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Final Report

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Evaluation of Drought and Excessive Moisture Preparedness Programming

Saskatchewan Watershed Authority

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I. Executive Summary

The goal of this project was to provide an evaluation of current agri-environmental programming in Saskatchewan in terms of the capacity to encourage adaptive measures for future extreme climate events, namely drought and flood. In order to effectively evaluate current programs, interviews with key program personnel were conducted relating to the development and delivery of the programs. An extensive literature review was also performed to determine successful and scientifically verifiable agricultural adaptation strategies to limit the negative effects of extreme weather events. Drawing from the interviews and the literature review, an evaluation of the programs and relevant beneficial management practices (BMPs) was developed. In addition to these external sources of information, the researchers also drew from their personal experience in working with agricultural producers and agri-environmental programming in Saskatchewan.

The programs that were evaluated were the Canada-Saskatchewan Farm Stewardship Program (CSFSP), the Farm and Ranch Water Stewardship Program (FRWIP), the Agri-Environmental Group Planning (AEGP) Program, and the Environmental Farm Plan (EFP) Program. A select group of BMPs within the CSFSP were chosen for evaluation based on their relevance to drought and flood preparedness.

This evaluation is part of a larger initiative, the Prairie Regional Adaptation Collaborative (PRAC), which seeks to produce policy recommendations aimed at reducing vulnerability and increasing resilience to climate change.

II. Interviews

A. Introduction and methods

Interviews were conducted with key personnel in Saskatchewan who have been actively engaged in agri-environmental program development and delivery. The goal of the interviews was to understand the effectiveness of the programs in responding to extreme weather events including droughts and floods. The second goal was to identify factors that facilitate or hinder the reduction of stakeholder vulnerability.

The questions for the interviews were developed and lead by a committee formed by Jeremy Pittman of the Saskatchewan Watershed Authority. The interviewers, Darren Steinley and Joel Mowchenko, collaborated with the committee to enhance the questions enabling them to be presented in a user friendly manner.

The interviews were conducted in a one-on-one style of interview. Wherever possible the interviews were done in person. When a face to face meeting was not possible, phone interviews were conducted. Both styles of interview proved to be effective, providing good discussion in all cases. The interviews were one segment of the larger project with the goal of examining and evaluating drought and excessive moisture preparedness programming.

In general, the interviews revealed two significant items. The first was that the programs being evaluated have beneficial implications for both drought and flood preparedness. With the exception of FRWIP, most preparedness benefits are what would be considered co-benefits, that is drought or flood preparedness was not the primary objective of the program. The second major noteworthy item was that the interviewee's occupation and role within the program significantly influenced their response to questions concerning climate variability and adaptation within the program. Interviewees within government and research organizations tended to focus on the big picture of climate variability. Administrators of the programs tended to be focused primarily on their projects and their immediate benefits to their clientele. Grassroots interviewees (ie. producers) tended to focus on the benefits to the producers over the short and long term and not necessarily preparing for climatic events.

For convenience and ease of reading, interviewees are often be referred to using their first names. For the full names of interviewees and their relationship to the programs evaluated, see below.

B. Summary of interviewed stakeholders

Shelanne Wiles Longley is the executive director of the Provincial Council of Agriculture Development and Diversification Boards for Saskatchewan (PCAB) who administers and delivers the CSFSP and the EFP.

Bill Henley is employed by the Government of Saskatchewan in the Ministry of Agriculture. He is the manger of regional offices (west) and is involved with the policy branch. Bill is also on the steering committee for the CSFSP.

Jim Stalwick is employed by the Government of Saskatchewan in the Ministry of Agriculture. He is a manager of strategic policy and provides direction to PCAB in the delivery of the CSFSP and EFP.

Gary Coghill is employed by the Government of Saskatchewan in programs and legislative services. He works primarily with the Farm and Ranch Water Infrastructure Program.

Terry Kowalchuk is employed by the Government of Canada in the Agri-Environment Services Branch (AESB). Terry is a member of the Agri-Environmental Working Group and has provided direction to the EFP in Saskatchewan from its inception. He was also involved with the administration and delivery of the CSFSP prior to 2009.

Craig Gatzke is employed by the Government of Canada in the Agri-Environment Services Branch (AESB). Craig worked on evaluating project proposals for the CSFSP prior to 2009. He has also worked with the permanent cover program and extensively with shelterbelt establishment.

Tom Harrison is a manager with Saskatchewan Watershed Authority (SWA) and is also on the steering committee for the CSFSP. He is actively involved with water issues in Saskatchewan and with Agri-Environmental Group Planning.

Doug Steele is a producer in the Gull Lake area. He is on the Board of Directors for the Saskatchewan Association of Rural Municipalities (SARM). Doug was on the committee that established the Farm and Ranch Water Infrastructure Program.

Larry Grant is a rancher in the Val Marie area who has been severely affected by drought. He was on the committee that established the Farm and Ranch Water Infrastructure Program.

Jeff Thorpe is employed with the Saskatchewan Research Council and focuses on grassland management in regards to climate variability.

Mark Johnston is employed the Saskatchewan Research Council and focuses on agro-forestry and climate.

C. Summary of information

i. Intent of the programs

According to the interviews, of the programs evaluated, only FRWIP was developed specifically to assist producers in dealing with climate variability and more specifically with droughts. Droughts have been a common occurrence in Saskatchewan for many years with the most pronounced problems occurring in the southwest portion of the province. FRWIP was designed to assist producers in developing secure water sources for livestock regardless of climate scenarios. The program was not specifically developed because of increased risk of climate variability in the future. In fact, both interviewees involved in the development of the program felt that drought is an ongoing issue and were reluctant to admit or even consider the possibility of increased climate variability and climate extremes in Saskatchewan. The program was developed and administered as a long term drought strategy for producers. In this regard FRWIP exemplifies a no-regrets characteristic in that it provides producers with a secure water supply that will have benefits whether or not Saskatchewan sees increased climate variability.

The CSFSP was not developed to address climate variability or extreme weather events. Its purpose was to reduce environmental risk and provide benefit to soil, water, air, and biodiversity. According to Bill Henley, "The intent of all this programming was for farmers to start to think about the effect they might be having on the environment in relationship to their farm. And it was air, water, soil and biodiversity." This sentiment was echoed by Shelanne, Terry and Craig. However the program does have some major co-benefits in terms of adaptation to climate variability – that is, many of the projects that receive funding do increase drought and flood preparedness while at the same time providing additional agri-envionmental benefits. Precision farming applications and reduced tillage both reduce erosion and decrease over-application of fertilizers and pesticides. But there is a co-benefit of improving soil structure and soil water holding capacity that increases adaptability for drought. A further co-benefit of these BMPs is the reduction in carbon footprint of agricultural operations and increased carbon sequestration that serve to mitigate the development of climate variability.

Craig Gatzke talked about the benefits of the conversion of cultivated land to permanent cover and the ability to buffer against both drought and excessive moisture. "So I think there is definitely some preparedness there. There was a forage component moving marginal lands into forage cover which reduces the impact of high (moisture) events. Conversely on the drought side if we have a big drought we have some management as far as protecting the water resource and covering up the soil. You don't see the erosive events. So I think I think as far as severe climate change or just climate change or just climatic events there was lots of things in there that would help prepare the farmer for future events." Jeff Thorpe also mentioned how grasslands and grass species can adapt to climate variability. Forage establishment in these program was not meant to be a solution to climate variability but the benefits in this regard were noted by some of the individuals interviewed. The CSFSP therefore has increased producers' capabilities to deal with climate variability even if this was not the primary objective.

ii. Does the program plan for extreme climate events

Both the CSFSP and FRWIP do have planning aspects for climate events. FRWIP has a direct correlation to climate events and was specifically designed for drought situations. Doug Steele noted in his interview that the program was designed to deal with weather patterns that producers face on the prairies. He commented, "I guess our goal with the program is to put long-term sustainable infrastructure in place. Much like roads and that type of thing, you want to put stability in the industry not just band aid solutions. You wanted to be able to get source water and sustainable source waters, not just dependent on seasonal runoffs and rains - something that was going to add value to the operations plus give them what they needed when they got hit with drought and severe weather conditions like they did." Larry Grant also talked about how the program could be accessed in a timely matter if a climate event was sprung upon an area in short notice. The program clearly enables managers of agricultural land to prepare for climate events.

The CSFSP and EFP provide co-benefits in preparing for climate events. Shelanne Wiles Longley noted no long term planning for climate was looked at when the program was developed and she doubts it will be in the future. She stated, "A lot of these questions are taking me back to when we first started out with the EFP. I think that there has probably been more pressure put on producers as well as the public in terms of the environment over the years, and I think that's nationally. And I think that this program, as well as many others, was probably developed as a result of it." Tom Harrison did mention that the EFP workbook recently had two new chapters added that examine drought and flood preparedness along with water conservation. Bill Henley and Jim Stalwick also both noted that the program does not plan for long term climate events. Terry Kowalchuk discussed how the Agriculture Policy Framework did a lot for mitigation of climate variability and water protection but until recently nobody had linked them to planning for extreme climate events. Although some work had been done toward reducing and mitigating severe weather events, the majority of efforts have not been focused in this direction.

iii. Past drought and flood events the program has faced

FRWIP was developed as a direct result of drought in Southwest Saskatchewan. To the credit to different levels of government, a program was made that allowed producers to utilize grasslands by expanding water supplies to areas that normally could not be grazed in a drought situation. Larry and Doug, both involved with the development of FRWIP, spoke about how the program needed to be accessed quickly by the producer. Doug commented, "And then we met with the minister and we talked about having a vision and that's when the provincial government changed from one to the other. With that long-term drought that they had in the southwest, they saw a need for something that could get up and running quickly, with some proper controls. We sat down with the minister and talked about it and he gave us the go-ahead. We met with a bunch of different provincial departments, I think PFRA and Sask. Water and Sask. Watershed and wanted to really find out how we could get something up and running in a timely fashion." The program did provide a quick turnaround time and gave producers flexibility to manage their operations. Larry and Doug also mentioned how the program developers were aware that all projects might not be perfect, but they were prepared accept this in order to ensure good projects went forward. Tom highlighted that this rationale varied greatly from that of AESB (PFRA) who preferred to take their time on projects and ensure they were technically correct. The contrasting views provide interesting food for thought, but the quick response of the FRWIP program to applications allowed many producers to maintain their cattle herds rather than liquidate their herd in order to survive.

Shelanne, Bill, and Jim all spoke about how the CSFSP was developed for reasons other than climate variability. To this end, the program has not been required to react to flood and drought events. The only real reaction noted was that producers who were hit by extreme climate events reacted by not spending money to invest in additional BMPs for their operations.

iv. Future climate risk

The responses to this segment of questions tended toward personal opinion rather than references to specific programs the individuals were involved with. The majority of interviewees were not convinced that we have witnessed any change in weather patterns or climate. However those who were more closely associated with the scientific community and who may be more prone to interpreting scientific data did express that we are entering into a stage of climate variability. Mark Johnston noted "I think there are a couple of general things that seem to be emerging. And one is that the future climate is more than just the climate. In other words, going along with that is going to be an increase in the level of CO2 in the atmosphere." Jeff Thorpe commented, "There's an indication in the literature that variability may increase in the future, which could be more frequent drought years and also more frequent extreme wet years, like we had last year. I don't think we've got a way to really predict how that's going to change. There's some indication that variability is going to increase, but exactly how much? I don't think we've got that yet."

An interesting observation was that even though the interview questions did not specifically ask for thoughts on the validity of climate change research, most interviewees felt they needed to express their opinions on climate change anyway. Bill gave the most definitive answer in regard to producers and climate change. He expressed that producers will continue to plant crops in the hope of rain. What other choice do they have?

Jeff and Mark, both employed by the Saskatchewan Research Council though not directly involved with agriculture, offered insights into climate variability. They are both witnessing changes to grasslands and forest species as well as diseases and they attribute both of these to climate change. They are confident they can match grass and tree species to new areas based on model projections but both wrestled with the implications of introducing a new species into an area that is not its natural habitat. Jeff stated "It's sort of a policy issue because people are pretty concerned about introducing non inter-species. But this climate change situation is a little bit different. If you look at grasslands, our grasslands are really part of the Great Plains. So it started as a big slate of grassland right from Saskatchewan down to Mexico, and there's continuous variation across that area. With climate change, we expect some of those species that we don't have yet to gradually move into the Canadian prairies." Mark commented on how the forest industry may address the issue. "And there's a ton of research going on in B.C. right now for lodge pole pine where they're doing exactly that. In fact, I was talking to the provincial forestry people just a few weeks ago about setting up a big experiment in Saskatchewan to start looking at different seed sources for jack pine and look at their drought resistance and things like that. So there's an adaptation option which is basically introducing new genetic material - still the same species but different genotypes of that species - into this forest fringe region. And the expectation would be that those new trees are more resistant to drought than the ones that are there now." This is a major emerging question for researchers and policy makers - how to utilize new information and scientific advancements without jeopardizing native species or causing other unintended consequences. It was expressed that we now know more than ever and we have certain tools to combat climate variability but how we choose to use those tools has yet to be determined.

In regards to program adjustments, none of the interviewees felt programs would be changed in order to adapt to increased climate variability. It was argued that we have had climate variability in the past and we will in the future. Tom stated, "Good ideas are indeed good ideas. If you go back over the years, you go back to the old GAP days when we talk about range science or range management - drought preparedness is a big issue of range management. Proper range management is drought preparedness."

v. What information is used in decision making

The majority of interviewees had no trouble accessing information. Jim commented on future weather forecasting information. “I see the forecasting getting a lot better, some of these outfits from the states.” For the most part interviewees found technology transfer was strong between different groups. They were also willing to trade information with other organizations. The individuals interviewed were not information collectors in regard to climate change. For the most part the decision makers were well educated about how their positions and programs relate to drought and flood preparedness.

vi. Resources and planning for extreme weather

The programs being evaluated receive funding from provincial and/or federal government. Concerns over the potential loss of funding were expressed. Shelanne observed that there may be a lack of education and awareness due to a lack of funds. “We’re not able to do to the degree (of awareness) that we used to because we don’t have the funds to get it out there. All of our funds right now are basically put into BMPs.” Loss of good employees and not being able to do the work properly were a few of the concerns expressed. Most interviewees felt they were able to get their priority work accomplished but would have liked additional funds to explore other possibilities.

vii. Stakeholders

Both FRWIP and the CSFSP actively engaged stakeholders in planning and implementation. Bill commented on the changes to the CSFSP brought on by stakeholders. “We think it’s better than it was. We think farmers are basically happier with farm stewardship now than they used to be.” Both groups actively engage stakeholders and producers have influence over how the programs evolve.

viii. Program revision

All programs look at success and failure. It is very difficult to establish how successful a program is. The best way to monitor this is if the program is still being used and if it is still receiving funding. The majority of interviewees felt they took ample time to monitor their programs and make positive changes for the future.

ix. Program partners

The discussion about program partners was limited. All interviewees claimed to have good working relationships with their partners. Jim commented on the direction of CSFSP and AEGPs. "If you go back to the partnerships that they're developing on the group plans and those local watersheds, clearly that's the way of the future. And I think that's working out fairly well. PCAB's going through a very significant learning curve in terms of this kind of delivery. But if I look at the direction of government I see more and more of this stuff moving to third parties. It's pretty hard to be a delivery agent and to be a farm lobby group and I think PCAB understands that." For the most part, this sentiment of positive program partnering between government, third parties agencies, and producer groups held true throughout the interviews. There was very little in the way of negative comments regarding program partners.

x. Conclusion

The purpose of the interview portion of this project was to gain insight into the various programs from a development and delivery perspective. It can be concluded that the majority of individuals involved with these programs feel they are accomplishing their stated goals. With this in mind, it was determined that FRWIP has directly addressed drought adaptation, specifically in the more acute problem areas of Saskatchewan. The CSFSP has also helped in both drought and flood preparedness although these are more co-benefits alongside other agri-environmental improvements. Regardless of program intent, the producers of Saskatchewan have been progressive in mitigating the adverse effects of climate variability.

The second major theme emerging from the interviews regarded predicting the future weather or modelling. It was clear from the opinions expressed that there is a need to improve modelling for weather events. Without proper modelling decision makers can only guess as to how to adapt to climate variability. This was the one aspect that all individuals interviewed agreed upon. More time and money need to be invested to understand the climate and predict long term trends. This will allow producers to make informed and educated decisions on how to manage their operations.

The third conclusion regarded how the information is used. If more accurate modelling is achieved who will be responsible for getting the information to those who need it? Further, who will make the decisions that impact the province? The comments on new forest and grass species being introduced and the effects it will have on eco-systems were cited above and are a good example of this issue. Another example regards the location of future irrigation projects in Saskatchewan. Decision makers must take into consideration the province's ability to improve drought and flood preparedness by expanding irrigation.

The final conclusion drawn from the interviews is that though we have made significant improvements in terms of drought and flood preparedness (reduced tillage, irrigation and water supply expansion, forage conversion, etc) there is still much work to be done. An important step is increased education of producers and landowners about the benefits of preparedness. Additionally, more research and increased understanding is needed regarding the effects of future climate events on Saskatchewan agriculture. Finally, continued cooperation between all stakeholders will lead to an agriculture community that will be more prepared and better adapted to the adverse effects of extreme climate events such as droughts and floods.

III. Literature Review

A. Introduction

The intent of the literature review portion of this project was to review relevant scientific literature in order to determine the effectiveness of various beneficial management practices (BMPs) toward drought and flood preparedness. In other words, in order to evaluate programs for their contribution toward climate change adaptation, it was necessary to first determine what BMPs should be encouraged.

The literature review was carried out in two ways. First, three prominent Canadian scientific agriculture journals were chosen for a comprehensive review. A review was conducted of the twenty most recent volumes (1990-2010) of the Canadian Journal of Soil Science, the Canadian Journal of Plant Science, and the Canadian Journal of Agricultural Economics. The researchers were looking for any articles pertaining to BMP adoption and the effects on drought or flood preparedness. Articles with reference to climate change adaptation, water conservation, dealing with excess moisture, and other possibly relevant topics were also noted. After a scan of article titles, abstracts were read of all possibly relevant articles. Finally a detailed review of the most relevant articles was conducted.

The second method utilized in the literature review was a key word search of peer reviewed scientific journals. Articles were surveyed that matched a combination of certain key words in a topical search – drought, flood, adaptation, preparedness, climate change, agriculture, Canada, practices, etc. This was by no means a comprehensive review of all existing scientific literature, but this method did yield some useful information.

B. Canadian Journal of Soil Science

With the exception of Bedard-Haughn (2009), there were no articles in this journal dealing specifically with beneficial management practices for dealing with extreme climate events. However, there were numerous articles pertaining to practices with benefits for soil moisture conservation and water use efficiency. The bulk of these semi-relevant articles pertained to tillage systems and pasture management.

Numerous articles found during the years surveyed emphasized the benefits of reduced tillage (often referred to as no-till or zero-till systems) toward increasing soil moisture levels (Izaurralde et al 1994, Lindwall et al 1995, Azooz and Arshad 1996, Azooz and Arshad 1998, Azooz and Arshad 2001, De Jong et al 2008) and improving water-stable soil aggregation (Franzluebbers and Arshad 1996, Angers et al 1993). An increase in soil water as a result of reduced tillage would seem to indicate that this BMP carries benefits in terms of drought preparedness. However the implications for flood preparedness are less apparent (see below).

Over the twenty years surveyed, four articles were found that examined the relationship between grazing management and soil moisture (Naeth et al 1991, Twerdoff et al 1999, Mapfumo et al 2003, Bradshaw et al 2007). Unfortunately, none of these studies looked specifically at the benefits of soil water conservation with rotationally grazed pastures as opposed to continuously grazed pastures. Twerdoff et al's (1999) *Soil water regimes of rotationally grazed perennial and annual forages* seemed the most promising but the article itself contained no mention of rotational grazing and only brief mention of short duration intensive grazing (SDIG). This article did suggest that soil surface water was greater under high intensity grazing due to decreases in transpiration. The general indication of the four articles was that soil water is affected more by forage species than by grazing systems. Naeth et al (1991) indicated that soil water levels are negatively affected by grazing due to soil compaction but positively affected by decreases in transpiration. Looking at all of these articles together, it could be suggested that delayed rotational grazing may lead to increases in soil water and water use efficiency that could be beneficial during drought years.

Two other articles suggested management practices that could aid with climate change adaptation. McConkey et al (1997) found that an increase in stubble height led to greater soil moisture due to increases in snow trapping. McGinn and Shepherd (2003) found that earlier seeding dates will likely benefit prairie farmers under future climate scenarios. Neither of these practices is relevant to the programs being evaluated.

As mentioned above, the only article that dealt specifically with BMPs for either drought or flood preparedness was *Managing excess water in Canadian prairie soils: A review* (Bedard-Haughn 2009). Bedard-Haughn suggests several practices that may benefit producers toward increasing adaptive capacity of flood events. Drainage, both surface and subsurface is offered as a potential positive practice. However, the author notes that there are increasing concerns over the negative environmental consequences of drainage. For this reason, policy makers should exercise caution in recommending drainage as a BMP to deal with flood events.

Bedard-Haughn gives consideration to the role of crop choice and crop rotation in preparing for years with excess moisture. Several crop choices are referenced that are better equipped for growth during periods of soil saturation. As well, plants with deep roots and high water-use ability such as alfalfa are recommended over annual, shallow rooted crops.

Bedard-Haughn also points to the issue of trafficability and timing of seeding operations. She highlights the fact that in years with excess moisture timely completion of seeding operations may be crucial as forced late seeding could result in frost damage to crops. While not mentioned in this article, BMPs that increase the speed and efficiency of seeding (and harvest) operations would seem to have a significant advantage toward flood preparedness. Anecdotal evidence indicates that precision farming technology increases the speed of field operations. The CSFSP's funding of GPS and autosteer would thus be seen to have advantages toward flood preparedness.

A final consideration raised by Bedard-Haughn is the effect that no-till systems have on managing excess water. She first observes that reduced tillage increases soil aggregation which improves water infiltration and therefore would be a benefit toward managing excess water. However, she also points out that reduced tillage improves soil moisture retention and therefore may be a detriment during flood events. An interesting observation by Azooz and Arshad (2001) is worth noting in this regard. The researchers evaluated the effects of no-till (NT) and conventional tillage (CT) systems on soil water regimes. They observed that in years of excessive moisture, NT systems were more prone to water-logging and negative results in plant growth. However a system of modified no-till (NTR) was found to increase evaporation and significantly reduce the problem of excess water. This system involved a 7.5 cm residue free strip along the seed row. Details on this method were limited, except that the residue was "pushed away from the crop rows" (46). This system of modified no-till may be worth considering as a potential BMP with positive implications for both drought and flood preparedness.

C. Canadian Journal of Plant Science

Very few articles in the twenty volumes reviewed pertained to BMP adoption and drought or flood preparedness. Articles that did co-relate agricultural practices and water issues mostly focussed on rates of fertilizer application under various soil moisture conditions. Two articles, Brandt (1992) and Lafond et al (1992), served to highlight the benefits of no-till systems in soil water conservation.

There were two other articles that may have implications for the current program evaluation. Asay et al (2001) indicated that introduced grass species (non-native) may have production advantages over native grasses on sites faced with water deficiencies. This research would suggest that when considering seed options for perennial cover in view of potential increases in drought severity, non-native grasses should be chosen over native grasses.

Angadi et al (2004) examined the benefits of early seeding for mustard and canola. The research concluded that timely seeding in association with available soil moisture was a significant factor in crop growth. Further, the researchers highlighted that the patterns of increasing moisture stress in the Canadian prairies will heighten the importance of timely (most often early) seeding operations. This research suggests for drought what Bedard-Haughn (2009) suggests for flood – that timely completion of seeding operations is crucial for preparedness. Thus, the use of precision farming technology that increases the speed and efficiency of seeding operations would seem to hold benefits for both drought and flood preparedness.

D. Canadian Journal of Agricultural Economics

Very few articles in this survey related to BMP adoption and water issues. Several articles were found that analyzed the possible economic impact of climate change and/or droughts and floods on Canadian agriculture. Several others examined the role of programs, policies, and economic instruments in the adoption of BMPs. This review suggests that little to no analysis has been done on agricultural practices that have mitigated the economic consequences of droughts and floods.

Quiggin et al (2010) suggest that with increasing water scarcity, more stringent water allocations will likely result. This study looked primarily at the situation in Australia, but the conclusions could easily be transferred to a Canadian context. Smith et al (2010) suggest that the same reality will apply to Canadian agricultural producers. Therefore, BMPs that increase the efficiency of water use in irrigation would be considered to increase producer preparedness for potential future droughts, especially prolonged droughts leading to situations of water scarcity.

Of the more relevant articles found in all three surveys of Canadian agricultural journals was Kulshreshtha (2011) *Climate change, prairie agriculture, and prairie economy: The new normal.* This article highlights the likelihood of increased extreme weather events and also touches on potential adaptation strategies. However, rather than point to scientifically verifiable adaptation strategies for drought and flood events, the article points more to the need for further research. The article highlights irrigation as the primary adaptation strategy for drought more from a common sense perspective than a scientific one. Also suggested is on-farm water storage as opposed to expensive infrastructure development. Adaptation strategies for livestock producers mentioned are grassland management, feed management, and use of agroforestry (shelterbelts). However, very little scientific evidence is provided supporting the recommendation of these practices. A phrase from the article’s abstract summarizes the situation: “The net impacts on agriculture are not clear, as various aspects of adaptation are not well understood.” Certainly there is need for further research in this area.

E. Other Sources

A review of other peer reviewed journals utilizing a topical electronic search revealed some relevant information, but moreover served to emphasize the lack of specific research into effective adaptation strategies for drought and flood in Canadian prairie agriculture, especially prolonged extreme weather events.

Smit et al (1996) examined producer response and adaptation to climactic variation, however there was no analysis of the effectiveness of various adaptations or even specific reference to the types of adaptations implemented. Reidsma et al (2009) looked at adaptation to climate change in European agriculture. This analysis had many of the same shortcomings, not providing specifics on adaptation techniques and their effectiveness. Numerous other articles were found that examined adaptation strategies in European agriculture but all contained similar shortcomings and where useful adaptations were presented, they were not relevant for the Canadian prairie context.

There were however more useful sources of information. Wittrock et al (2010) drew from numerous interviews with producers to identify and evaluate adaptation strategies to drought. Among the successful adaptation practices identified were refurbishing of existing water sources to increase storage capacity and reduce evaporation losses and reduced tillage and continuous cropping that led to reductions in soil erosion. Further, the article highlighted the need for improved efficiency of irrigation systems due to anticipated shortages in stream flow. The article includes a comment that current adaptations have been successful in dealing with shorter periods of drought but that further research should be conducted on adaptations for prolonged droughts.

Motha (2007) highlights the need for more work to be done on the development of an agricultural weather policy that would include adaptation measures for climate change including extreme weather events. Some of the BMPs mentioned as useful are conservation tillage, careful fertilizer and pesticide applications, strengthened argometeorological systems, and improved irrigation scheduling.

Chavez and Davies (2010) highlight a few key adaptation strategies for improved drought preparedness. First, the need for further development in plant improvement for drought resistance is noted. In terms of BMPs, irrigation strategies that conserve water while at the same time take advantage of recent scientific advances, such as deficit irrigation, are recommended. Reduced tillage is recommended for its benefits toward increasing microbial activity which has been shown to improve drought resistance in crops.

Wheaton et al (2008) comment on the need for improved irrigation efficiencies under situations of water scarcity and potential rationing. The researchers also mention the benefit of new water source development such as new wells and pipelines. Also highlighted is that producers often use the adaptation strategy of reducing inputs to keep costs in line with decreasing returns. To this end, BMPs that improve the efficiency of fertilizer and chemical applications would be seen to be a successful adaptation. The researchers also mention the difficulties for livestock producers in dealing with widespread feed and water shortages. To this end, BMPs that improve pasture and hay land production and as well as protect feed supplies would be a benefit in the short term, but may not be sufficient adaptation for prolonged droughts. As well, the development of new water sources for livestock production would be seen to be essential as a drought preparedness measure. The article concludes with the observation that improvements in adaptation strategies were not sufficient to deal with the widespread drought of 2001 and 2002. Thus, further work is required in the area of drought preparedness to avoid the social and economic difficulties that would be experienced under future droughts.

Gan (2000) points to the need for increased efficiencies in water use in preparing for future droughts. Among the BMPs recommended are irrigation improvements, small-scale water resource development, and improved snow trapping. Gan particularly praises the work of government programs that assist with on-farm and community water source development such as dugouts and community wells and stresses the need for more programs of this type.

Arthur and Kraft (1988) empirically analyzed the increases in adaptive capacity to drought of Manitoba agriculture from the 1930's to the 1980's. The researchers concluded that the use of conservation tillage and improved irrigation made the area less prone to the negative consequences of drought.

Pittman et al (2010) highlight the economic benefits of irrigation during drought years in a specific area of Saskatchewan. Further expansion of water supplies and improvements in irrigation efficiencies would thus be considered highly beneficial practices toward drought preparedness. However, the researchers also identify numerous obstacles to adaptation and continued vulnerability of Canadian prairie agriculture to future extreme climate events.

F. Conclusion

The literature review of three Canadian agricultural journals as well as a key word search of other peer reviewed scientific journals revealed an emphasis on certain BMPs in preparing for and adapting to climate change and in particular extreme weather events. Most commonly referred to were conservation tillage, increased irrigation and improved irrigation efficiencies, improved pasture management, timely completion of seeding operations, and expansion of water supplies. While these activities were shown to improve the adaptive capacity of Canadian prairie agriculture to extreme weather events, most often drought, the need for further research and development of adaptive capacity was often highlighted, especially in preparation for expected prolonged extreme weather events. Further, very little research has been done on successful adaptation for flood events in prairie agriculture. As the 2010 crop year has shown, more research and action is required in preparedness for future extreme climate events on the prairies.

IV. Program Evaluation

A. Overview

The evaluation of agri-environmental programming in Saskatchewan was carried out drawing from interviews with key program personnel, the literature review of peer reviewed scientific journals, and the researchers' own personal experience with the programs and Saskatchewan agriculture in general. The programs evaluated were the Canada-Saskatchewan Farm Stewardship Program (CSFSP), the Farm and Ranch Water Infrastructure Program (FRWIP), the Agri-Environmental Group Planning (AEGP) Program, and the Environmental Farm Plan (EFP) Program. As both the AEGP program and the EFP program focus on increasing producer education and awareness of agri-environmental issues, they were grouped together in the evaluation. Programs were evaluated with consideration given to the following criteria: intent drought preparedness, excessive moisture preparedness, urgency, co-benefits, program statistics, geographic area, adaptability, no-regrets characteristic, reversibility, cost, and social networking,

B. Farm and Ranch Water Infrastructure Program

The Farm and Ranch Water Infrastructure Program (FRWIP) provides producers and communities with financial assistance to develop new water sources. Funding for the program is cost-shared between the federal and provincial governments and the program is administered by the provincial government. The following overview is provided on the Saskatchewan Ministry of Agriculture's website:

A province-wide Farm and Ranch Water Infrastructure Program will support the development of secure water sources in Saskatchewan to expand the livestock industry, encourage rural economic activity and mitigate the effects of future drought. Farmers, ranchers, Rural Municipalities (RMs) and Indian Bands across Saskatchewan are eligible for funding of the following projects:

- Community Wells
- Large diameter and small diameter wells
- Shallow or deep-buried pipelines
- Dugouts

This program contributes significantly to drought preparedness. The original concept of the program was to aid Southwest Saskatchewan during an extreme drought period. All projects that are eligible for funding greatly enhance a producer's capacity to deal with extreme drought conditions. The two main components of the program are storage and delivery of water. The storage of water in dugouts allows producers to utilize pastures even during the driest years. The expanded water holding capacity from increased dugout numbers and size also help to more properly utilize pastures. The delivery aspect allows producers to deliver water to locations where storage is not an option. This allows the same drought protection capabilities that extra storage provides. This added water capacity allows producers to manage grasslands more effectively. As Tom Harrison noted in an interview, "Good range management is drought preparedness."

The drought preparedness aspect of this type of program was highlighted by the literature review. Gan (2000) states, "A majority of the Prairie farms now rely on one or more of these dugouts or stock-water dams. These small-scale projects, together with improved soil management techniques, and financial assistance provided to farmers under several drought assistance agreements or crop insurance programs, have made the Prairies less vulnerable to drought. In theory these small-scale projects can provide water for up to two years, which means that the farmers can survive one drought year with little or no water supply." Wheaton et al (2008) also highlight the benefit of new water source development in terms of drought adaptation. Wittrock et al (2010) highlighted that increasing the depth of existing dugouts reduces the percentage of surface water evaporation and therefore improves water storage during dry years.

While this program was designed to improve preparedness for drought, the storage component of this program could also work effectively in times of excessive moisture. A properly sized dug out will capture water during runoff and store it for future use. Water being stored in dugouts reduces the amount of water flowing over the soil surface contributing to soil erosion.

The interviews with Doug Steele and Larry Grant highlighted the fact that FRWIP was designed to respond to the urgent needs of producers facing water shortages. Quick turnaround time for approvals and elimination of regulatory requirements were built into the program's design. The majority of water expansion situations do require immediate attention and this program addresses these needs.

One co-benefit that this program offers is that it allows for improved range management. Well planed livestock watering will allow producers to utilize rotational grazing in a meaningful and effective manner. This practice can lead to healthier pastures with increased production and decreased risk of erosion. Rotational grazing may also lead to increased soil water and therefore further drought adaptation.

FRWIP was originally established as a program for producers and communities in Southwest Saskatchewan. However, the program has since evolved to a province wide program that is accessible by producers, RMs, and First Nation bands across Saskatchewan.

This program allows producers a high degree of adaptability in that producers can plan for and make their own decisions on how to best handle water needs for their operations. It allows for grass to be grazed at specific times in order to maximize its production. The program increases the flexibility that a producer has to control his or her land and increase its net use.

Establishing new water supplies can be quite expensive. The cost sharing through the program makes it an affordable option to producers. The program's website states, "Individual farmers, ranchers and Indian Bands within Saskatchewan can apply for grants of up to one-half of eligible costs to a maximum of $60,000 over the life of the program to develop long-term sustainable water sources."

C. Canada-Saskatchewan Farm Stewardship Program

The Canada-Saskatchewan Farm Stewardship Program (CSFSP) delivers cost shared funding to producers for the implementation of beneficial management practices (BMPs). The *Guide to the Canada-Saskatchewan Farm Stewardship Program* states, "The program is designed to help Saskatchewan producers address on-farm environmental risk. The CSFSP provides eligible Saskatchewan producers with financial assistance to implement beneficial management practices (BMP) to help maintain or improve the quality of soil, water, air or biodiversity resources." In order to be eligible to apply for funding, producers need to complete an Environmental Farm Plan for their operations. Alternatively, producers who are part of an Agri-Environmental Group Plan can apply for funding under certain BMP categories.

As became apparent through the interviews conducted, the CSFSP program was not designed with the intent of encouraging drought or flood preparedness. It was specifically designed to reduce environmental risk and provide benefit to soil, water, air and biodiversity. Any adaptive capacities for climate variability would be considered strictly as co-benefits. That said, numerous BMPs funded through the program do have advantages in terms of drought and flood preparedness (see "BMP Evaluation" below).

Aside from the secondary benefits of drought and flood preparedness, there are numerous primary benefits of the CSFSP. The program fosters a reduction in environmental risk through the funding of improved storage of farm inputs and farm waste. Improvements to water quality occur through the implementation of remote watering systems, relocation of livestock facilities, and riparian area management. Reductions in soil erosion are supported by the conversion of marginal land to perennial cover and the adoption of low disturbance openers. And the funding of precision farming technology has resulted in increased fertilizer and pesticide efficiency and a reduction water contamination.

The CSFSP allows producers a certain amount of adaptability in that there is a wide variety of categories that are eligible for funding and various BMPs allow producers to open up new possibilities for their operations. However, the program does not foster adaptability in that producers cannot receive funding for projects that may be beneficial but fall outside the scope of the program. Projects are also not eligible for funding if they are deemed to be part of an expansion of an operation.

Producers are unlikely to regret the implementation of BMPs regardless of future climate events. As mentioned above, the primary benefits of most BMPs lie outside of adaptive capacity to drought and flood. Economic, social, and environmental benefits are likely to result from the adoption of BMPs. For this reason, it is also unlikely that the adoption of BMPs will be reversed. That said, as the program does not enforce prolonged adoption, the possibility does exist for a reversal of BMPs. A good example is the case of forage establishment on marginal land. The conversion of marginal land to perennial cover may be an attractive practice to producers when grain prices are low. However an increase in grain prices may see a reversal of this practice. Unlike other programs (Green Cover for example), the CSFSP does not penalize the reversal of a BMP.

The CSFSP provides cost-shared funding to producers for the adoption of BMPs. The level of funding provided is determined by the amount of public versus private benefit. For example, the adoption of precision farming technology is considered to have significant private benefit and is therefore funded at 30%. The decommissioning of abandoned wells is considered to have significant public benefit and is therefore funded at 75%. BMPs considered to have an equal amount of public and private benefit, such as the use of remote watering systems, are funded at 50%.

There is very little social networking fostered by the CSFSP as practices are largely adopted by individual producers. However, providing funding for popular items such as remote watering systems and GPS equipment has encouraged dialogue between producers on the economic and environmental benefits of such practices. More and more producers are learning from one another that environmental stewardship and economic returns go hand in hand.

D. Agri-Environmental Group Planning/Environmental Farm Plan Program

Agri-Environmental Group Planning (AEGP) and the Environmental Farm Plan (EFP) program are similar in that both programs focus on promoting education and awareness among Saskatchewan producers regarding agri-environmental issues. AEGPs exist in Saskatchewan as a means to address geographically specific or sector specific agri-environmental concerns. The vast majority of AEGPs have addressed the concern of water quality within a particular watershed. The EFP program on the other hand is available to all Saskatchewan producers regardless of geographic location and addresses a broader range of agri-environmental isues.

Producers who participate in either program become eligible to apply for funding through the CSFSP. Producers who complete an EFP for their operations can apply for projects under all 30 BMP categories. Producers who participate in an AEGP can only apply for a select group of eligible BMPs that address the specific environmental concern of the AEGP. Both programs have strengths and weaknesses in terms of improving adaptability to climate variability.

As both programs focus on education and awareness, the primary benefits toward preparedness for extreme climate events would be in promoting awareness of the issue. The recent addition of two chapters to the EFP workbook focussing on water conservation and drought preparedness have greatly improved the EFP program in this regard. Now every producer who participates in the program is required to evaluate their operation along these lines. The drawback of the EFP program here is that these new additions to the workbook only reach new participants in the program and not those who have already completed an EFP. AEGPs on the other hand have the ability to continually engage participating producers. While the traditional focus of AEGP education has been on issues surrounding water quality and biodiversity, the structure of the groups allows them to respond to emerging issues such as adaptation to climate variability and to engage producers along these lines.

In terms of BMP adoption leading to adaptability to extreme weather events, the EFP program has the advantage over AEGPs in that all 30 BMPs are accessible to EFP participants. For example, there has been a high rate of adoption of precision technology and low disturbance openers by EFP participants, both of which have benefits for climate variability adaptation (see below). These BMPs are not accessible to producers through an AEGP. That said, there are BMPs available to AEGP members that do have adaptability benefits, such as land conversion and pasture management BMPs.

Adoption of BMPs for adaptability through both programs would be seen as co-benefits on two levels. First, as both programs focus primarily on education and awareness, any BMP adoption would be seen as a secondary benefit. Second, as the CSFSP was not designed to address climate variability, any improvements in this regard would also be seen as co-benefits as opposed to primary benefits.

Perhaps the greatest strength of both programs is the opportunity for social networking. AEGPs bring together numerous producers to collectively address specific issues. Producers are introduced to the concepts of a watershed and the collective impact of various actions on the environmental health of the watershed. The extensive use of workshops and field days encourage the social networking of producers from similar areas addressing similar issues. More than anything, AEGPs emphasize the interconnectedness of producers within a geographic area and the need to collectively address areas of agri-environmental concern. The EFP program also draws together producers and fosters engagement and discussion amongst participants. However, as the EFP program consists of only two workshops, the ongoing social networking of the AEGP is not present.

V. BMP Evaluation

A. Overview

The evaluation of beneficial management practices (BMPs) was carried out drawing from interviews with key program personnel, the literature review of peer reviewed scientific journals, and the researchers' own personal experience with these practices and Saskatchewan agriculture in general. BMPs were chosen for evaluation based on their relevance to drought and flood preparedness and were grouped together where appropriate. BMPs were evaluated with consideration given to the following criteria: intent, drought preparedness, excessive moisture preparedness, urgency, co-benefits, program statistics, geographic area, adaptability, no-regrets characteristic, reversibility, cost, and social networking.

B. Pasture management (BMPs 201 and 302)

These two BMPs, fencing to protect the environment and remote watering systems, both serve to improve pasture management. The *Guide to the Canada-Saskatchewan Farm Stewardship Program* states, "Well managed grazing systems allow for sufficient rest periods for plants to re-grow, remain healthy and produce adequate plant litter to reduce water evaporation, protect the soil surface from erosion and act as a natural filter to improve runoff water quality." By fencing new areas or cross-fencing existing pastures and by expanding watering options, producers enhance their ability to properly manage rangeland.

Improved pasture management does have positive implications for drought preparedness. As Tom Harrison stated, "Good range management is drought preparedness." There was some indication from the literature review that rotational grazing of pastures leads to increased soil water (Naeth et al 1991, Twerdoff et al 1999). This is the combined result of limits to both soil compaction and transpiration. As noted above, increased plant litter on well managed pastures also reduces soil water evaporation. Increases in soil water would lead to sustained production in dry years. Therefore, improvements in range management would be considered a successful adaptation for drought.

As mentioned above, well managed pastures see reductions in soil water erosion and improvements in runoff water quality. These qualities would be considered as positive adaptations for excessive moisture events.

These BMPs were not designed with preparedness for climate variability in mind. Therefore these benefits would be considered co-benefits. Additional co-benefits of improved rangeland management include control of invasive plants, increased biodiversity, improved health and productivity of pastures, reduced soil erosion and improved runoff water quality.

This BMP affords flexibility to producers by offering them more grazing management options. It allows them to utilize specific forages in specific areas for certain grazing seasons. This flexibility will help them to increase forage production, improved plant health, and ensure environmental sustainability.

While there are substantial costs involved with the implementation of these BMPs, it has been demonstrated that proper range management leads to increased production and therefore increased revenue for producers. The CSFSP estimates that it costs a producer $3700/mile to build perimeter fence and $2100/mile to build cross fence. These costs as well as the costs of remote watering systems are funded at a rate of 50%.

It has been said that good fences make good neighbours. It should also be said that good fences lead to good range management. The use of cross fencing and remote watering systems allows producers to go the extra step to improve range management. This improved range mitigates the adverse effects of drought and excessive moisture, improves riparian areas and water quality, and benefits biodiversity – all of which have benefits for producers and society as a whole.

C. Water quality protection (BMPs 101, 401 and 801)

This group of BMPs including relocation of livestock confinement facilities, farmyard runoff control, and modifying and revegetating waterways all help to protect water quality during extreme moisture events.

The objective of the relocation of livestock confinement facilities BMP is to assist producers to relocate confinement facilities away from at-risk surface or groundwater sources. The objective of the farmyard runoff control BMP is to provide producers with assistance in addressing the environmental impacts of uncontrolled runoff passing through farmyards and livestock facilities. The objective of the modifying and re-vegetating waterways BMP is to assist producers in placing natural and/or man-made erosion control structures to minimize erosion in riparian areas and on soils prone to erosion.

While these BMPs have little to no impact on drought preparedness, they can be shown to have significant benefits to flood preparedness. Livestock producers in particular need an effective and efficient method to safely deal with excess moisture as flooding in livestock wintering sites can lead to livestock health problems and water contamination. The relocation of feeding facilities offers protection to ground and surface water during periods of excessive moisture. Potential contamination of surface and ground water during heavy flooding is greatly reduced due to relocating to more environmentally friendly sites. Farmyard run-off control allows farm owners to safely divert water around wells or sources of contamination. Revegetating waterways is an erosion control measure which allows land managers reduce soil degradation due to excessive moisture. All of these BMP'S are used to deal with excessive moisture but do not enable the producers to manage their operations in order to conserve water in dry years or utilize excessive moisture in wet years more efficiently. They are merely strategies to limit environmental impacts during heavy moisture events.

Once again, the preparedness for climate variability that results from these BMPs must be considered a co-benefit as it is not the primary intention of the funding of these practices. Other benefits include improved water quality, improved livestock health, reduced soil erosion, improved livestock handling facilities, and improved manure management.

The cost of implementation for these projects can be significant. Due to the protection of water quality, these BMPs are deemed to have a high degree of public benefit. For this reason the CSFSP funds 75% of modifying and revegetating waterways, 60% of livestock confinement relocations, and 50% of farmyard runoff control projects. Due to the expense and permanent nature of these projects, there is unlikely to be any reversibility once completed.

E. Forage establishment (BMPs 901, 1101 and 1305)

These BMPs, planting vegetation to protect riparian areas, protecting high risk marginal soils, and native plant re-establishment, allow producers to convert cultivated land to perennial forages. These BMPs can be shown to have benefits for extreme climate events such as droughts and floods.

Land under perennial cover has better soil structure and higher organic matter content than land used for annual cropping. These properties enable the soil to absorb and hold more water allowing continued forage production as compared to annual crops in dry years. The deep roots of most forage plants allow the plant to access water reserves that are inaccessible to shallow rooted annual crops. Forages are universally known to produce in dry years. Although their production may fall, their yield is more predictable and stable compared to annual crops. Land under perennial cover is also less prone to wind and water erosion during droughts than annually cropped land. For these reasons, these BMPs are shown to increase drought preparedness.

An interesting question arose in both the interviews and the literature review regarding the use of non-native species as perennial cover as a means of adaptation to climate variability. Both Jeff Thorpe and Mark Johnston expressed that newly developed varieties of forages and trees could be used as a means of drought preparedness. These new varieties have increased water use efficiency and therefore are more adaptable to drought conditions. However both interviewees expressed that there are social concerns with introducing new non-native species. Asay et al (2004) also suggested that non-native forages may have advantages over native in terms of production during dry conditions. There may of course be other benefits that native species offer, increased pest competition and biodiversity for example, but in terms of drought preparedness, the research indicates that non-native species should perhaps be considered as more appropriate choices.

Conversion to perennial cover also offers preparedness for extreme moisture events. Bedard-Haughn (2009) highlights that plants with deep roots and high water-use ability such as alfalfa are recommended over annual, shallow rooted crops when dealing with excess moisture. She also points out that reduced trafficability of fields is a significant issue in years of excess moisture. As was evidenced in 2010, many acres of crop land were left unseeded for this reason. While fields in perennial cover are still prone to flooding, there is increased likelihood of a harvest after spring moisture has dried up. Even if a hay crop is not able to be harvested, land under perennial cover benefits for decreased erosion in excessively wet years. For these reasons, these BMPs are shown to increase flood preparedness.

These BMPs offer other benefits aside from adaptation to climate variability. Decreases in soil erosion, improvements in water quality, increased biodiversity, and improved pasture management would be considered the primary benefits of these BMPs. Conversion of land to forage also allows producers flexibility in management options. Land can be used for hay production, grazing, or can be rented out to other livestock producers.

The CSFSP estimates that the cost of establishing perennial cover is $65/acre for non-native species and up to $100/acre for native species. The program funds 50% of costs for forage establishment. One of the downsides of this BMP is that it is highly reversible. Producers are not obligated to leave land in perennial cover for any length of time. Therefore the benefits to variable climate adaptation and other benefits could be erased.

F. Protection of livestock feed supplies (BMPs 202 and 1201)

Both of these BMPs, fencing to protect damage by wildlife and agricultural product's safe storage and handling, have elements that relate to protecting feed supplies. BMP 202 allows for the protection of hay storage sites from big game wildlife and BMP 1201 allows for improvements to silage storage.

Both of these BMPs have limited applicability to climate variability adaptation, however, the ability to increase the longevity of feed supplies can be considered preparation for reduced production during years of extreme climate events such as droughts or floods. Wheaton et al (2008) highlighted the feed shortages faced by livestock producers during dry years. Producers are well advised to stockpile feed however decreases in silage quality and losses due to wildlife can make this practice difficult. These BMPs allow for the protection of feed supplies and can therefore be demonstrated to have a certain degree of benefit toward preparedness for extreme climate events. There are also potential benefits of using silage wrap for hay bales. This method of harvesting and preserving hay may also allow producers to store forages for longer terms without compromising quality.

G. Climate information collection and integrated pest management (BMPs 1302, 1303, 1304, and 1306)

All four of these BMPs promote the development of integrated pest management systems for agricultural operations. The *Guide to the Canada-Saskatchewan Farm Stewardship Program* states, “An integrated approach to pest management is the most effective to achieve the goals of economic production and environmental protection. An integrated approach involves the judicious use of approved agricultural pesticides in combination with other management options, such as crop rotation, pest resistant varieties, biological control, and physical control methods.”

While the information collection and monitoring BMP (BMP 1302) is primarily intended to assist with integrated pest management, there is a strong co-benefit toward preparedness for climate variability. Motha (2007) comments that the strengthening of agrometeorological networks is an important step in preparation for climate variability. Purchasing of weather systems with network capabilities is an eligible project under this BMP and contributes toward stonger agrometeorological networks. In addition to providing increased information on weather trends and patterns to climatologists, producers who implement these BMPs also increase their own awareness of climate realities including trends and local variability. With these considerations, this BMP can be shown to increase preparedness for climate variability.

Integrated pest management may be an important practice with increasing climate variability. Application of chemical pesticides may not be feasible due to water shortages or field trafficability issues. For these reasons, integrated pest management may be more essential in years of extreme weather conditions. Additionally, climate variability may bring changes and increases in pests and pathogens. Again, a diverse approach to pest management will likely see improved results over a sole reliance on chemical pesticides.

The primary benefits from these BMPs are not related to climate variability. Targeted benefits include increased biodiversity and ecosystems, reduction in input costs, improvements in water quality, and improved control of pests, including weeds, insects, and vertebrate pests. These BMPs are funded at 30% or 50% by the CSFSP.

H. Irrigation modification and planning (BMPs 1401 and 1402)

The objectives of the improved irrigation management BMPs are to provide producers with assistance to improve irrigation efficiency and lessen impacts of irrigation on the environment by developing well thought out plans and upgrading irrigation equipment. These BMPs are some of the most important in terms of drought preparedness.

The literature review consistently revealed that future shortages in water supply during periods of prolonged drought will likely lead to rationing and other restrictions on water use and that more efficient irrigation methods will be required (Quiggin et al 2010, Smith et al 2010, Wittrock et al 2010, Wheaton et al 2010). By utilizing BMPs that improve irrigation efficiencies, producers will be better able to deal with water shortages during droughts and the potential resulting restrictions on water use.

Chavez and Davies (2010) highlight that the use of efficient irrigation techniques such as deficit irrigation may lead to increased yields regardless of water availability. Efficient irrigation also has the co-benefits of reducing erosion and decreasing the leaching of nutrients. Improvements to irrigation systems can be costly and are therefore unlikely to be reversed once implemented. The CSFSP funds 50% of irrigation management planning (BMP 1402) and 30% of irrigation equipment modification (BMP 1401).

Improved irrigation allows producers increased flexibility in their operations by increasing cropping options including the possibility of high value crops such as fruit and vegetables. Irrigation improvements also facilitate the scheduling of irrigation to maximize efficiency and more accurately meet a crop’s water requirements.

I. Low disturbance placement of seed and fertilizer (BMP 1501)

The intent of this BMP is to assist producers in implementing practices to decrease erosion and excessive application of nutrients. Lowering the amount of soil disturbance that occurs during seed and fertilizer placement has numerous benefits in terms of drought preparedness. Producers who use reduced or zero-till systems tend to also favour continuous cropping. Zero-till in association with continuous cropping increases the amount of trash and/or stubble cover on a field over the winter months. This results in increased snow being trapped on the field and increased moisture being held in the soil. This increase in soil moisture can be very valuable in years with limited precipitation.

Reductions in tillage also lead to an increase in soil organic matter content over the long term. Increases in organic matter mean, among other things, that the soil will be less prone to erosion in years of drought. Increases in organic matter also increase the soil's water holding capacity which aids crop production in dry years.

Reducing tillage during seeding and fertilizing also leads to an improvement in soil structure. Improved soil structure aids in drought preparedness by increasing the water holding capacity of the soil. In years of drought, limited moisture is held longer in the soil and made accessible to growing plants. Numerous articles in the literature review attest to the increased water holding capacity of soils when soil disturbance is reduced (Brandt 1992, Lafond et al 1992, Izaurralde et al 1994, Lindwall et al 1995, Azooz and Arshad 1996, Azooz and Arshad 1998, Azooz and Arshad, 2001, De Jong et al 2008). Chavez and Davies (2010) made the interesting observation that a reduction in tillage can lead to increased microbial activity which has been shown to improve drought resistance in crops. With all these factors considered, this BMP can certainly be said to lead to an increase in drought preparedness.

The implications of reduced tillage for excess moisture preparedness are less clear. Bedard-Haughn (2009) observes that reduced tillage increases soil aggregation which improves water infiltration but at the same time improves soil moisture retention. Thus it is unclear whether or not this BMP contributes to excess moisture preparedness. Azooz and Arshad (2001) also identify this dilemma with this BMP. However, their research found that leaving a 7.5 cm strip of residue free soil above the seed row in a no-till system increased evaporation and reduced problems with excessive moisture. This finding may be an important one if this BMP is to have benefits for both drought and excessive moisture preparedness. A further consideration in this regard is that soils with good soil structure and high organic matter produced by a reduction in tillage will see decreases in water erosion during heavy rainfall and runoff events. Therefore, while this BMP may inhibit production during years of excessive moisture, the long-term health of the soil and therefore ability to produce may be improved.

The primary benefits of this BMP are increases in soil health, decreases in erosion, and increases in production. Adoption of this BMP has lead to an increase in equipment purchases and therefore co-benefits to implement manufactures and dealerships as well as the economies of local communities. Reductions in tillage also lead to a greater level of carbon sequestration which may inhibit the degree to which climate variability takes place.

Adoption of this BMP has in general allowed producers greater flexibility in their operations. Particularly, producers practicing zero-till save time otherwise consumed by tillage operations. This allows them greater flexibility in seeding dates and crop choices. However, under a zero-till system, producers have fewer options in terms of weed control relying primarily on herbicide application. Not only does this limit the possibility of an integrated approach, it can also increase costs. In years of hydro-climactic extremes, producers can potentially be faced with high input investments and limited production returns.

Producers who adopt this BMP may choose to change practices in the future, though given the benefits of this BMP and the social movement toward reduced tillage, such a change is unlikely. However, the increasing cost of inputs may encourage producers to resort to increases in tillage as a means of weed control. Most of the benefits of a reduction in tillage would be lost upon a return to conventional tillage.

The cost of converting to a low or zero-till system can vary substantially. Some seeding units can be adapted to low disturbance simply by a change in opener. Other units require a change to the shank, opener, and packing system or the purchase of a completely new unit. Therefore, costs can range from a few thousand dollars to over one hundred thousand dollars. The farm stewardship program will fund 30% of eligible project costs up to a maximum of $5000.

J. Precision farming applications (BMP 1503)

The objective of the precision farming application BMP is to assist producers in purchasing precision farming systems that will create an on-farm benefit to the environment. While at first glance there would seem to be little benefit toward adaptive capacity for climate variability, further investigation does reveal certain benefits.

Bedard-Haughn (2009) observes that one of the significant barriers to agricultural production in years of excessive moisture is one of trafficability - lack of access to fields to complete seeding operations. As a result, in order to adapt to these conditions, producers must quickly and timely complete field operations when conditions allow. The use of precision farming technology promotes the efficient and quick completion of field operations. Further, reduced operator stress allows for increased intensity of field operations (longer hours) without causing as much operator fatigue. With increasing climate variability, harvest operations may also need to be completed quickly when weather conditions allow. The increased speed with which this BMP allows producers to complete spring and fall field operations is thus demonstrated to have significant benefit toward excess moisture preparedness.

Likewise, timely completion of seeding operations may be viewed as a successful drought adaptation strategy. Angadi et al (2004) observed that the typical prairie weather pattern of increasing moisture stress from spring into summer meant that seeding of mustard and canola should be completed as early as possible. This would likely be true for other crops as well. Even more so, in years of drought conditions, quick, early seeding would allow crops to take full advantage of available spring soil moisture. Thus, the increased speed with which this BMP allows producers to complete seeding operations can be demonstrated to increase adaptation to drought.

Another consideration in terms of this BMP's relevance to adaptation to climate variability is the more efficient use of inputs. Wheaton et al (2008) observed that one adaptation measure of producers in drought years was a reduction in inputs to keep costs in line with decreasing returns. This reduction in inputs however would likely lead to further reductions in returns. Improvements in input efficiencies on the other hand would reduce input costs while at the same time maximizing returns. GPS technology, including overlap control and variable rate applicators, leads to an increase in input use efficiency. Therefore, a further benefit of this BMP to climate variability adaptation can be demonstrated.

Other benefits from this BMP include reductions in fuel, seed and fertilizer, water quality protection, reductions in carbon footprint, and protection of biodiversity and ecosystems. The cost of precision farming systems varies greatly. The CSFSP funds 30% of project costs to a maximum of $15,000. The adoption of this BMP is easily reversible but the economic benefits received make this unlikely.

K. Shelterbelt establishment (BMP 1601)

The objective of the shelterbelt establishment BMP is to increase shelterbelt planting and ensure proper establishment of trees and shrubs for livestock facility protection, dugout snow trap, wildlife habitat, and field enhancement.

This BMP has some benefits toward preparedness for climate variability, but they are limited. Gan (2000) stresses the benefits of increased snow trapping in dealing with climate variability. McConkey et al (1997) also highlight snow trapping as a means to improve soil moisture. While both of these articles point to stubble height as a method for snow trapping, shelterbelt establishment is also an effective method of trapping snow to increase available soil moisture. In this regard, this BMP has benefits toward drought adaptation.

Wind erosion is an often associated concern with drought conditions. Drier soils with reduced ground cover are more prone to wind erosion and resulting decreases in production. Shelterbelt establishment reduces wind speed at field level and therefore reduces wind erosion. This can be seen as a considerable benefit to production, especially in dry years. This is another benefit of this BMP toward drought adaptation.

Shelterbelt establishment also provides benefits in terms of improved biodiversity, shelter for livestock, and aesthetic enhancement of property. The costs to establish shelterbelts are primarily associated with labour, equipment, and weed control. The CSFSP funds $600 per mile of shelterbelt established.

VI. Conclusion

This evaluation of agri-environmental programming in Saskatchewan found that there are current programs in place that increase producer preparedness for extreme climate events such as droughts and floods. However, further research into successful adaptation strategies is required if future programming is to be more targeted in this regard.

The Farm and Ranch Water Infrastructure Program was specifically designed to increase producer adaption to drought. The program financially assists with the development of new water sources and water delivery systems. These water sources and infrastructures have been shown to be a positive adaptation strategy for producers during years of drought allowing for sustained production. The program was designed to be accessed quickly in order to address impending water shortages.

The Environmental Farm Plan Program and the Agri-Environmental Group Plan Program both have the ability to increase producer awareness regarding climate variability. Both programs foster social networking as a means of increasing awareness and BMP adoption. As well, participation in both programs leads to the ability to receive funding for BMP adoption.

The Canada-Saskatchewan Farm Stewardship Program provides cost shared funding to producers for the implementation of beneficial management practices. While the primary intent of the program and the BMPs is not an increase in preparedness for climate variability, certain BMPs have been shown to have benefits in this regard.

Improved pasture management leads to increased soil water storage and increased production during drought events as well as erosion protection during excessive moisture events. Certain water quality protection BMPs mitigate the possibility of water contamination during flood events. Conversion of cultivated land to perennial cover decreases erosion during extreme climate events and also leads to more sustained production. Protection of livestock feed supplies helps ensure adequate feed in years of production shortages due to drought or flood. Weather information collection increases knowledge of climate trends and integrated pest management allows for pest control when conventional methods are not viable. Irrigation efficiency improvements protect producers from potential future water shortages and rationing. Reduced soil disturbance increases water storage capacity that helps buffer the effects of drought. Precision farming technologies allow for quick field operations when windows for seeding and harvesting are small due to lack of or excessive moisture. And shelterbelts increase snow trapping and decrease wind erosion both of which help mitigate the adverse effects of drought.

While these programs do assist producers in adapting to drought and excessive moisture events, further programming that specifically targets these issues would be beneficial. As well, research, policy, and programming that addresses prolonged droughts and excessive moisture is needed if Saskatchewan agriculture is to remain sustainable during future climate variability.

VII. References

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