinformation (often termed “fake science”). Few people outside of farming understand the high level of science and technology that is used in the production of food that ensure its safety and quality.

There was also a general feeling that consumer pressure would result in quality and safety assurance requirements for producing crops increasing over time. As an example, traceability was mentioned frequently as something that farmers will need to adopt. Block chain was considered to be a useful technology to maintain accountability of farm practices through to delivery to the processor or elevator. Respondents mentioned traceability and the increasing power of processors and export markets in setting standards that would require more accountability at the farm level. Others suggested an increased acreage of crops that would be grown under contract to companies where the growing conditions would be dictated by a processor. Farmers will provide the elevator or processor a list of the production practices for each load of delivered grain and auditing of these practices by independent sources may also be a reality.

Consumers both in Canada and in our export markets will increasingly drive crop choices made by western Canadian farmers. Opinions varied on the future of livestock production and its impact on the acreage of traditional feed crops. Some saw increased livestock production meeting global increases in animal protein demand whereas others saw livestock production at a plateau or even on a downward trend due to increased environmental concerns. In Canada there are a growing number of flexitarians who choose a couple of weekly nonmeat meals and this trend, if it continues both domestically and globally, will fuel the demand for plant protein.

Consumer opinion was thought to be of increasing importance in driving the restrictions farmers would face in future years in access to and use of crop inputs and increased environmental regulation. Some thought that the Government may subsidize low input, low technology agriculture. Some suggested more organic or low input crop production would be demanded by consumers particularly for more local markets, but others suggested that organic production was at a plateau. An example given was that the Verdient Foods pea plant in Vanscoy, Saskatchewan was built to process only organic peas but as production ramped up nonorganic peas have become the main supply crop.

In summary, farming will become more regulated with less use of chemicals and energy from fossil fuels. Level of accountability on what goes on at the farm to consumers will substantially increase so they are assured their food supply is both safe, inexpensive and of high quality. Farmers will provide the elevator or processor a list of the production practices for each load of delivered grain and auditing of these practices by independent sources may also be a reality.

The right to farm and documenting good farming practices that are environmentally friendly for chemical usage and soil health will be an important opportunity to improve consumer understanding of farming practices. The Grain Farmers Voluntary Code of Practice that is under development to document sustainable practices and improve processor and consumer confidence was regarded by some as a big future change that would also be costly for the sector. Others suggested that the draft document in circulation was very prescriptive over fertilizer and pesticide usage and could have been written in a more positive manner. Many also saw this process as a forerunner to a producer license to operate along with approved plans for chemical and fertilizer inputs. However, others suggested that farmers not recognizing themselves as food producers and understanding that accountability and transparency to consumers are becoming much more important in food production was also a problem. There was varied opinion about who was driving the Code of Practice, but the majority were concerned with the uncertainty of what it means to farm practices.

Policy

Many regarded Governments as one of the biggest threats to the viability of farming on the prairies through increased regulation of farm practices. The Federal Government will be increasingly focused on increased environmental regulations for the use of pesticides and fertilizers and reducing the Carbon footprint of farming. Canadian Government policies such as the Carbon levy were also perceived to have a short-term impact on crop production as farms need a reliable supply of fuel and inputs to produce crops. Some respondents indicated that an increasing Carbon levy would put a lot of pressure on farmers to be more efficient with fuel usage and would make farmers look more carefully at input costs and consider lower input crops.

This threat is exacerbated if farmers are not recognized for the carbon they sequester. Some thought there would be a huge pushback on the future use of N fertilizers due to the release of NO_2 as a greenhouse gas and suggested that a broader range of N-fixing crops would be useful along with N sources that did not leach and had much lower volatile losses of N. Changing government priorities can also be a big threat with a switch towards environmental issues in government innovation programming and corresponding reduced research to improve production efficiencies.

Many respondents saw reduced government investment in crop research as a result of large deficits leading to a general decline in public research capacity in government and Universities with a general loss or reduction in independent public research. Unbiased research was regarded by many as being the most useful for farmers to make decisions on crop input choice and cropping system. Public plant breeding was considered to play an important role for improving disease resistance and yield in many crops and for looking at new traits (drought resistance; nutrient use efficiency) but there were concerns that public breeding may decline as the costs of the technology to support breeding increased. Others suggested that with out-of-control government deficits, producers needed to invest and take ownership in variety development as the public programs would come under considerable financial pressure in the next 5 years. The importance of agronomy research conducted independently was also considered to be important by many farmers for both large acreage and niche crops and would be essential to understand and get the best returns from soil and crop management and precision agriculture. Others saw reduced government investment in crop research leading to a general decline in research capacity with a general loss or reduction in independent public research. Unbiased research was regarded by many as being the most useful for farmers to make decisions on crop input choice and cropping system.

Many respondents placed a high value of public research conducted by Universities and Government research facilities and the research undertaken by farmer-driven applied research associations. There was a general feeling that declines in public research would lead to less independent research and reduce the availability of unbiased data for farmers. Respondents mentioned that farmers were very willing to co-invest in research. A few commented on the importance of having a prairie wide funding agency versus individual provincial funding agencies where the research funding models needed more integration.

Farmers expressed concern regarding the potential loss of pest surveillance networks and that there were no short-term solutions to counter significant diseases in canola (rapidly changing pathotypes in clubroot) and pulses (Anthanomyces in peas and lentils). Some respondents indicated a concern with the loss of crop scientists with field-based experience. In recent years the replacement of retiring scientists (Universities and Federal Government) has often been with those who have strong laboratory and molecular skills. This has resulted in a lack of field-based training of students.

It was also thought that governments would continue down the path of reducing extension services and resources and other groups like universities, colleges and applied research organizations may need additional support to get important information to farmers. Some saw a much greater role for organizations like WGRF to get more involved in knowledge transfer.

Section 5 – Analysis of what was heard and the Research Implications.

Every spring one of the largest economic engines in Canada springs into action to seed crops that spinoff into 2.1M jobs and 6.7 percent of our GDP. It was very clear from our interviews that the agricultural industry is made up of smart, intelligent people from farmers, scientists and industry. Our sample size was low but still represented organic producers and food processors, but this did not detract from the overall trends that emerged from the issues presented.

After 60 interviews, 187 respondents talking about 5 questions summarized in Section 3 and reorganized as themes (Section 4) it became quite clear that the profession of farming is becoming much more complex. Big data, biotechnology, increased efficiency, crop and soil management, and climate change all have research implications at the farm level. Consumer confidence, government policy and the demographics of future farms and farmers were all identified as issues that may or may not have research implications but definitely required some sort of response. Awareness was high for the consumers need and expectation of more transparent food production processes. Rising temperatures create opportunities for new crops, while water stress and higher energy and production costs will drive innovative solutions. Future farms demand better soil, more advanced crop protection solutions and higher energy efficiency to provide all people with high quality foods (The Future Farm – BASF https://www.basf.com/cn/en/media/BASF-Information/Food-nutrition/The-future-farm.html). There were three key areas that emerged from the interviews - Crop and Soil Management, Sustainability and Precision Farming.

Crop and Soil Management

Crop choice was discussed throughout the questions but mainly because it was a direct question (Q2). Crop and soil management was also discussed in the area of biotic stress, abiotic stress, biotechnology, sustainability, and social issues, particularly economics, consumers and policy. The growing of crops from crop choice to protecting them from biotic and abiotic threats was evident throughout all the calls.

It was clear that everyone indicated profitability determined crop choice. Based on what we heard, canola and wheat will remain the dominant large acreage crops on the prairies for the foreseeable future (Section 4 – Crop Production). Pulse crops like pea and lentil will probably show some increases in acreage with the increasing demand for plant protein and the positive effect of pulses in adding soil N. However, the two new processing plants (Roquette and Merit Functional Foods) will likely process less than 250,000 tonnes of peas and other crops for protein extraction when at full capacity and this volume would not represent a big shift in acreage. The Merit Functional Foods Plant is planning to process both peas and canola into protein isolates.

The warm season crops like corn and soybeans were cited by many as crops that could show expansions in acreage, but considerable advancements would still be needed in varieties that perform well under shorter and cooler growing seasons than found in the US for this to happen.

Respondents often cited “corn and soybeans” together without differentiation to their potential areas of adaptation. While both crops may profit from agronomic research for continued development of best practices or best areas of adaptation, it may be longer term before any large change in acreage of both these crops becomes viable. Any expansion in corn acreage would likely be associated with much heavier tillage without further work on the management of corn residues under conservation tillage.

Winter crops require more research attention particularly if the current trend in some regions of the prairies for early spring moisture continues. The winter wheat acreage planted in western Canada tends to be less than a million acres and varies on a year-by-year basis. Winter durum, winter peas and winter canola/camelina were crops that were considered to have opportunities for growth but would need significant genetic improvements and agronomic research to reduce risks of crop failure.

Other crops covered in Section 4 – Crop Production have significance in research implications. Barley, oat and flax may see some acreage changes up or down but overall, these crops will not play an increasing role in Western Canada Crop Production. Fababeans were often mentioned as a crop that could replace pea and lentil where root rot was a problem. However, fababean needed development of best management practices and shorter season varieties. Niche crops like quinoa, hemp, sunflowers, canary seed, lupins, kernza, forages and poppies were all mentioned as needing agronomic work but the prospects for acreage increases are quite modest.

There was considerable diversity of opinion about crop rotation and the types of rotations that would be popular in the different growing regions of the prairies. A general feeling was that large farms would simplify, and small farms would diversify. The three crop (cereal, canola, pulse) rotation was widely practiced. Farmers needed more information on different crops that could extend these rotations and reduce some of the present disease pressures. Farmers did not extend their responses to the type of information in general but implied general agronomy for specific crops. It seems that any crop choice beyond the big three will be niche crops without further research in this area.

Intercropping and choice of the intercrops that work best together was also an area that needed agronomic work. Cover crops were frequently mentioned as viable options for farmers, particularly in organic farming systems and any move towards Regenerative Agriculture. There is limited knowledge on cover crops in current systems and the benefits they provide in sustainability.

Government regulation would increasingly creep into farmers management decisions. Farmers expected increased restrictions would be placed on fertilizer usage, mainly based on what is happening in the EU. There was a strong need for farmers to improve nutrient and water use efficiencies and more focus placed on independent studies to update fertilizer recommendations that have become outdated. Crops have more nutrient uptake from soils because of higher yields through genetic selection, better agronomy or climate. Improving the placement of fertilizer and a comparison of the costs of broadcasting vs precision placement was thought to be an important need and for the N losses in both systems to be quantified. There are a lot of studies completed on 4R fertilizer practices so it would be useful to identify the problem and target the anticipated areas that are perceived to be soon restricted.

There was also discussion about having a better understanding of phosphorus dynamics in the soil and how much of this element was removed under different crops. Overall, we heard that more independent field scale trials were needed to study slow-release type nitrogen fertilizers, P dynamics in the soil and updated research with modern equipment in zero till situations on the basics such as safe rates of seed row fertilizers and not just N (also include P, K and S). Long-term verification sites are needed across all soil zones with a focus on P and micronutrients (prill coated) so that recommendations made to farmers are based on up-to-date research.

The overall need for better seed and fertilizer placement were mentioned as needing further development as well as residue management tools that will be different for the different ecozones across the prairies. Chaff and straw distribution equipment required improvements so as to provide organic matter for the soil and not have crop residue impede seeding or effect efficiency of fertilizer application. Seeding and harvesting systems have a direct impact on sustainability.

Biotic stresses were covered in Section 4 but worth repeating here because of the research implications for disease, insects and weeds on crop management. Respondents were most concerned about the continuing evolution of new pathotypes of clubroot and blackleg in canola. Cereals will continue to be challenged with fusarium head blight and other leaf diseases, yet progress is being made, albeit very slow. There are several available varieties with a moderately resistant designation. The growing number of pea and lentil acres that were infected with root rot (Aphanomyces) was the cause for many respondents to indicate pulse acres would stay the same or decline, despite the increased interest in plant-based protein or the increasing number of protein processing facilities.

Pathologists suggest that land infected with Aphanomyces may need to be kept free of peas and lentils for 7-8 years. With a growing potential demand for plant protein, control measures for Aphanomyces would seem to be an important area of ongoing and future research. This might include switching to pulses like fababean, that are resistant to Aphanomyces, but have lacked the research investment in both variety development, agronomic management and quality characteristics important for protein processing.

The continued investment to confer plant resistance to diseases that can cause considerable economic loss in cereals, oilseeds and pulses was considered to be essential. Much of this work is conducted in the public sector. The identification and introgression of resistant genes into commercial varieties is a long-term endeavor, often taking more than 10 years. The most often cited diseases were Aphanomyces in peas, Clubroot in canola and Fusarium Head Blight in wheat. Other diseases were mentioned when they were a problem on some farms. It is interesting that cereal rusts were hardly mentioned. This is probably because the breeding community has continuously stayed ahead of the disease since the rust outbreaks of 80-100 years ago. There are stacked genes to combat multiple races and yearly investment is large. These investments are justified to stay ahead of new rust races like UG99 and breakdown of resistance.

Nervousness over the regulation of pest products and the weed resistance issues appearing in prairie crop production evoked a lot of discussion during the calls, particularly when discussing biotic stress, available technology and what was needed. Herbicides were most often mentioned regarding reduced pesticide use but fungicides and insecticides were of equal concern. Pre-harvest glyphosate and neonicotinoids were mentioned in every call and increased regulation expected based on the increasing restrictions coming from the EU. Wild oat resistant to Group 1 and 2 herbicides and kochia resistance to glyphosate continue to be weeds that were difficult to control and mentioned by many respondents as needing new control measures to be developed. Climate change is having an impact on new invasive weeds, survivability of pests overwintering and the expected changes to the pest dynamics in crop production. There was a concern about the single gene, SM1, that controls wheat midge and rightfully so. The search for other genes that could confer resistance to wheat midge has been difficult.

Alternatives to pesticides were discussed often. Management practices available for the cultural control of weeds include increased seeding rates, more tillage, intercropping, cover crops, weed clipping and more diverse cropping as part of an integrated weed management approach. Seed destructor technology (Harrington Seed Destructor) was mentioned by many as an emerging method for weed control but there were divergent opinions on the effectiveness of this control method, how it fits into a weed management plan and the ongoing need for independent study. Management practices available for disease control include rotating varieties or species with different resistant genes, growing more than one variety in the same field with different genetic resistance or longer rotations which is not always possible in the crops grown. In the last 20 years there has been a higher awareness of the use of beneficial insects to manage insect problems. However, this area of research is a long way from being mature. Alternative pest products were also frequently mentioned to replace what may be lost in the near future. These are discussed further down when discussing biotechnology.

Surveillance is the key to understanding current and emerging threats. Farmers rely on all sorts of maps developed from surveys whether these are weed, disease or insect maps. The resources to produce these maps have generally come from government, federally and provincially. Crop scouting by walking fields has always been recommended so that farmers can quickly recognize and respond to biotic challenges in the field. It is clear that these government resources are gradually eroding. The surveillance work in the Wheat Cluster and perhaps other Clusters was rejected by AAFC Programs Branch as not being innovative. Reliable, newer approaches to surveillance/crop scouting are badly needed, networks developed, and collaboration of all stakeholders required. In the past few years @AgBugChat was created on Twitter where farmers could send in pictures of insects they were seeing on their farm for identification and problem-solving. In a sense this is an effective forecasting system despite how primitive it is. Farmers were very receptive. The use of drones to complete some of these tasks to identify weeds, disease and insects has potential but it is extremely undeveloped. Even with drones more work will need to be done on ground truthing these techniques to ensure the data is reliable. Other tools that could be important in the ongoing fight against biotic pressures include rapid tests to identify pathogen race, weed resistance to herbicides and a quicker turnaround for pest and disease risk assessment.

It is well known that agriculture production and productivity are vulnerable to abiotic stresses with losses as high as 50% of agriculture production and likely more in any given year on an individual farm. These stresses emerge due to drought, temperature extremes, radiation, or excess moisture. Edaphic factors like nutrient deficiencies, salinity, soil pH, low water-holding capacity, impeded drainage, low structural stability and/or root-restricting layer also create abiotic stress in plants. (Minhas, P. & Rane, Jagadish & Pasala, Ratnakumar. (2017). Abiotic Stresses in Agriculture: An Overview. 10.1007/978-981-10-5744-1_1.)

Abiotic stresses were infrequently mentioned during the interviews, yet it was always present. Respondents identified weather forecasting as the greatest need. Weather stations on farms have become quite common and provide important information on local temperature, moisture, wind speed and humidity. Better weather forecasting would allow farmers to make more effective decisions on time of spraying and fertilizer applications. Longer term more accurate weather forecasting would aid greatly in crop choice, variety selection and management practices to ensure the best producer returns. The main variable of interest would be the prediction of moisture during the growing season.

Climate change was recognized through responses that supported longer growing seasons in all areas of western Canada and the prospects of more crop diversity north of highway 1. The potential to double crop was recognized as an opportunity where a winter crop could be harvested in early July and a forage cover crop at end of season. However, significant knowledge gaps remain about the impacts of climate change. Some mentioned that extreme weather events such as excess rain falling in a short period has resulted in erosion in land that was zero tilled for twenty years and the need for more work on under seeding or in season seeding to provide a cover crop that prevents soil being exposed to the elements.

Changes in temperature, moisture levels and concentrations of atmospheric gases can stimulate the growth and generation rates of plants, fungi and insects, altering the interactions between pests, their natural enemies and their hosts. In part, climate change is also responsible for the upsurge in transboundary plant pests and diseases. It is modifying the dynamics of pest populations and creating new ecological niches for the emergence or re-emergence and spread of pests and diseases. The effects of climate change could be felt in a number of ways, such an increase in the frequency of outbreaks, the expansion of pests into new environments, the evolution of new pest strains and types, and increases in the vulnerability of plant defense mechanisms (FAO. 2017. The future of food and agriculture – Trends and challenges. Rome).

To mitigate the effects/impact of multiple abiotic stressors, proposed strategies include improved agronomic management, while the breeding of stress tolerant genotypes can enhance capacity for adaptation to stress environments. However, a holistic integrated multidisciplinary approach in a systems perspective is the need of the hour to get the best combination of technologies for a particular agroecosystem. Future research needs to pay closer attention, for example, to the impact of yield variability on the quantity and quality of food production.

Biotechnology in the form of genetic resistance or new pest management products as discussed earlier were often mentioned as cures for the future regulation of pest products. Biotechnology appeared in the comments in all five questions and was a key theme mainly focused on breeding as well as a solution to alternate control methods of pest issues. FAO has described agricultural biotechnology as 'any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use' that can make a significant contribution to productive and sustainable agriculture.

With more challenging growing conditions expected in the future, the role of research and innovation will become of even greater importance to keep prairie agriculture productive, sustainable and competitive in global markets. Advancing the performance of crop varieties through increased yield, disease and insect resistance or end product quality will make an important contribution to farm profitability. The new advances in breeding techniques such as gene editing, often referred to as CRISPR, need to be exploited and fully incorporated into research programs. Gene editing allows for a planned mutation (or mutations) in a plant's genetic material for accelerated improvement and rapid expression of important economic traits. CIBUS in the US has already released a gene edited non-transgenic sulfonylurea herbicide tolerant canola (Falco™ Canola). China has more than 20 groups of researchers working on a wide range of crops and using gene editing to introduce new and improved traits although no gene edited varieties have yet been released.

In the short-term, gene editing should be a research focus for introducing traits that are difficult to improve by conventional breeding. Examples include resistance to drought or very wet conditions and protection against diseases and insects. Based on survey responses gene editing would help lessen the days to harvest in pulses like pea and fababean or improve genetic resistance to diseases like Aphanomyces in pea or fusarium head blight in wheat. Longer term there could be a concerted effort to look at the potential to add N-fixing capability to a range of crops. Agriculture and Agri-Food Canada Lethbridge has patented a method of mitochondrial N-fixation in triticale and wheat and potentially in canola with promising early results. Gene editing could also be of considerable value in the production of varieties adapted for organic or low input regenerative cropping systems as the resulting product would likely be non-GMO.

Hybrid wheat has been relatively successful in Europe but still in the research phase in North America. Hybrids have generally been found to be more resistant to abiotic stressors than conventionally bred varieties. Although respondents thought hybrid wheat would be useful as a crop choice there are very few companies developing hybrid wheat. Since it not being developed in the public domain little is known about the progress toward a Canadian quality wheat. While hybrids are the norm for crops like canola, the commercial introduction for cereals will have significant challenges.

RNA interference (RNAi) has been successfully commercialized in Canada with the release of the non-browning apple (Artic Apple). Genetically modified crops expressing double stranded DNA, or dsRNA, have also been developed with great potential to control insects. For example, Bayer has recently received import approval from China for their SmartStax PRO technology corn. In the next few years, Chinese farmers will be offered this third-generation corn rootworm trait that offers three modes of action for nematode control that includes the Bt trait and an RNAi-based mode of action.

Sprayable RNAi based products can also be used for suppressing pests on seeds and foliage and both approaches appear to offer potential alternatives to conventional chemical-based pesticides. The AAFC Saskatoon lab facility is making some progress in RNAi studies to control a number of diseases in wheat and canola. The area of RNAi based approaches for control or identification of insects, diseases and weeds is an area that will require considerable research investment.

It is clear that the crop production in the future will be under more pressure to be more efficient, reduce the use of major inputs, notably fertilizer and pesticides, and show that the farm is sustainable. There were strong widespread opinions that more and more pesticides and fertilizers will be regulated by consumer demand and less pesticides are being developed with different modes of action. The desire to reduce pesticide use, the development of weed resistance and the relatively ineffectiveness of cultural controls in a world supporting 9B people calls for the development of new biotechnology products like RNAi to mitigate the annual threats of biological systems.

Nanotechnology also offers opportunities for innovation in agriculture which was mainly absent from the conversations. Nanotechnology applications include both nanoformulations of pesticides and fertilizers for crop improvement and nanosensors for the identification of diseases and residues of agrochemicals. (Applications of Nanotechnology in Agriculture by Alaa Y. Ghidan and Tawfiq M. Al AntarySubmitted: May 8th 2019 Reviewed: July 4th 2019 Published: September 9th 2019 DOI: 10.5772/intechopen.88390). The Nanotechnology Research Centre is a National Research Council Institute located on the campus of the University of Alberta and has focused its research in nanobiology, nanoelectronics and next generation microscopy. However, despite the numerous potential advantages of nanotechnology, agricultural applications have not yet made it to the market, likely because agriculture does not demonstrate a sufficient economic return to counter the high initial costs of investment.

The debate about GMOs has been underway since the beginning of the century. This debate revolves around their potential impacts on food security, the environment, biodiversity, human and animal health, and control of the global food system. The respondents of the survey repeatedly wondered if these newer biotechnology advances would be accepted by the public. The European Court of Justice declared gene edited crops as being GMOs in July 2018 but more recently a UK team have suggested that the ruling may not be as prescriptive as it seems as a large field of use would be to use CRISPR to give useful mutations that could happen in nature and not defined legally as a GMO (John Innes Centre, A CRISPR picture emerges on European Union GMO directive. News Release Jan 6, 2021).

Genetics were often cited as a means to increase efficiency or reduce inputs. Fertilizer use efficiency, disease and insect resistance and resistance to abiotic stresses were factors that are available today and was anticipated that they will always be available. New technologies to address these issues are critical to advances in sustainable agriculture. There are few who link the agronomy of growing a crop with these genetic traits, yet it is critical that agronomy build durability into the genes that provide so may services.

Sustainability

Sustainable agriculture at the farm level is defined by three interactive components: economic profitability, environmental stewardship and social responsibility. Consumers are increasingly concerned about the way their food is grown and processed and sustainability has become an increasingly important element of corporate social responsibility. Companies like Cargill have its sustainable canola program and General Mills has indicated it will advance regenerative agriculture on a million acres (Country Guide, Regenerative Agriculture Hits the Mainstream, July 4, 2019)

Modern farming practices have changed the game in terms of environmental impact. Over the last 30 years, the adoption of direct seeding, reduction in frequency of summer fallow and use of less intensive soil cultivation equipment has seen significant movement towards land management practices that have positively influenced soil quality and profitability. It was obvious that the two main farming systems were direct seeding/no-till and organic production. Farmers were concerned that the amount of tillage could potentially increase in the future for various reasons. These could include loss of access to certain herbicides, wet seeding conditions, weed management, straw management or nutrient stratification. It would be important to review potential problem areas in conservation tillage as more tillage will lead to greater soil erosion and declines in soil organic matter over time.

In the 1980’s governments focused on conservation following Senator Herb Sparrow’s book ‘Soil at Risk’. Scientists, R&D managers and policy people all converged on the problem. R&D managers hired agronomists, soil scientists, weed scientist’s, etc. to work on Conservation/no-till cropping systems. Research was mostly funded internally by governments. Producer funding was sometime in the future. The scientific capacity hired in the 1980’s to focus on conservation tillage have basically all retired. Replacements have been lab-oriented scientists, climate scientists and policy makers. The new mantra is the ‘low carbon economy’ with new challenges, new ideology and new solutions around the corner. Today, the integration of a cropping system seems to be lost, agriculture researchers are committed to a topic area, partly because their internal funding has been replaced by producer funding. Cropping system research can support the farmer and the new methods of farming on the horizon in this new economy if the current R&D managers and researchers could be integrated to focus on a problem. Understanding the relationship of biotic and abiotic stresses in a cropping system is much more valuable to a farmer than understanding the biotic stress alone. A sustainability focus would rise to the top compared to how to control that one weed.

Regenerative agriculture has received a lot of popular press coverage in recent years and has become the darling of many policymakers, food companies and some farmers. For example, Elizabeth Royte (National Geographic Published February 5, 2021.These widely used insecticides may be a threat to mammals too) wrote about Jonathan Lundgren, Blue Dasher Farm, Estelline, South Dakota. He discussed the damaging effects of insecticides in current agriculture systems. Regenerative agriculture restores “degraded land to a natural healthy uncontaminated state – tilling less, planting cover crops and promoting beneficial insects and more diverse crop rotations”, thus, reducing the need for synthetic insecticides.

The practice has no universal definition but generally is thought to include zero or minimum tillage, the use of cover crops, much more diverse rotations and also rotating crops with livestock grazing for mixed crop/livestock operations. Many of our conservation systems practice in whole or in part the ideology of regenerative agriculture. Organic producers have been practicing many aspects of regenerative farming through use of composting, green manures, diverse rotations, shallow cultivation and increased biodiversity. Low input agriculture is also often linked with regenerative agriculture where there is a focus on reducing purchased crop inputs like nutrients and pesticides. Research implications suggest that regenerative agriculture needs more work on definitions and the overall system impacts both on soil quality and profitability.

The Carbon levy was referenced repeatedly (Section 4, Policy) and was considered a major threat. In response a national coalition of industry-wide farm organizations have launched the Agriculture Carbon Alliance (ACA) (Real Agriculture, March 1, 2021). The ACA was established to ensure that Canadian farmers’ sustainable practices are recognized through a policy environment that maintains their competitiveness, supports their livelihoods, and leverages their critical role as stewards of the land. Many farmers voiced widespread concerns about the costs of the federal government’s climate policies and the lack of recognition of agricultural practices that reduce greenhouse gas emissions. Carbon capture could be included as part of sustainability and the government’s climate change strategy. Farmers wanted to be paid for their eco-system services. Environment and Climate Change Canada (ECCC) is drafting regulations to sell federal greenhouse gas emission credits to offset industrial Carbon levyes that have been started in the past four years and go “beyond business-as-usual practices” under proposed regulations unveiled by Ottawa. Canadian farmers are concerned because the draft regulations mean the sector won’t be rewarded for responsible practices they’ve been adopting for decades, said Drew Spoelstra, a grain and dairy farmer who is also a vice-president with the Ontario Federation of Agriculture (The Canadian Press, March 5, 2021).

Demonstrating soil health maintenance and improvements by farming practices that increase soil organic C are important. A SaskCanola press release January 7, 2021 described the Prairie Soil Carbon Balance Project (PSCBP) findings where soil carbon is increasing (reducing GHG levels). Saskatchewan growers using minimum- or zero-till (direct seeding) are sequestering 8.75 million new tons of CO2 every year on more than 23 million acres of farmland. This is the equivalent of taking 1.83 million cars off the road. Farmers need a rapid low-cost way of demonstrating changes in soil organic matter and Carbon.

An area that needs more independent study is the use of biologicals that are claimed to improve soil health and also increase crop yields. There are a number of these products emerging in the marketplace with various claims that often lack rigorous scientific verification. Farmers need to know the responses to these biological additives across the different soil types, crops and regions of the prairies.

The Grain Code of Practice, an initiative of the Canadian Roundtable for Sustainable Crop, is a way to showcase Canada's current farming practices. Many respondents were concerned about this initiative, whereas a few thought it would be an opportunity to address consumer concerns. The concerns likely stem from the lack of information at this time and will likely dissipate as the Code of Practice is further explained. The intention is to change the narrative around food production and the sustainable practices already happening in Canada. Documentation such as the SaskCanola press release will contribute to the narrative. Research implications will become obvious as the Code of Practice becomes clearer, and the metrics required to change the narrative are enhanced.

Precision Agriculture

There are many articles written on the future of farming and predictions on how agriculture will feed a growing urbanized population. The farm of the future will have more advanced crop protection tools, advanced breeding techniques, high tech machinery performing routine tasks like seeding and harvesting and precision farming. Like advancements in smart homes the rural landscape will be powered by sensors, analytics and early detection of problems. The RBC Farmer 4.0 report found the emergence of advanced technologies on the farm will change the skills needed in the coming decades. Farmers will shift further away from manual labour and more toward managing technologically complex operations, providing technical support and other highly skilled tasks (https://www.rbcroyalbank.com/business/advice/industry-expertise/agriculture/_assets-custom/pdf/Farmer4_aug2019.pdf). What we heard in the interviews was that this scenario was moving further away from fiction. The farm of the future is beyond 'business-as-usual'.

Farm tractors will be fully autonomous and widely available in the not-too-distant future. It is an extension of the GPS dependent autosteer technology, where the operator will be eliminated. The proprietary DOT/Raven Technology of a single platform that can be remotely controlled and can conduct a range of crop activities is a good example. Brian Tischler, a grain farmer from

Mannville, AB, has developed the self-driving application as open-source-software, a knowledge sharing concept. Farmers will adopt autonomous equipment, with the rate of uptake depending on whether it makes sense for their operation and the safety issues that come with driverless vehicles, whether it be a car, truck or tractor. The consensus was that autonomous self-driving equipment would become common on the farm. The opinions varied on whether it would be on big equipment or several smaller units to manage operations like seeding. It would be expected that the costs for autonomous equipment would be easier to justify on large rather than small farms although manufacturers will likely offer different sizes of autonomous equipment to better fit farm requirements. Although the development of autonomous equipment has few research implications itself there could be research implications if seeding equipment changes. The basic questions on optimum crop establishment, seeding through stubble, soil water content would need to be reset.

The emergence of precision agriculture as a technology, that has the potential to disrupt and change the way farm practices are conducted, was evident from our analysis of the survey responses. Precision agriculture would include automation of farm equipment, optimizing equipment use, variable rate seeding, fertilizer application, spraying and yield monitoring during harvesting. The digital agriculture revolution that is occurring opens the door for farmers to get more efficient usage of farm inputs through a precision farming system.

Variable rate nutrient application (VRNA) will become a much more widely used practice as prices of fertilizers are expected to increase in future years. Large amounts of energy are used to produce N fertilizer and Federal climate change policies will almost certainly increase regulation on fertilizer usage along with the increasing Carbon levy. Companies or consultants provide VRNA services that are often based on soil management zones within a field that have different nutrient requirements to achieve maximum economic yield. There are many companies offering simplified precision farming systems where they soil sample, develop zone maps and provide the software to apply variable rate fertilizer.

The nutrient requirements of the soil management zone could be based on soil sampling (nutrients or soil characteristics), combine yields in a previous year or predictions based on vegetation growth from satellite imagery (Normalized Difference Vegetation Index, NVDI). However, field characteristics vary enormously across the prairies with different soil types, moisture, slopes, salinity, drainage and probably many more variables that ultimately impact crop yields. Creating soil management zones and predicting nutrient needs to give best returns is a complex undertaking. The majority of this work has been done by the private sector. We heard from some farmers who considered that the accuracy of nutrient maps for soil management zones needed more independent assessment along with an evaluation of the cost effectiveness of VRNA.

With increased environmental concerns on the use of pesticides, variable rate spraying has the potential to significantly reduce pesticide usage, a need consistently identified throughout the 60 interviews. Targeted spraying for weeds, diseases and insects will likely be the future direction for prairie agriculture in order to target weeds that reduce chemical applications to crops and land. There is a lot of work ongoing at present to develop effective systems that can identify weeds in crop and then spot spray using a field sprayer or a drone. Application of this technology, where a nozzle on the spray boom turns on a spot spray for each weed or vegetation detected, has been available for some time. For example, the Weed-it system in Australia. On March 2, 2021 John Deere announced its See and Spray Select which uses computer vision and machine learning to precisely spray herbicides only where weeds are present. Spot-spraying is only currently available for non-crop management, either pre-seeding or post-harvest but it is felt it won't be long before technology is available for in-crop spraying. These spray systems are generating a lot of excitement in the farm community but will require independent ground truthing to confirm the utility and effectiveness of these technologies. It will be of value to farmers to fully understand the effectiveness of spot spraying of weeds in growing crops and the overall cost effectiveness of this technology. It is a tool, when available, to address increased efficiencies and reduced pesticide usage, a key point in what we heard.

A technology that was rarely mentioned but has been available for quite some time is variable rate seeding (VRS). Variable rate seeding is a technology that has been used to produce a planned number of plants per square foot and it has also been suggested that higher seeding rates can provide a cultural practice that can help control weeds. Research implications abound with VRS, particularly when integrated with zone maps, in a precision farming system. The cost of seed, slope position in the field overlayed with weed mapping are applications underdeveloped and likely creeping into digital agriculture service providers options. An example of VRS when overlayed with a weed map would be to increase the seeding rate in a weed patch to provide some cultural control. Simple, right! Not so fast. How much to you boost the rate to obtain the cultural control and is it the same for all weeds? Farmers will need a clear idea of what the ROI of this investment will be when offered.

Effective implementation of precision agriculture will result in the integration of large amounts of data from multiple sources that is analyzed, and the resulting recommendations provided to the user in a form that is readily understood. The backbone of precision agriculture will be the sensors that collect and transmit the data to a central processing area. Modern farm equipment can transmit a wide variety of information such as the machine health indicators, hours and fuel used, machine location, diagnostic codes, machine attachments and this is all collected by the manufacturer. Weather stations have sensors that record temperature, humidity, rainfall, wind speed and are being increasingly installed on farms with the data supporting crop management including predictions of crop yield. Soil moisture, pH and temperature sensors could determine optimum levels for crop growth and be integrated with irrigation schedules. Satellite or drone imagery may be able to detect crop growth, outbreaks of disease or insects and be useful for developing nutrient maps. The level of data collection that is possible on the farm will continue to increase and companies will develop and refine applications to allow better on-the-go crop management decisions. While data and its management will aid farm management, there are no perfect relationships that precisely link back to crop yields and profitability. At the present time the accuracy of these integrated techniques to predict crop nutrient requirements, the most effective variable rate applications of pesticides and nutrients, early recognition of disease and insect outbreaks, selecting the best variety and maximizing profitable crop yields and crop quality are not well understood, nor integrated, and will need much more independent study.

Without a doubt, the discussion around autonomous equipment, precision farming and variable rate everything is heading in the direction of farming in real time where all data collection devices are connected wirelessly or through a USB stick. The tools themselves will be developed by large and small companies or farmer ingenuity, but the recipes, dose, or treatment provided will need rigor in science-based solutions.

The right to service farm equipment has also become an important issue. Equipment manufacturers maintain that farmers have no rights to access copyrighted software that controls every facet of today's equipment and even to the repair of their own machines. The proprietary software enables sensors and computers on machines to log and transmit data on everything: moisture and nitrogen levels in soil; the exact placement of seeds, fertilizer, and pesticides; and, ultimately, the size of the harvest. Having access to so much real-time data enables farmers and their computer-controlled machines to plant, spray, fertilize, and harvest at optimal times with as little waste as possible. Farmers indicated in the survey that they were concerned about privacy and security. The sharing of data collected by companies with farm input suppliers was an issue as it weakened their position to negotiate on prices of farm inputs and security could be a big issue if a hacker shut down all company equipment. A debate on who owns the data is brewing. A data strategy for the agri-food sector in Canada is clearly needed to securely collect agronomic and economic data from farmers and food processors that foster system-wide transparency and traceability, all through partnerships with analytical platform providers.

Like farming, research management and investment will not be, 'business as usual'. This includes the funding of science. Respondents were concerned about government cutbacks and the health of the science community. New thinking is required to meet these challenges. Some specific examples will follow where WGRF could easily lead.

One issue that has importance for funding agencies in the future concerns the declining support for knowledge and technology transfer provided by Provincial Governments. Extensive networks of specialists have all but disappeared and universities, colleges and applied research organizations may need more support to get important information to farmers. The changing demographics with the younger generation being much more comfortable with digital information and social media suggest that the time may be ripe to look at the effectiveness of knowledge transfer and what tools would be the most appropriate to transfer the results of farmer supported studies. Surveillance, crop scouting and emerging threats were often cited as a concern it would not be available in the future or at least much reduced.

A **farmer science portal** could be developed where farmers themselves provide data (eg #agBugChat) which could be integrated with the advances in drone scouting and sensors in the field. This type of effort will be needed to accompany the 'boots on the ground' surveying for insects, diseases or weeds during the growing season. A science portal is not without precedent. A good example is the Agroclimate Impact Reporter, Agriculture and Agri-food

Canada. Many farmers are reporting their weather on the farm. Maps are developed for all across the country showing drought, excess moisture and other factors that affect farmers. The sharing of data could be a very powerful tool in the farmers hand and provide an alternate approach to scouting and surveillance. Farmers helping farmers.

A few respondents to the survey wanted to see a more coordinated research funding effort, even a Prairie-wide model. However, it is not always well understood that projects submitted for producer funding are reviewed, shared and often co-funded by other producer groups not always in the same Province or other funding partners. In most cases it is more informal where producer groups make their individual decisions and passively wait to see who else will co-fund. A **Producer Research Coordinating Committee** (PRCC) would formalize the integration of research projects among producer groups for the prairies and bring together different crop commodities. The membership of the new Coordinating Board would/could/should include the agency heads or reps and external experts of all prairie producer research groups. The Coordinating Board would determine and implement avenues for harmonization, collaboration, and coordination of programs, peer review procedures, and administration and address issues of common concern. A well-run PRCC would likely maximize the ability of researchers across disciplines to carry out world-leading research.

Agriculture is not short of challenges as expressed by the enthusiastic responses in the interviews. Sustainability, loss of products, reduced usage of inputs, crops, reducing the carbon footprint, cropping systems, and many more topics will need to be discussed with a wide range of expertise to drill down to solutions. Farmers everyday are solving an increasingly complex puzzle. Farming today is more like chess, less like checkers.