RURAL DEVELOPMENT INSTITUTE

PHASE 2

ADAPTING RISK TO RESILIENCE

A Survey Report of Economic Costs and Benefits Analysis of Proposed Investment Options for Farm-Level Extreme Moisture Management

RDI RURAL DEVELOPMENT INSTITUTE

BRANDON UNIVERSITY

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Acknowledgement

The funding for this research and related report was generously from a collaboration with the Manitoba Crop Alliance and the Canada Action Plan with the Manitoba Government and Government of Canada. Special thanks to the organizing efforts of Brent VanKoughnet, who gathered a multi-disciplinary team to tackle extreme moisture in Manitoba.

The authors would like to thank Manitoba producers and organizations who generously shared their time, experience, and materials for the purposes of this survey. Hard-working Manitoba producers play a critical role in Canada's food chain.

It is important to recognize that the land on which we're gathered is the traditional and ancestral lands of the Dakota, Anishinabe, Ininewak, Oji-Cree, Dene and Metis peoples. We respect the treaties that were made on these lands and acknowledge that Brandon University is located on Treaty 2 Lands. We at Brandon University acknowledge and respect the history, land and the people of this area.

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RDI functions as a not-for-profit research and development organization designed to promote, facilitate, coordinate, initiate and conduct multi-disciplinary academic and applied research on rural issues. The Institute provides an interface between academic research efforts and the community by acting as a conduit of rural research information and by facilitating community involvement in rural development. RDI projects are characterized by cooperative and collaborative efforts of multi-stakeholders.

The Institute has diverse research affiliations, and multiple community and government linkages related to its rural development mandate. RDI disseminates information to a variety of constituents and stakeholders and makes research information and results widely available to the public either in printed form or by means of public lectures, seminars, workshops and conferences.

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Foreword

Manitoba's rapidly changing climate conditions are characterized by increased frequency and intensity of extreme moisture events. For instance, four of the top ten Assiniboine River floods and five of the top ten Red River floods took place during the last 25 years. In addition to these spring floods, other extreme moisture events include prolonged or intense periods of rain. Generally, from an ag-producer's perspective, these events result in soil moisture in extreme of field capacity for a period sufficient to significantly inhibit crop production.

Moreover, the impacts of such events can be local or regional as well as downstream. For producers, the impacts may be short-term, prolonged or persistent depending on the locale, previous moisture mitigation strategies, and the local and regional water infrastructure. These extreme water events harm farm livelihoods as well as the well-being of all downstream rural municipalities and urban centres having to deal with the social, economic and environmental costs due transportation interruptions, property damage, and agricultural run-off impacts on surface and ground water quality.

There are several longer term strategies producers can invest in to manage extreme moisture in their fields. Reducing the risk of crop loss or reductions in yield and quality are generally the main reasons why producers make such investments. Others at the local and regional levels may also benefit from these water management practices as well (e.g., reduced peak flows). This project aims to provide agricultural producers at the early stage of long-term planning with critical factors in estimating socio-economic costs and benefits of different on-farm extreme moisture practices, along with identifying other stakeholder considerations.

To achieve that goal, this project consists of three main activities and took place in two distinct phases. The focus of Activity 1 was to provide producers with an on-farm costs and benefits framework to help evaluate different investment strategies for managing extreme moisture. Activity 2 focused on using farm models to provide information on the impact on yield and farm income due to extreme moisture. Lastly, Activity 3 focused on identifying the downstream impacts and costs of extreme moisture events with a particular focus on the 2011 Assiniboine River flood. For each activity, Phase 1 consisted of gathering and synthesizing academic and other publicly available information and data. Phase 2 of the project sought to get feedback from producers and other stakeholders in an effort to validate the findings of the Phase 1 activities. Overall, the 2 phases of the 3 activities of this project resulted in the completion of 6 reports which are outlined in Figure 1.

Summary of the 6 reports indicating the main objectives for each phase and activity

	ACTIVITY 1	ACTIVITY 2	ACTIVITY 3
	Economic Costs and Benefits Analysis of Excess Moisture Investments	**Impacts of Excess Moisture on Crop Field and Farm Income**	**Downstream Effects of Excess Moisture in Manitoba**
PHASE 1	1. Identify farm investment options for excess moisture management. 2. Identify of on- and off-farm costs and benefits of investment options. 3. Quality costs and benefits of investment options and select suitable proxies for qualitative costs and benefits. 4. Develop a framework to assess costs and benefits of excess moisture investment options.	1. Identify, calibrate and adapt a farm model that could be simulating the impact of excess moisture events in southern Manitoba's field conditions.	1. Identify the physical and socio-economic impacts of excess moisture 2. Identify the direct the indirect costs excess moisture losses. 3. Identify the downstream economic impacts of excess moisture.
PHASE 2	1. Validate the economic cost-benefit framework of proposed investment options of farm-level extreme moisture management. 2. Determine what extreme moisture management strategies are currently being use. 3. Evaluate the willingness of producers to adapt their farm using proposed extreme moisture management strategies. 4. Conduct a Manitoba local market survey to validate cost estimations used in the development of cost-benefit framework.	1. Identify current yield forecasting tools available and being used by stakeholders at different scales of operations. 2. Evaluate the willingness of producers and other stakeholders in crop yield forecasting models.	1. Validate the completeness and accuracy of the physical and socio-economic impacts of excess moisture. 2. Assess the relevance and usefulness of the information for the procedures and stakeholders. 3. Identify other effects, outcomes, and strategies that producers and stakeholders considered in response to the 2011 Assiniboine River Flood

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Executive Summary

Agriculture is a dynamic sector which is constantly adapting to stresses such as market and climate changes. Changes in climatic conditions are now widely accepted with forecasts of increasing extremity and variability of weather events in the Prairie provinces of Canada. Manitoba's rapidly changing climate conditions are characterized by increased frequency and intensity of extreme moisture events. Extreme moisture in the Prairies has occurred as a result of major rainfall events in summer and fall and also the impact of high volumes of snowmelt runoff in spring. Adaptation has the potential to reduce the magnitude of challenges associated with extreme moisture events and increase the capture of possible benefits. Increasing soil organic matter, implementing flexible cropping systems, and installing well designed drainage systems are examples of on-farm actions that can reduce the impacts of extreme moisture events expected to increase as a result of climate change. Providing responsive insurance programs and supporting strategic research are examples of adaptation responses that governments and industry can offer. In addition to building resilience to extreme moisture conditions, actions like these also enable the agriculture sector to take advantage of potential benefits of climate change such as more heat units or a longer growing season. The impacts from reduction in extreme moisture, avoided drought, reduced eutrophication, carbon credits, and new wetland habitat could provide more benefits over costs. For benefits to be observed, practices will need to be chosen that can accommodate the current and changing climatic conditions.

The overall aim of this project is to assist Manitoba producers in better understanding on-farm investments to manage excess moisture and to catalogue downstream impacts of such events. In the phase-1 of this project activity, Rural Development Institute (RDI) demonstrated how different farm investment options adopted for extreme moisture management could mitigate the negative impacts of floods and can also provide significant nutrient management and other types of co-benefits on the farm. With the base case representing current conditions, four other strategies were selected for potential use in southern Manitoba, namely: water reservoirs, tile drainage, landscaping or cut and fill, and cover cropping. An economic cost-benefit framework of each of the four investment options was developed to compare benefits over invested cost. Cost benefit ratios were provided to develop the understanding of the amount of return that could be expected on each dollar of investment for each of the four proposed options. This cost-benefit framework provides Manitoba producers the knowledge to make and support on-farm investment decisions based on their experience of extreme moisture events at their farm, land holding, and scale of operations. It also enables producers to take into account potential benefits of proposed investment options. In phase-2 of this project, RDI organized a series of surveys to validate the economic cost-benefit framework of proposed investment options for farm-level extreme moisture management, and to receive feedback from targeted stakeholders involved in this study in terms of how these analyses might be useful to their decision making.

This baseline survey of Manitoba producers provides a valuable and unique insight into the current management strategies, and willingness of producers to adapt their farm using extreme moisture management strategies proposed by RDI to mitigate the impacts of extreme moisture events at Manitoba farms. In order to counter the detrimental impact of extreme water on agricultural production, producers in southern Manitoba are using a diverse range of management techniques and resources including subsurface drainage, water retention ponds, zero-tillage, change in cropping systems, growing moisture tolerant crops, cover cropping, surface drainage practices, and excess moisture insurance programs. A profound interest was observed to adapt farms by means of extreme moisture management systems to add numerous benefits to the agricultural land in the context of water management. A majority of survey participants verified that the economic cost-benefit

framework provides them with a systematic way of looking at investments in the introduction of proposed investment options for farm-level extreme moisture management, which should prevent them from ignoring important benefits or constraints which may inhibit its adoption. Moreover, because all producers were in agreement with costs and benefits identified by RDI, it would improve the consistency of the information on which different investment decisions were made. Producers were convinced that all four farm strategies proposed by RDI have long infrastructure life and provide more benefits over costs. However, they also revealed concerns about higher capital cost of systems and a rapid variability in civil work cost every year which effects the capital, operating, and maintenance costs calculated in the report. Given the interest of study participants, a customized cost-benefit framework tool is developed in the form of an excel spreadsheet where Manitoba's producers can conduct costs and benefits analyses of a chosen investment option for their farm with the selection of their land holding and desired benefits. The information about available funding opportunities was shared with producers for the adoption of beneficial management practices to help them improve sustainability and reduce environmental risks on their farms.

Introduction

Climate change and extremes in weather are continuously affecting Prairie agroecosystems. Agriculture is among the most vulnerable sectors to climate change due to its dependency on weather conditions. Extreme weather conditions resulting from climate change effects create challenging decision-making situations for the agriculture industry in Canada. Flooding can be viewed as an environmental risk and the most significant natural hazard, farmers are experiencing worldwide. Manitoba's rapidly changing climate conditions are characterized by increased frequency and intensity of extreme moisture events. These changes result in soil moisture in excess of field capacity or below wilting point for a period sufficient to inhibit crop production significantly. Spring snowmelt and intense precipitation conditions are major causes of flooding conditions in Manitoba, which can damage agricultural crops, prevent seeding/harvesting activities, carry away productive topsoil, as well as damaging infrastructure and property. Inability to access saturated land due to low trafficability results in delayed spring seeding, which subsequently cause lower yield and decreased farm income.

Manitoba has a long history of flooding including major floods in 1950, 1997, 2009, and 2011. Four of the top ten Assiniboine River floods and five of the top ten Red River floods took place during the last twenty-five years. Manitoba's flood of 2011 was of a scope and severity never before experienced in the province. Three million acres of cultivated farmland went unseeded in 2011. Thousands of cattle had to be relocated. More than 650 provincial and municipal roads and nearly 600 bridges were damaged, disrupting transportation networks throughout the province. According to the Manitoba 2011 Flood Review Task Force Report, costs associated with flood preparation, flood fighting, repair to infrastructure and disaster payments have reached $1.2 billion (Government of Manitoba, 2013). Most recently, a series of extreme moisture events took place in Manitoba from June 6 to 10, 2020; when southeast Manitoba was hit by heavy rains (> 7 mm h-1), with some areas receiving 200 mm in the span of three days. Due to these extreme moisture events, overland flooding was reported in the rural municipalities of De Salaberry, Piney, Reynolds, La Broquerie, Stuartburn, and Emerson-Franklin. Approximately 20 to 30 % of the land in southern districts of eastern Manitoba remained unseeded due to extreme moisture soil conditions. Crops already seeded in the worst affected areas were drowned out as significant portions of seeded fields were under water. Pastures and hay-land in affected areas were also flooded and forage productivity was severely impacted. Another series of extreme moisture events took place between June 28 and July 5, 2020 in western and southern Manitoba around the Brandon, Rivers, and Neepawa areas. During this extreme moisture event, the rain-swollen Little Saskatchewan River made its way to the Assiniboine River, which impacted Minnedosa, Rapid City, and Rivers. Thousands of acres of crop- and hay-land flooded in southeastern Manitoba due to these recent extreme moisture events. Many acres were too wet to plant by the June 20 crop insurance deadline.

Manitoba's producers face the continued effects of extreme moisture conditions and seek adaptable, and resilient approaches to overcome disasters caused by extreme moisture events. A large number of producers in Manitoba rely on drainage systems for the removal of excess water from farmland to address extreme soil moisture issues caused by extensive precipitation, spring snowmelt, and storm water. The purpose of agricultural drainage is to remove, during the growing season, water in excess of the needs of crops and to prevent sitting water from reducing yields. Efficient field drainage system helps in rapid removal of excess soil moisture to reduce or eliminate waterlogging and return soils to their natural field capacity. The demand for agricultural drainage has increased recently to tackle uncertainties in precipitation patterns that are anticipated under a changing climate. Manitoba's producers use several field management techniques to reduce the extreme soil moisture stresses during the growing season by improving soil physical properties including tile drainage, water retention ponds, zero-tillage, change in cropping system, growing moisture tolerant crops, cover cropping, and surface drainage practices.

Considering historical flood events, Manitoba's diverse soil and crop conditions, and long-term benefits of adopting excess moisture management strategies; Rural Development Institute (RDI) of Brandon University proposed four farm investment options including water reservoirs, tile drainage, land grading, and cover cropping. These options also provide nutrient management and other types of co-benefits on farms in the southern Manitoba. It is important to consider the economic costs and benefits associated with different adaptation strategies as management decisions are often based on this information (Belcher, 1999). Initial costs for adaptability measures can be prohibitive for some operations and a thorough understanding of all operating costs and potential cash-flow is imperative in making an economic decision. In the phase-1 of this project activity, RDI recommended basic design considerations and developed a cost-benefit framework for proposed investment options to manage on-farm extreme moisture. The report generated in the phase-1 manifested how different farm investment options adopted for extreme moisture management could mitigate the negative impacts of floods and can also provide significant nutrient management and other types of co-benefits on the farm by quantifying and monetizing benefits of these investment options. When choosing an extreme moisture management strategy, any current issue on the farm must be clearly identified in order to choose one or more approaches to invest in to address and solve on-farm problems. The frequency, magnitude, and trend analysis of floods, and size of the farm will help in deciding the investment option best suited for the area in order to reduce risk to farmers and the region. An economic cost-benefit framework of each of the four investment options was developed to compare benefits over invested cost. Cost benefit ratios were provided to develop the understanding of the amount of return that could be expected on each dollar of investment for each of the four proposed options. This cost-benefit framework provides Manitoba producers the knowledge to make and support on-farm investment decisions based on their experience of extreme moisture events at their farm, land holding, and scale of operations.

Phase-2 of this project aims to validate findings and outcomes of this activity executed in phase 1. In order to achieve this objective, RDI organized a series of surveys to receive feedback from targeted stakeholders involved in this study in terms of how these analyses might be useful to their decision making. The main objectives of this research activity are to:

1. Validate the economic cost-benefit framework of proposed investment options for farm-level extreme moisture management.
2. Determine what extreme moisture management strategies producers are currently using at their farms.
3. Evaluate the willingness of producers to adapt their farm using proposed extreme moisture management strategies.
4. Conduct a Manitoba local market survey to validate cost estimations used in the development of cost-benefit framework.

Review of Literature

In order to counter the detrimental impact of extreme water on agricultural production, producers in Southern Manitoba are using a diverse range of management techniques and resources including subsurface drainage, water retention ponds, zero-tillage, change in cropping system, growing moisture tolerant crops, cover cropping, surface drainage practices, and excess moisture insurance program. A brief overview of current extreme moisture management strategies used by Manitoba producers is given below.

Drainage Management

In agricultural lands, improved productivity can be achieved through the removal of excess water using a drainage system. Drainage provides several benefits, such as better soil aeration, improved trafficability, early warming of the soil to enable early planting, and reduced soil salinity and waterlogging. However, the drainage water can carry nutrients, such as nitrogen and phosphorus, from farmlands that eventually reach downstream water bodies and cause nutrient enrichment. Nutrient enrichment of Lake Winnipeg by nitrogen and phosphorus has contributed to water quality issues, such as algal blooms and oxygen depletion. Community-based watershed management is a process for managing water resources that involves engaging stakeholders in making and implementing management decisions that are sustainable and appropriate for local conditions. It is important to understand the interaction between the upstream system conveying the flow, and the downstream receptor system to assess the impact on downstream systems and select an appropriate extreme moisture management technique.

Surface drainage involves the provision of drain outlets such as open drains, ditches or channels to remove extreme water from the surface. However, subsurface drainage involves placement of tiles, or perforated pipes, at a certain depth and spacing below the surface. The highest suitability for subsurface drains is for the coarse, moderately coarse, and medium textural classes presented in Table 1. These soils have high enough saturated hydraulic conductivities to deliver water to the drain such that loss of water from the soil is rapid enough to meet agricultural needs. For fine-grained soil surface drainage is generally more suitable.

Table 1: Soil Textural Groupings and Soil Infiltration Rate under Different Ground Cover Classes

Soil Texture	Infiltration Rate (cm/hr) by Ground Cover Class					
	Bare Soil	Row Crop	Poor Pasture	Small Grain	Good Pasture	Forest
Coarse	0.8	1.3	1.5	0.8	2.5	7.6
Moderately Coarse	0.5	0.9	1.1	1.4	1.9	4.0
Medium	0.3	0.5	0.8	1.0	1.3	1.5
Moderately Fine	0.2	0.3	0.5	0.7	0.9	1.0
Fine	0.1	0.2	0.3	0.4	0.5	0.6

Compiled from: Gray et al. (1970), Bennett et al. (1983), Ahuja et al. (1999), and Radcliffe and Rasmussen (2000).

Crop Selection and Rotations

As an added extreme moisture management tool, Manitoba producers also take into account soil properties, landform characteristics, and salinity in making crop selection and rotation decision at their farm. Among cereal, legume, and forage crops typically grown in Manitoba, some crops are better suited to conditions of extreme water than others (Table 2 and 3).

Table 2: Relative Crop Suitability in Different Soil Texture Classes under Extreme Moisture Conditions.

<table>
<tr><th rowspan="14">Annual Crops</th><th colspan="3">Soil Texture</th></tr>
<tr><th>Coarse</th><th>Medium</th><th>Fine</th></tr>
<tr><td colspan="3">Soybean</td></tr>
<tr><td colspan="3">Faba bean</td></tr>
<tr><td colspan="3">Canola</td></tr>
<tr><td colspan="3">Flax</td></tr>
<tr><td colspan="3">Sunflower</td></tr>
<tr><td colspan="2">Pea</td><td rowspan="7">Not Suitable</td></tr>
<tr><td colspan="2">Lentil</td></tr>
<tr><td colspan="2">Corn</td></tr>
<tr><td colspan="2">Wheat</td></tr>
<tr><td colspan="2">Oat</td></tr>
<tr><td colspan="2">Barley</td></tr>
<tr><td>Field bean</td><td>Not Suitable</td></tr>
</table>

Compiled from: Eilers et al. (1995), Saskatchewan Agriculture and Food (2004), Manitoba Agriculture Food and Rural Initiatives (2006)

Table 3: Relative Forage Suitability in Different Soil Texture Classes under Extreme Moisture Conditions.

<table>
<tr><th rowspan="15">Forages/ Cover Crops</th><th colspan="3">Soil Type</th></tr>
<tr><th>Coarse</th><th>Medium</th><th>Fine</th></tr>
<tr><td colspan="3">Alsike clover</td></tr>
<tr><td colspan="3">Timothy</td></tr>
<tr><td colspan="3">Creeping foxtail</td></tr>
<tr><td colspan="3">Western wheatgrass</td></tr>
<tr><td colspan="3">Reed canarygrass</td></tr>
<tr><td colspan="3">Tall fescue</td></tr>
<tr><td colspan="3">Tall wheatgrass</td></tr>
<tr><td colspan="2">Meadow bromegrass</td><td rowspan="6">Not Suitable</td></tr>
<tr><td colspan="2">Orchard grass</td></tr>
<tr><td colspan="2">Alfalfa</td></tr>
<tr><td colspan="2">Intermediate wheatgrass</td></tr>
<tr><td colspan="2">Smooth bromegrass</td></tr>
<tr><td colspan="2">Slender wheatgrass</td></tr>
</table>

Compiled from: Eilers et al. (1995), Saskatchewan Agriculture and Food (2004), Manitoba Agriculture Food and Rural Initiatives (2006)

Tillage Management

Producers in Manitoba are also using tillage management as a tool to mitigate the impacts of extreme moisture events on their farms. Conservation tillage practices reduce erosion by protecting the soil surface and allowing water to infiltrate instead of running off. Owing to a lack of infiltration caused by soil sealing or crusting flood disasters are frequently the consequence of extensive amounts of water originating from surface runoff from soils. Soil sealing is caused by raindrops that strike the surface of the soil with a force strong enough to destroy soil aggregates. A thin sealing soil layer is created by scattered surface clods and aggregates, which prevents water infiltration in a very efficient way. Inhibited infiltration through soil sealing causes surface water runoff on sloped arable land, which causes on- and off-site degradation by soil erosion. The best way to decrease or to prevent surface runoff on arable land is to prevent soil sealing and crusting. Conservation tillage has an influence on a number of physical and hydrological soil parameters. In most cases, this contributes to a drastic reduction of surface runoff on arable land. Since reduced water erosion is closely connected with reduced water runoff, conservation tillage on arable land in the whole catchment may be both an effective strategy against water erosion and an efficient element of flood control.

Excess Moisture Insurance (EMI)

Out of 17.6 million acres farm area of Manitoba, about 9.6 million acres were insured in 2019-2020 under Agri-Insurance program of Manitoba Agricultural Services Corporation (MASC). Excess Moisture Insurance (EMI) is a basic component of the Agri-Insurance program of MASC. EMI compensates producers who cannot seed their crops before June 20 due to extremely wet conditions (flooding or rainfall in the spring). EMI has a standard deductible of 5% of the total acres available for seeding.

Eligibility:

Manitoba producers are eligible for an EMI claim if they are unable to seed before June 20 due to extremely wet conditions with a minimum of 10 unseeded acres. However, EMI is not provided on the following:

- Land under sod, pasture, or perennial forage, unless the acreage was destroyed by June 10 and is ready for spring seeding.
- Fall rye, winter wheat, or fall seeded forages.
- Land which was not seeded due to extreme moisture in the previous year and which could have been worked in that previous year but was not.
- Land that MASC has deemed to be uninsurable due to high risk of flooding and/or extreme moisture.

Costs and Coverage:

All Manitoba producers participating in Agri-Insurance pay $0.54 per acre for basic EMI. The basic EMI coverage of $50 per acre is included for all MASC contract holders subject to a standard 5% deductible. A producer's EMI deductible percentage increases five per cent for each year if they have an EMI claim and decreases 5% in each non-claim year to the minimum standard of 5% (Table 5).

The deductible is calculated based on the number of acres that would normally be available for seeding in the spring excluding cultivated land that was seeded the previous fall and land that is in perennial crop, sod, pasture, or forest. If a producer has a claim on one unit, the deductible on the other unit(s) will also increase.

Table 4: Coverage, and Producer Share of Premiums (per acre) under EMI Program

Claim Year	0	1	2	3	4	5	6	7
Producer Deductible	5%	10%	15%	20%	25%	30%	35%	40%
$50 Basic Coverage	$0.54	$0.54	$0.54	$0.54	$0.54	$0.54	$0.54	$0.54

Claims:

- A claim is calculated based on the number of acres not seeded due to extreme moisture, less the EMI deductible multiplied by $50.
- An EMI indemnity will not be paid if there are less than 10 acres that were not seeded due to extreme moisture on a whole farm basis.
- Claims must be filed early so that an adjustor can verify the acreage and assess the inability to seed.
- Claims must be filed by submitting a completed Seeded Acreage Report no later than June 22.
- Claims registered after June 22, but on or before June 30, will be charged a late filing fee of 25 per cent of the claim (to a maximum of $1,000). Claims filed after June 30 will not be accepted.

Example:

A producer has 400 acres of cropland. The producer reports that 50 acres were unseeded due to extreme moisture. The producer has a 10 per cent deductible.

Number of eligible acres	=	400		
Producer premium for EMI	=	400 x $0.54	=	$216
EMI 10% deductible	=	400 x 10%	=	40 acres
Acres not seeded	=	50		
Eligible acres after deductible	=	50 – 40	=	10 acres
EMI Indemnity	=	10 x $50	=	$500

Cost-Benefit Analysis of Proposed Investment Options

In the phase-1 of this study, RDI determined which costs and benefits should be taken into account based on ease of quantification. This was done in the light of recommendations provided by economic experts, and policy makers available through a review of literature in order to support the decision-making. Other sources of information include Manitoba Agriculture and Resource Development reports, published research, interviews with industry professionals, academics and research experts, workshops and seminars, extension events and publications, thesis reports, and news reports with a focus on Manitoba origin. The various costs and benefits that RDI deemed to be worthy of inclusion are listed in Table 5.

Table 5: Costs and Benefits Considered in the Development of Economic Cost-Benefit Framework

Costs	Monetized Benefits	Non-monetized Benefits
Capital costs	Reduction in excess moisture	Recovered soil
Operating and maintenance costs	Avoided flooding costs	Reduced sedimentation
Lost farmland	Avoided drought Reduced eutrophication Production of cattails Carbon credits New wetland habitat	Aquaculture Watering livestock Avoided water treatment costs

In order to quantify and monetize the costs and benefits for the four investment strategies, a number of assumptions were employed in the analysis, the data sources used and how data from other contexts was converted to suit the context of the four proposed investment options. The assumptions made for the cost benefit analysis were based on review of the latest literature, local market, and expert analysis. Using this information, an economic cost-benefit framework of each of the four investment options was developed to compare benefits over invested cost. Cost benefit ratios were provided to develop the understanding of the amount of return that could be expected on each dollar of investment for each of the four proposed options. This cost-benefit framework provides Manitoba producers the knowledge to make and support on-farm investment decisions based on their experience of extreme moisture events at their farm, land holding, and scale of operations. RDI estimated costs using the best knowledge available based on the 2019-20 market analysis, but both the ultimate capital and operating costs would very much depend on local economic and geographic conditions. Better cost estimates would be useful in helping confirm the results presented in the report of phase-1.

Research Design

RDI organized a series of surveys to validate the economic cost-benefit framework of proposed investment options for farm-level extreme moisture management, and to receive feedback from targeted stakeholders involved in this study in terms of how these analyses might be useful to their decision making.

Criteria for Selecting Survey Participants

Producers and other stakeholders were recruited using a snow-ball sampling approach following the selection criteria set by RDI, focusing on the prospective research participants' experience in managing extreme moisture events, their farm age and history, their major crop commodities, and their interest to participate in the survey activity.

Agricultural producers were identified by the RDI research team by reaching out to contacts available in the database of Manitoba Agriculture and Resource Development (MARD), University of Manitoba, agricultural/commodity organizations and other stakeholders groups. These organizations and stakeholders were asked to provide names and contact information of producers whom they believe might be interested in the research project. After receiving a formal consent from producers, these organizations provided a list of potential participants to RDI. These producers were contacted by phone and/or email, based on their expressed interest and contact sources available, to send an invitation of participation in the survey along with the Project Overview document. The invitation to participate included an overview of the data collection activities, time commitment, and protocol for giving informed consent and withdrawal of data.

After receiving an expression of interest from a producer to participate in the survey, the RDI research team scheduled a date, time, and venue with the producer to conduct the survey interview. These interviews were conducted during a six months period starting from July 2020; in the middle of a pandemic (COVID-19). In order to follow Brandon University's research travel orders and Provincial State of Emergency & Public Health Orders, the RDI team adopted a hybrid in-person and remote model to collect survey data. With the relaxation in provincial health orders during months of July, August, and September; a total of 70% surveys were conducted in-person at the personal choice of producers and stakeholders following provincial physical distancing protocols and other fundamentals (e.g., use of face masks/shields, hand sanitizers etc.). However, we used remote communication mediums (Zoom, MS Teams, phone, and Email communications) to conduct rest of survey interviews when the province of Manitoba moved to first code orange and then code red on the Provincial Pandemic Response System to halt COVID-19 transmission.

Recruiting Survey Participants

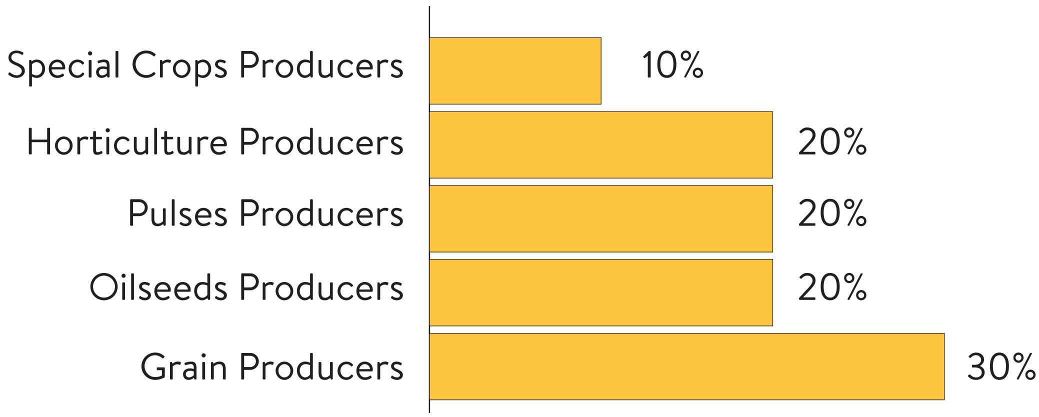
According to Statistics Canada (2016), there are 20,140 farm operators in Manitoba. A total of sixteen representative producers growing a range of crop commodities were selected from southern Manitoba following the selection criteria set by RDI to send an invitation of participation in the survey. Out of 16 producers, a total of ten producers submitted an expression of interest to participate in the survey.

Characteristics of Survey Participants

Following the selection criteria and filters developed by RDI survey team, a number of producers were selected with characteristics listed below:

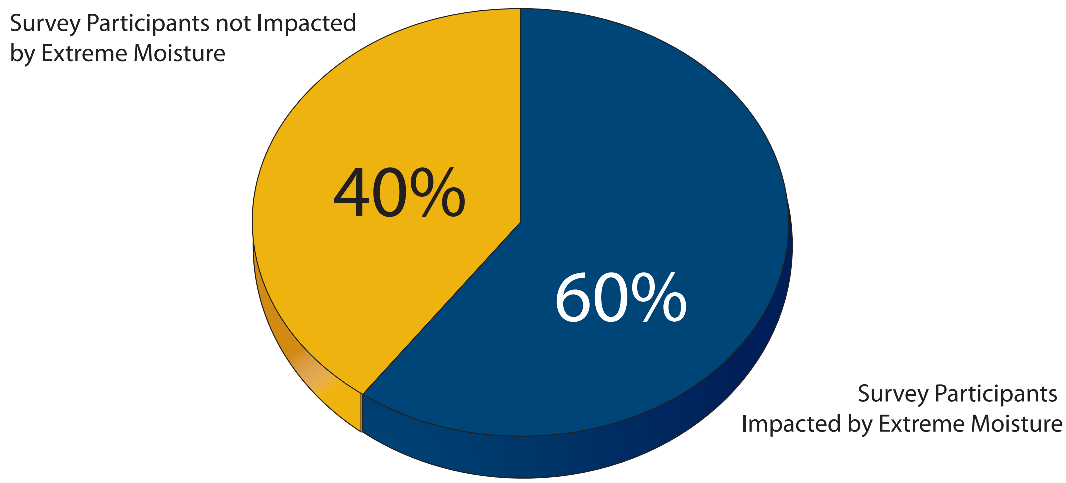
- The participants in this survey include agricultural producers/farmers from a cross-section of all crop commodities produced in southern Manitoba such as grain, forages, and vegetable crops (Figure 1).

Figure 1: Major Crop Commodities Grown by Survey Participants



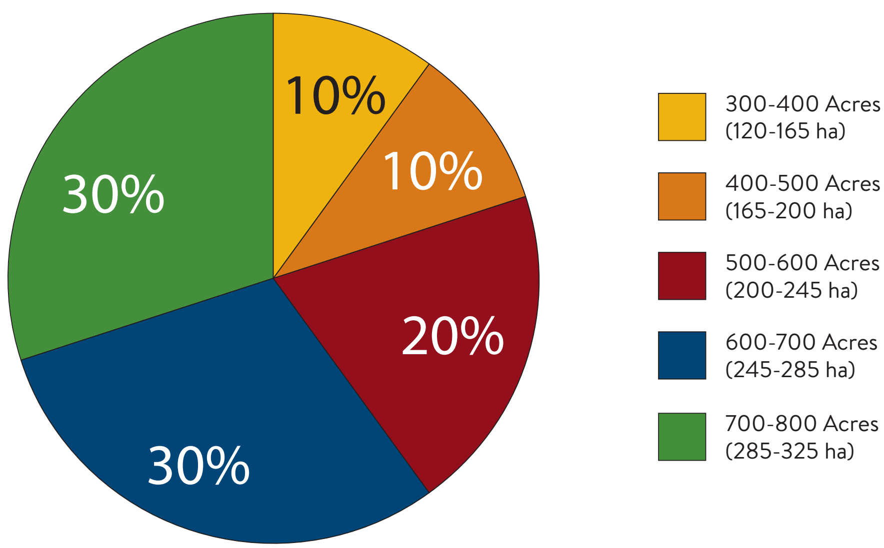
- All producers are performing their field operations either within the Assiniboine River Basin or Red River Basin.
- Out of ten participant producers, six producers' farming operations have been impacted by extreme moisture events during last 25 years. However, four participant producers have not been impacted by extreme moisture events during last 25 years. (Figure 2).

Figure 2: Extreme Moisture Events Occurrence History of Survey Participants' Farms during Last 25 Years



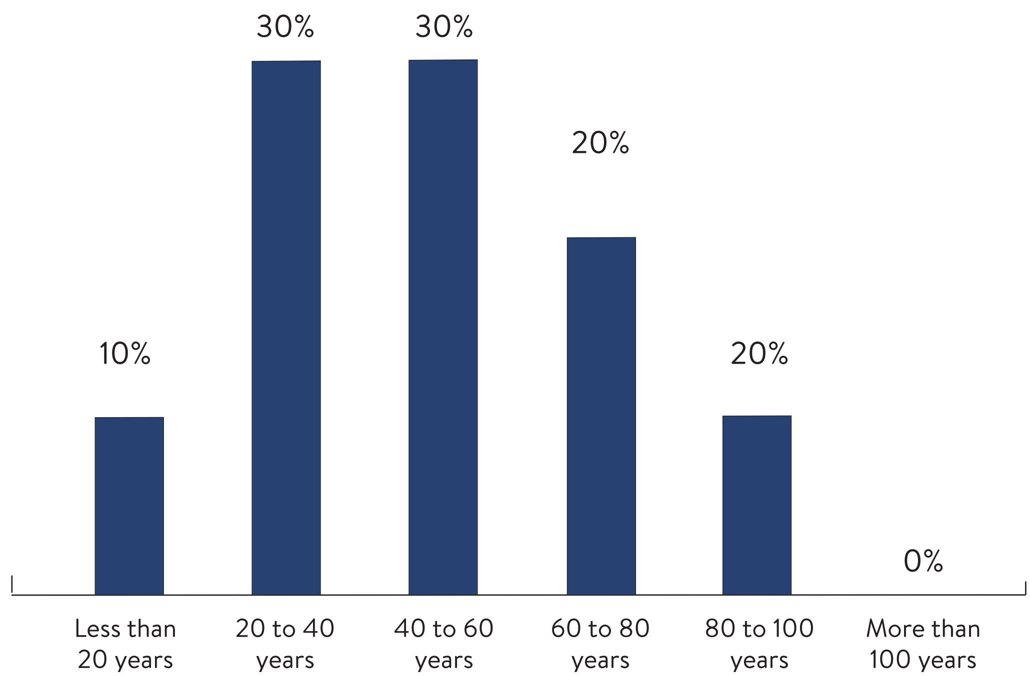
- Participant producers' land holding, and scale of operation were also taken in to account in selecting a representative sample of participants (Figure 3).

Figure 3: Land Holding, and Scale of Operations of Survey Participants



- Figure 4 shows the participation of producers with a diverse range of farm history where producers have maintained continuous production on new and family farms.

Figure 4: Farm Possession Age of Survey Participants



Research Methodology

The RDI survey team developed two research instruments for this survey activity. The first instrument was a discussion guide of investment options to manage on-farm extreme moisture; the second instrument was a set of open-ended interview questions and discussion topics to facilitate the identification of decision factors and investments strategies considered by producers to mitigate on-farm extreme moisture.

All survey participants were asked to provide feedback on the discussion guide of investment options to manage on-farm extreme moisture and to provide responses to the interview questions and discussion topics. The aim to discuss the economic framework of the four proposed investment options for farm-level extreme moisture management was to receive producers' feedback about cost and benefits involved in the framework and evaluate their willingness to adapt their farm using proposed extreme moisture management strategies. The aim of interview questions was to identify issues surrounding extreme moisture on their farms, flooding experiences, farm and crop history, what are they currently doing to manage extreme moisture, and what their future plans are to manage possible extreme moisture events at their farms. The length of the interview process was targeted as 60 minutes. However, the surveyor was available to discuss in detail the cost benefit framework of the four investment options identified by RDI after the formal interview process. If the interview was not completed during this time-period, the RDI surveyor asked to schedule another meeting time to complete the data collection at the producer's convenience, providing an estimate of the time required to complete the interview. Within a period of two weeks after the survey interview, the RDI surveyor scheduled a 5-10 minutes follow-up call with the survey participant to clarify the data collected during the interview. According to terms and conditions of the survey process, all survey participants will remain anonymous through the use of pseudonyms (e.g., a producer, a stakeholder etc.).

Key questions addressed during this survey are:

- What are key characteristics of agricultural enterprises (years of operation, types and yields of agro-produce, scale of operation, etc.) that factor into managing on-farm extreme moisture events?
- What strategies do, or might agricultural producers consider, in their efforts to manage extreme moisture at their farm?
- What investment issues do, or might agricultural producers consider, in their efforts to manage extreme moisture at their farm?
- What other factors do, or might agricultural producers consider, in their efforts to manage extreme moisture at their farm?
- Are survey participants willing to adapt their farm using extreme moisture management strategies proposed by RDI?
- What type of benefits from proposed investment options for farm-level extreme moisture management producers consider important in the cost-benefit framework?
- How do market appraisals of cost factors used in the extreme moisture management vary from year to year?

In order to seek survey respondents' feedback to find answer for key questions, survey interviews in this study surrounded topics listed in Table 2:

Table 6: Data Collected from Survey Participants during Interviews

Survey Topic	Data Collected
Farm Information	• Farm location • Site characteristics • Major crops • Crop production area • Yield patterns • Irrigation sources
Non-crop Activities	• Livestock production • Poultry production • Fishery production • Cattail production
Farm Flooding History	• Flood frequency and pattern • Extreme moisture impacts • Access to flood information
Current Management Strategies	• Flood management (arrangement and structures) • Impacts and efficiency of current structures • Structures' maintenance • Land area under management
Future Considerations	• Willingness to adopt extreme moisture management strategies • Preferable strategies • Land area under management • Accommodation of wetlands
Market Analysis	• Capital costs • Operating and maintenance costs • Lost farmland • Capital recovery factor for amortizing capital cost

In discussing the importance of analysing costs and benefits of an extreme moisture management option, the RDI surveyor manifested that the economic cost-benefit framework equips producers with a systematic way of looking at investments in the introduction of proposed investment options for farm-level extreme moisture management, which should prevent them from ignoring important benefits or constraints which may inhibit its adoption. The surveyor recognized that the most important feature of the cost-benefit framework is that it prompts the producer to search systematically for certain types of information, three of which are highlighted below.

1. The cost-benefit framework makes it relatively easy to identify the nature of complementary investments, which the extreme moisture management option may require to be fully effective. In effect, the use of the cost-benefit framework to identify constraints on the introduction of the extreme moisture management option highlights the question of the relevant size of the farm.
2. The cost-benefit framework provides a check-list which facilitates the systematic identification of the effects of the introduction of the extreme moisture management option on farm income. The identification of relevant benefits which lose or gain as a result of an investment option preference allows the selection of an appropriate extreme moisture management strategy to mitigate adverse impact of extreme moisture and increase farm income.
3. The explicit inclusion of environmental effects should make it less likely that the environmental consequences of the extreme moisture management option will be ignored simply because they are hard to value.

Limitation of the Study

The survey questions were designed to measure producers' interest in the cost-benefit frame work. The survey data was collected with a target of performing measurements to be as reliable and valid as possible, in order to have confidence in the findings and in their ability to generalize beyond the current sample and setting. However, the researchers identified following limitations of this study:

1. The survey data was collected in the southern Manitoba from a limited number of producers soon after an extreme moisture event during the 2020-planting year. It is difficult to measure changes in the population unless two or more surveys are done during different times of the year. Such repetition is often expensive and time-consuming, making frequent periodic surveys impractical.
2. A small sample size was studied to gain preliminary insight from a range of producers. Although, the participants in this survey include agricultural producers from a cross-section of all crop commodities produced in southern Manitoba, the study findings can not be generalized to all producers growing a range of crop commodities in the province. However, it provides sufficient information regarding producers' current extreme moisture management activities and their interest level in investment options proposed by RDI.
3. Since agricultural producers were recruited based on the recommendations of Manitoba Agriculture and Resource Development (MARD), University of Manitoba, agricultural/commodity organizations, and other stakeholders groups, they were not randomly selected participants. They may already be in favour of managing extreme moisture at their farms, which may bias findings and they may not fully represent full range of producers in the southern Manitoba.
4. The researchers aimed to conduct face-to-face surveys during this study as these surveys are clearly structured, flexible and adaptable for producers. However, mandated social distancing and lockdowns made physical surveys a challenge in this study.

Research Findings and Discussion

In order to report survey respondents' feedback to find answer for key questions, research findings from survey interviews surrounds producers' feedback on cost-benefit framework of proposed investment options, current extreme moisture management strategies, and producers' experience about recent extreme moisture events.

Cost-Benefit Framework of Proposed Investment Options

A diverse feedback was received from all survey participants about making investment option choice out of the four extreme moisture management options identified by RDI. Recognizing the viability of extreme moisture management strategies identified by RDI, a majority of producers indicated, *"All four farm level extreme moisture management strategies can independently reduce crop damages, livestock losses, and human suffering."* However, few survey participants acknowledged, *"Farm investment strategies in league with other resources e.g. EMI, crop selection/rotation etc. can reduce the potential damage due to extreme moisture conditions caused by floods or spring snowmelt runoff."* Three out of ten producers said, *"Not all proposed investment options are suitable at every farmland. The selection of an investment option highly depends on soil type, geographical location of farm, scale of operation, and major growing crops."* They further identified, *"Excavation of water reservoir is suitable for all farms and gives several benefits in farming operation but the initial investment cost is too high."*

A great level of interest was observed in the cost-benefit framework developed by RDI to track farm benefits against the investment made. All survey participants found the cost benefit framework a useful tool in their investment decision making. Identifying the advantage of cost-benefit framework in investment option selection, seven out of ten producers acknowledged, *"The economic cost-benefit framework provides a systematic way of looking at investments in the introduction of proposed investment options for farm-level extreme moisture management, which should prevent a producer from ignoring important benefits or constraints which may inhibit its adoption."* They further recognized, *"All four farm strategies proposed in this report have long infrastructure life and provide more benefits over costs."* Eight out of ten survey participant producers suggested, *"It is also essential to have a customized framework in producers' hand to calculate the initial investment required for their farmland and come-up with a benefit proportion, so producers can make business informed decisions of management planning."* These producers' further identified, *"There is a variability in civil work and excavation cost every year which effects the capital cost, and operating & maintenance cost calculated in the report."* The RDI survey team contacted civil work service providers to receive an updated appraisal cost to develop an understanding that how dollar values of cost factors used in the extreme moisture management are varying from year to year. After making a comparison between 2019 and 2020 cost appraisals, a considerable variability was observed in civil work cost estimations.

Two out of ten producers were already using one of four investment options identified by RDI. They endorsed, *"The development of a customized cost-benefit framework tool would allow to calculate monetized co-benefits of these interventions in the farm setting."* All survey participants were in agreement with quantifiable/monetized benefits identified by RDI including reduction in extreme moisture, avoided flooding costs, avoided drought, reduced eutrophication, production of cattails, carbon credits, and new wetland habitat. However, the least amount of interest was observed in the production of cattails in water reservoirs and wet-lands. In this regard, eight out of ten participating producers identified, *"Cattails grow vigorously and the resulting biomass can eventually block out the growth of more desirable and less invasive plant species. The cattail growth can obstruct critical elements of a water reservoir. These include drain structures, emergency spillways, auto-fills, and irrigation intakes. Blocking of drain structures and spillways increases the risk of flooding. The cattail harvesting is also a challenge and specialized equipment and expertise are required to harvest cattails from water reservoir's banks."*

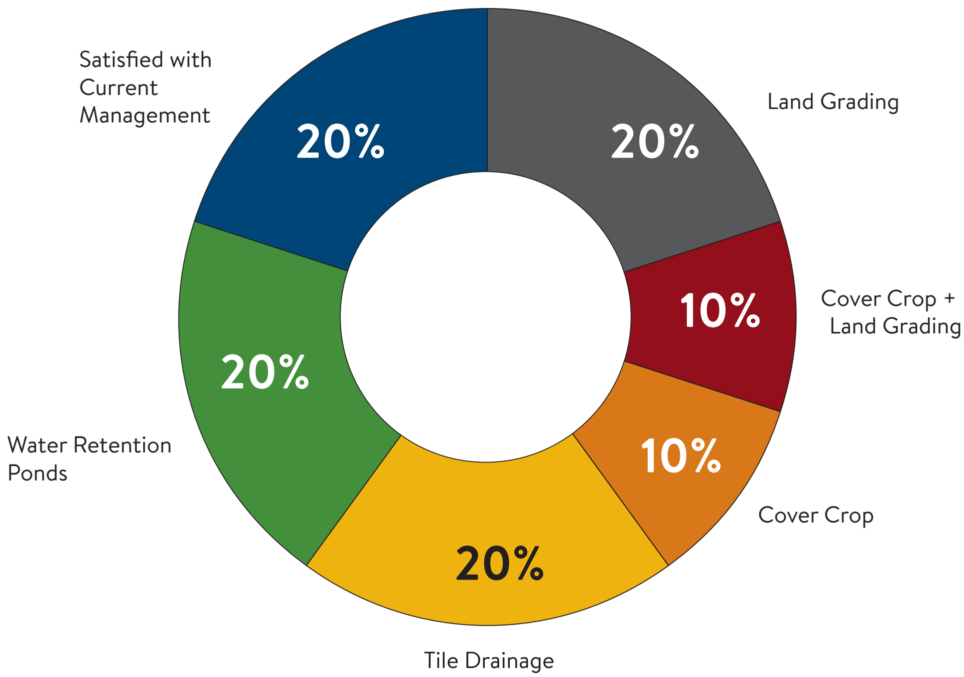
A reduction in the risk of drought by storing water in on-farm water reservoir and controlled tile drains was discussed as a unique benefit during survey interviews. All ten survey participants identified, *"It is important to retain flood water in a storage structure e.g. water reservoir, or controlled tile drains that could travel downstream or near farms during an extreme moisture event. In this way, the stored water would be at producer's disposal should drought conditions arise."* A majority of producers also recognized the importance of un-quantifiable benefits excluded from the cost-benefit calculation because they were difficult or impossible to measure and/or monetize. *"Depending on the investment option selected, all or few of these benefits would certainly be received to varying degrees"*, they acknowledged. Eight out of ten study participants recognized, *"Water reservoir and wetlands are sustainable long term solutions of extreme moisture management. However, the capital cost involved in the construction of a water retention pond is a major barrier to adopt this intervention."* Participating producers were also interested to know what funding opportunities are available for the adoption of beneficial management practices to help farmers improve sustainability and reduce environmental risks on their farms. The RDI survey team shared the information of available funding and subsidy opportunities for Manitoba producers including "Ag Action Manitoba Program for Farmers".

Given the capital cost involved, scale of farming operations, and interest in farm adaptation using different investment options identified by RDI, survey participants showed their willingness to adopt extreme moisture management options in the following order:

1. Cover Crops
2. Land Grading
3. Cover Crops + Land Grading
4. Tile Drainage
5. Cover Crops + Tile Drainage
6. Water Reservoirs

Figure 5 shows the data collected in the survey regarding future considerations of all survey participants to manage extreme moisture events at their farm holding.

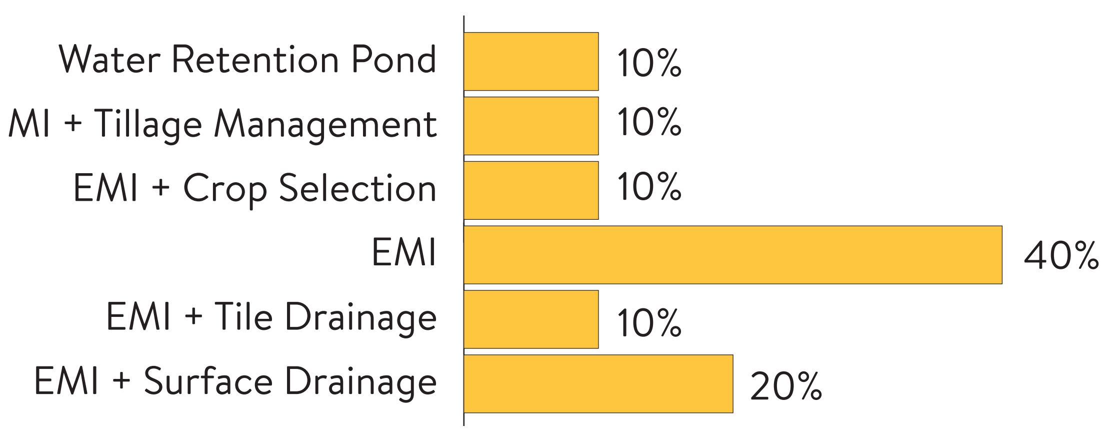
Figure 5: Future Considerations of Survey Participants to Manage Extreme Moisture Events at their Farms



Current Extreme Management Strategies and Resources

In order to counter the detrimental impact of extreme water on agricultural production, producers in Southern Manitoba are using a diverse range of management techniques and resources ranging from drainage to cropping systems solutions (Figure 6).

Figure 6: Management Strategies and Resources including EMI (Excess Moisture Insurance) used by Manitoba Producers for On-farm Extreme Moisture Management



A brief overview of producers' feedback regarding their current choices of extreme moisture management strategies and resources is discussed below.

Drainage Management

In this category, Manitoba producers are using two drainage methods for removing extreme water from their agricultural land:

1. Surface drainage
2. Subsurface drainage

Surface drainage

Two out of ten producers who are using surface drainage as an extreme moisture management tool are in agreement that the design of surface drainage system is very important for efficient removal of excess water from farmland. They said, *"Farm ditches minimize crop damage from water ponding after a precipitation event, and control runoff. An extensive surface drainage is viable on level or inclined surfaces. The slope of the land surface should be between 0.1 and 0.5%, but caution has to be exercised at slopes greater than this because of the possibility of water erosion."* Six out of ten producers said, *"Surface drains are effective at removing surface water from the soil, but do not play a major role in removal of water from within the soil profile."* A producer further identified, *"Surface drainage has never been my first choice because of erosion and filling in of ditches which requires frequent maintenance."*

Subsurface drainage

In the support of using subsurface drainage system, three out of ten producers said, *"Subsurface drains are better compared to surface drains as they accelerate the removal of water from the upper soil profile, increasing the infiltration rate and reducing the duration of extreme water. Recent occurrences of extreme moisture events have increased their interest in the sub-surface drainage approach."* Speaking about the economics of this extreme moisture management tool, five out of ten producers said, *"Sub-surface drainage is more expensive and, therefore, surface drainage is preferred on sub-surface drainage."*

Crop Selection and Rotations

In this survey activity, one out of ten producers identified that they bring crop rotation in to the consideration for the management of extreme moisture at farm. The producer said, *"Of the cereals, I choose oats as the most tolerant cereal crop of extreme water, followed by wheat, and then barley. In the legumes category, faba beans are first choice in extreme moisture conditions, followed by soybeans, with field beans and then peas being considerably less tolerant. In the forages category, I prefer grasses over legumes, if soils are too wet during seeding window. Barley may be suitable where salinity and extreme water both are issues to deal with, however, salt-tolerant forages may be the best selection in this case."*

Tillage Management

Seven out of ten survey participants acknowledged, *"Reduced tillage practices have shown to improve soil moisture retention in the upper 30 cm of the soil, which is an advantage in most of the semi-arid growing region, but may not be helpful under extreme water conditions."* However, only one producer is using tillage management as an extreme moisture management tool. The producer reported, *"No- or zero-tillage practices have a significant impact on infiltration and drainage compared with conventional tillage."*

Excess Moisture Insurance (EMI)

Nine out of ten survey participants reported that they rely fully or in part on excess moisture insurance to compensate the impact of extreme moisture events at their farm. However, they also identified several limitations and challenges associate with EMI. Speaking about constraints of EMI, all producer participants acknowledged, *"Crop insurance covers total production for insured crops on a farm, not each field individually. We would prefer field-by-field coverage."* They also threw some light on advantages of EMI by saying, *"Producers who can re-seed drowned fields by June 20 are entitled to a re-seeding benefit of 25 per cent of the coverage for the crop they are re-seeding. If the producer can re-seed by the deadline but chooses not to they are entitled to 50 per cent of the coverage. This option gives farmers more management flexibility. Some farmers may feel it's too late to seed and not worth the risk."*

To get an insight of EMI, an MASC official was contacted. They responded, *"The premium costs would be too high by covering each field individually, reflecting the much higher risk of payouts. The deadline for planting insured green-feed is July 15, with reduced coverage. Producers can seed green-feed even if they have received a payout because their crop was destroyed by the extreme moisture event. However, to be eligible to insure green-feed, producers will have had to have selected it as an insurable crop. Some producers only select crops they know they are going to grow, even though selecting all crops for potential coverage doesn't cost any extra. Producers only pay premiums on the crops they grow."*

Producers' Experience of Recent Extreme Moisture Events

One of several discussion topics of this survey activity was to get a feedback from survey participants about their experience of extreme moisture events' occurrence at their farms. This discussion surrounded the series of most recent extreme moisture events of the southern Manitoba. A number of producers' statements and experiences about recent extreme moisture events are being reported here. Identifying the impact of recent extreme moisture events on different crops, several producers reported,

- *"I lost 10% of my crop, including 250 acres of canola, 100 acres of wheat, 25 acres of peas and some oats."*
- *"Crop damage has been very dependent on crop. Soybean, sunflowers and wheat had come out of the moisture best, while peas have been hard hit and canola ranges."*
- *"Cereal crops and soybeans seem to have weathered much of the extreme water, while crops like canola have much more mixed results and field peas have sustained considerable damage."*
- *"Peas don't like having wet ground, for sure but as much as anything it's the growth stage of the crop. So crops like canola, and cereals, if they were a little more advanced, they seem to handle it a little bit better. If it was a little bit later seeded so they were quite small when that rain hit, then certainly they seem to be suffering a little bit more than some of the ones that were seeded a little bit earlier."*
- *"Most of the grain crops, like your wheat and what not, for the most part are doing quite well with the rain. There is going to be places where there is rain on the fields, but they are doing much better than the canola."*
- *"We contacted MASC about green-feed on those damaged acres in late July. They told us that green-feed must have been planted by July 15 in order to be insured."*

Sharing an overall experience of handling extreme moisture events, some producers identified,

- *"In my 21 years of farming, I have never seen worse flooding than flooding caused by 2020 rains. Our fields are all waterlogged. It's knocked out quite a bit of the young canola. During a four days period, my farm had received more than 200 millilitres of rain, which came as a big shock after such a dry early spring. If we can't save it, we will wait till it dries and we will have to turn it over and maybe plant a fall crop."*
- *"We were stranded for the first three to four days following the rains, due to road damages."*
- *"In my 38 years of farming in southeastern Manitoba, I can not remember a worse 12 months. I had the same situation last fall. I was just into harvesting my crops and the water came along and I could not take most of it off, it was too wet to take off. Here we just got the crop in last week and it's all underwater again, so what do we do now?"*
- *"Fungal disease has also become a problem, something that has been complicated by the difficulty many producers found attempting to access their fields."*

- *"Our basement is flooding and our farmland is covered in water. The hay crops could be saved, but the grain crops on the low-lying land are likely done, adding some rainfall was necessary, but not this much. We hope to replant the damaged crops, if and when we can."*
- *"Two weeks after record rains hit the Brandon and Minnedosa regions, some low spots still had standing water."*

A producer who is using water retention pond as an extreme moisture management tool recognized that, "The flooding around our farm could have been worse. The marshland (wetland) and retention ponds on our property took the edge off the floodwater."

Discussion

The survey was undertaken to directly ask Manitoba producers to validate the economic costs and benefits framework of proposed investment options for farm-level extreme moisture management and to evaluate the willingness of producers to adapt their farm using proposed extreme moisture management strategies. All survey participants recognized the importance of this study as majority of them have been impacted by recent extreme moisture events in Manitoba. They acknowledged that all four farm strategies proposed in this report have long infrastructure life and provide more benefits over costs and the cost-benefit framework of extreme moisture management options is a valuable attempt to identify farm investments in a systematic way. With recognized benefits of farm investment options, a profound interest was observed to adapt farms using extreme moisture management systems to add numerous benefits to the agricultural land in the context of water management. A majority of producers recognized that the values of costs and benefits identified in the framework vary from farm to farm and the development of a customized cost-benefit framework tool would allow to calculate monetized co-benefits of these interventions in the farm setting. These responses were used to improve the utility of cost-benefit framework of extreme moisture management investment options. Respondents identified that a variable trend in the proposed farm interventions' cost, and interest rates are a major obstacle to estimate the actual cost and subsequent benefit in a particular year. Given the interest of study participants, a customized cost-benefit framework tool is developed in the form of an excel spreadsheet where Manitoba's producers can conduct cost-benefit analyses of a chosen investment option for their own form with the selection of their land holding and desired benefits. Producers are advised to confirm current capital cost and interest rate with their local market, and lost farmland using Government of Manitoba's Cost of Production Guide. This customized cost-benefit framework tool is available at RDI's Website of Brandon University in the downloadable format with this report. Given survey participants' interest, a link to the Ag Action Manitoba program for farmers is provided here for funding opportunities available for the adoption of beneficial management practices to help farmers improve sustainability and reduce environmental risks on their farms. This program provides funding to farmers for training and consulting, adoption of beneficial management practices, and research and innovation.

https://www.gov.mb.ca/agriculture/canadian-agricultural-partnership/ag-action-manitoba-program/for-farmers.html

In order to counter the detrimental impact of extreme moisture events on agricultural production, producers in Southern Manitoba are using a diverse range of management techniques and resources including drainage, crop rotation, tillage management, and excess moisture insurance. It was observed that a large number of study participants were using excess moisture insurance independently or in-league with other extreme moisture management strategies to compensate impacts on extreme moisture events at their farms. Climate change is expected to continue to bring higher levels of extreme moisture to Manitoba's farms, making producers dependent on EMI. At the same time, the program needs to be actuarially sound and viable over the long term. The EMI program is currently facing a number of issues that could impact its long-term viability. For example, low risk producers currently share in the cost of the program. Their premiums will likely need to rise in the future, which may lead some to opt out of the program. The program is not viable without universal participation. MASC must also take steps to ensure the program adheres to sound insurance principles, including that it cover accidental loss (protect against moral hazard), group similar risks together, adhere to a principle of indemnity (restore to position prior to the loss) and to maintain an affordable premium. Additionally, a MASC review has determined that in some cases, losses are more related to management than to climate. This speaks to the need to tie program participation and premium rates to producers' farm management practices. Producers also need to understand that EMI is insurance as opposed to compensation. It manifests the importance of long-term action plan; for example, farm adaptation with extreme moisture management strategies to receive multiple benefits over investment.

At a producer's interest to know about how long newly seeded crops survive under extreme moisture conditions, the RDI survey team summarized below an article available at Manitoba Agriculture and Resource Development's website.

- How long newly seeded or seedling crops survive under water depends on the crop and the weather (MARD, 2021).
- Seeds and seedlings are living organisms and need oxygen to live. Within 48 hours of being oxygen-deprived, chances of survival are limited.
- To combat extreme water and disease, drainage within one to two days will increase the chances of survival. Most annual crops can withstand 24 to 48 hours in waterlogged conditions and up to seven days. In general, grasses are more tolerant than legumes. In cereal crops, oats are the most tolerant, then wheat, and then barley. In legumes faba beans followed by soybeans are most tolerant, with field beans and peas considerably less tolerant.
- Cool water and soil temperatures will help flooded crops survive better than hot temperatures.
- After the water is gone, it is recommended to examine the colour of the seedlings' growing points. The stem germinating out of the seed (radicle and coleoptile) should appear white or cream coloured. If no germination has occurred, seeds can be cut in half to determine if turgor pressure is still present. If the seed is extremely soft and does not hold form, it probably won't survive. Surviving plants will resume growth within three to five days after the water recedes.
- It is recommended to evaluate plant population and uniformity and weigh out what the crop stand left will potentially yield versus a replanted crop at this later date.
- An additional nitrogen application may be necessary in fields that show signs of yellowing or uneven growth. A late test for nitrate can determine if more nitrogen is needed.
- It is recommended to maintain a good weed control program so that crop plants are not robbed of nutrients and moisture later in the season.

Conclusion

Canadian producers are leaders in climate-smart agriculture, finding new approaches to sustainably feed Canada and the world. The agricultural sector's vulnerability to climate change is dependent on the nature of climatic change, regional climatic sensitivity and the capacity to adapt to changes. With the conscious development of resources to build adaptive capacity, agriculture can adapt to and meet the challenges presented by climate change. Farm adaptation has the potential to reduce the magnitude of challenges associated with extreme moisture events and increase the capture of possible benefits. For benefits to be observed, practices will need to be chosen that can accommodate the current and changing climatic conditions. In the phase-1 of this project activity, Rural Development Institute (RDI) demonstrated how different farm investment options adopted for extreme moisture management could mitigate the negative impacts of floods and can also provide significant nutrient management and other types of co-benefits on the farm. With the base case representing current conditions, four other strategies were selected and used in southern Manitoba, namely: water reservoir, tile drainage, landscaping or cut and fill, and cover cropping. An economic cost-benefit framework of each of the four investment options was developed to compare benefits over invested cost. Cost benefit ratios were provided to develop the understanding of the amount of return that could be expected on each dollar of investment for each of the four proposed options.

In phase-2 of this project, RDI organized a series of surveys to validate the economic cost-benefit framework of proposed investment options for farm-level extreme moisture management, and to receive feedback from targeted stakeholders involved in this study in terms of how these analyses might be useful to their decision making. This baseline survey of Manitoba producers provides a valuable and unique insight into the current management strategies to mitigate the impacts of extreme moisture events at Manitoba farms. Participating producers were convinced that all four farm strategies proposed by RDI have long infrastructure life and provide more benefits over costs. However, they also revealed concerns about a rapid variability in civil cost every year which effects the capital cost, and operating and maintenance cost calculated in the report. Given the interest of study participants, a customized cost-benefit framework tool is developed in the form of an excel spreadsheet where Manitoba's producers can conduct costs and benefits analyses of a chosen investment option for their own farm with the selection of their land holding and desired benefits. A majority of survey participants verified that the economic cost-benefit framework provides them with a systematic way of looking at investments in the introduction of proposed investment options for farm-level extreme moisture management, which should prevent them from ignoring important benefits or constraints which may inhibit its adoption. Moreover, because all producers were in agreement with costs and benefits identified by RDI, it would improve the consistency of the information on which different investment decisions were made.

This cost-benefit framework provides Manitoba producers the knowledge to make and support on-farm investment decisions based on their experience of extreme moisture events at their farm, land holding, and scale of operations. It enables producers to take into account potential benefits of proposed investment options which have been discussed in the standard literature for many years. It is necessary to examine the infrastructure to ensure it is capable of meeting the uncertainties and challenges of a future where climate is more variable and extreme. We need to realize that activities that are suitable in dry years may not be suitable in that same location in wet years and plan accordingly. Although we have outlined a framework suitable for four investment options identified by RDI, it could be adapted easily for the analysis of other types of extreme moisture management options. Cost-benefit analysis that takes all the possible effects into account is very complicated and it necessarily includes several assumptions and estimates concerning the valuation of the benefits and disadvantages. All effects cannot be valued in a cost-benefit analysis. Even though some of these effects are not directly reflected in the results, they still have to be taken into account in the interpretation of the overall impacts and results. The results will obviously remain open to various interpretations in respect of the values in monetary terms. However, the results are indicative for agricultural policy-making and provide a basis for further quantitative and qualitative analyses, and general discussion. One area of future research would be the assessment of suitability of proposed investment options for different crop types. Moreover, Manitoba's livestock producers face devastating impacts of extreme moisture events including livestock losses, pasture damage, lost grazing, cost to repair, clean-up, ongoing loss of production, weed problems, and impact on hay production. Development of a cost-benefit framework of flood management strategies suitable for livestock producers may be another area of future research.

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