We would like to thank the reviewers for their insightful and constructive comments and efforts towards improving our manuscript. We present our point-to-point responses as follows:

**Reviewer #1**

**General comments**:
The manuscript presents modelling results to evaluate the potential of replacing arable crops by forage crops to reduce eutrophication problems in the Canadian Prairies. It approaches the topic from a hydrological perspective by investigating to which degree the different crops affect runoff formation causing nutrient losses. This topic fits the scope of HESS. The manuscript reads well and is generally easy to follow. Nevertheless there are a number of critical issues that need to be resolved before the manuscript is ready to be published.

*Unbalanced discussion and literature review*. The Introduction and the Discussion is not very balanced regarding potential advantages and disadvantages of forage crops. Advantages of forage crops are highlighted, disadvantages such as observed increased nutrient concentrations in runoff are neglected despite referring to articles (Liu et al., 2014) that point out these aspects in very clear manners (see below). A more comprehensive discussion is needed to provide the reader with broad and differentiated arguments. It might be also useful to touch upon the question what such a large-scale land use change might imply for the agricultural sector. I am aware that the authors aren't the specialists for that aspect. Nevertheless, it may be useful to at least refer to that aspect to avoid naive views on the problem. This broader view may also be relevant for asking relevant questions for hydrological research in the future to address the topic from a more interdisciplinary perspective.

Reply: Both the introduction and the discussion sections have been revised to expand the arguments about nutrient concentration in runoff as well as large scale implications to the agricultural sector.

The revision is as follows:

**Introduction**:

The Red River Valley in Manitoba is prone to large overland flooding events and is one of the largest sources of water and nutrients to Lake Winnipeg. In recent decades, the frequency of flooding, the intensification of agricultural activities in the basin, and environmental implications on associated water courses have come into increased focus (Benoy et al., 2016; Mccullough et al., 2012; Rattan et al., 2017; Painter et al., 2021; Cordeiro et al., 2017). Since the mid 1990s, an increase in runoff during the spring snowmelt season and frequency of spring flooding has been observed in the Red River Valley (Ehsanzadeh et al., 2012; Schindler et al., 2012). This, combined with the amplified nutrient availability as a result of the intensification of agricultural production in the region, is considered to be the major driver of the eutrophication of Lake Winnipeg (Mccullough et al., 2012; Schindler et al., 2012; Yates et al., 2012). Conversion of some portions of land from annual cropping systems to perennial forages in intensive agricultural basins has been proposed as means to increase agricultural system resilience in frequently flooded locations, increase carbon sequestration, increase infiltration, and water retention (Kharel et al. 2016; Hutchinson et al. 2007). However, the hydrologic changes associated with broad scale conversion of large portions of the Red River Valley to perennial forages remain understudied.

From a hydrological perspective, previous studies carried out in cold regions suggest that nutrient export from crop land is mainly driven by snowmelt runoff (Corriveau et al., 2013; Uusi-Kamppa et al., 2012; Cade-Menun et al., 2013). Therefore, reduction in nutrient loads could be achieved through reducing agricultural runoff (Li et al., 2011; Liu et al., 2014). Hydrological alterations that reduce runoff volume could also help to address downstream flooding problems, which are also a significant challenge associated with the flat topography of the Canadian Prairies under intensive agriculture (Bower, 2007; Manitoba Conservation and Water Stewardship, 2014). Several major floods have occurred in recent years in the Canadian Prairies, causing concern over causal factors ranging from climate change to agricultural management practices (Buttle et al., 2016).

Conversion from cropland to perennial forages has been observed to cause fundamental changes in the hydrology of small Canadian Prairie drainage basins, such as increases in snow trapping, snowmelt infiltration to frozen soils, and annual evapotranspiration, as well as decreased soil moisture; together, these changes have been attributed to causing reduced runoff and declining wetland storage (van der Kamp et al., 2003). However, changes in hydrology have been mainly described as a result of field-scale observations in Saskatchewan and were made outside the higher rainfall and warmer climate of the Red River Valley of Manitoba, which also has high incidence of clay soils. These differences make it difficult to extrapolate the impact of forage conversion to broader scales due to the role of landscape physiography (e.g., soils texture, topography) and climate on hydrology (van der Kamp et al., 2003).

However, from a nutrient export perspective, research also suggests that conversion from cropland to perennial forages could result in increased nutrient losses in the years directly following conversion. For example, a field experiment carried out by Liu et al. (2014) observed increased P and NH3 losses from perennial forages planted on former cropland and attributed this pattern to increased concentrations following nutrient release from forage residue due to freezing. Likewise, Cade-Menun et al. (2013) found significantly more N in pasture runoff than crop land, despite no significant difference in total phosphorus loss in runoff between those land covers.

These contrasting perspectives suggest that comprehensive studies integrating long-term land use (e.g., land cover and land management), climate, and physiography (e.g., soil properties, topography, and drainage conditions) are still required to understand the impacts of land conversion on water quality in the Lake Winnipeg basin. Full investigation of nutrient export is complex at large spatial scales, requiring available data on nutrient management practices adopted at field scale (e.g., fertilizer application rates, times, source; Mikkelsen, 2011). Research to more fully define the factors controlling nutrient dynamics in the region is ongoing (e.g. Liu et al. 2019), and continued research is required before the influence of forage conversion on nutrient source can be accurately represented in a modelling framework. Particularly, the relative importance of freeze-thaw release of nutrients from frozen vegetation, stratification of nutrients near the soil surface, and legacy of past nutrient inputs cannot be differentiated in those observational studies cited above.

On the other hand, assessing hydrological dynamics at large scales is more feasible due to the availability of ancillary data [e.g., soils databases and weather records (Cordeiro et al., 2018; Cordeiro et al., 2019)], hydrometrics observations (ECCC, 2018), and modelling tools (Beven, 2011). The Cold Regions Hydrological Modelling (CRHM) platform was specifically developed to address the challenges of modelling cold-region hydrology in the context of the Canadian prairie physiography (Pomeroy et al., 2007). CRHM adopts a physically-based representation of key hydrological processes in the Canadian Prairies such as blowing snow transport, redistribution and sublimation of snow, infiltration to frozen soils, energy-balance snowmelt, snowmelt runoff, combination of aerodynamic and energy balance evapotranspiration, soil moisture redistribution, runoff, and streamflow routing (Fang et al., 2010; Pomeroy et al., 2007). The platform is also robust for scenario assessment of land use and climate change (Fang and Pomeroy, 2020; He et al., 2021; Pomeroy and Krogh, 2019), and is under constant development to incorporate recent advances in physically based descriptions of hydrological processes (e.g., Fang et al., 2013; Harder and Pomeroy, 2014).

The objective of this research was to evaluate the basin-scale hydrological impacts of land use conversion from annual crop to perennial forages in the Canadian Prairies using the CRHM platform framework. A custom model was developed using CRHM to represent the typical perennial forage and cropping conditions in the Red River Valley. The hydrological impacts were assessed by comparing simulations between annual crop and perennial forage models. The analysis focused on changes in annual discharge volumes and peak discharge rates but also considered other water balance components such as surface runoff, snow water equivalent (SWE) accumulation, infiltration, soil moisture, and seasonal evapotranspiration (ET) volumes.

**Discussion:**

During the study period, surface runoff under annual crop contributed 72.2% of the stream discharge, which was consistent with previous studies performed in this region (Dibike et al. 2012; Glozier et al. 2006). Under the perennial forages' scenario, this contribution was decreased to 54.4%. This reduction in surface runoff, combined with an increase in evapotranspiration, resulted in reduced annual discharge from perennial forages simulated by CRHM at basin scale, which agrees with hydrological observations at field-scale in the Canadian Prairies (van der Kamp et al., 2003). Reduced overland flow in perennial forages is primarily caused by enhanced infiltration (Rachman et al., 2004; Self-Davis et al., 2003; Tricker, 1981). Through measuring infiltration to fine-loamy soils during snowmelt in Saskatchewan using single-ring infiltrometers, van der Kamp et al. (2003) found that the infiltrability of the frozen soil was much higher in grassland than cultivated fields. Their results at most of the infiltration test locations showed that the frozen soil in the grassed areas had infiltration rate in excess of the typical snowmelt rates (i.e., ⩽10 mm hr-1) while all the infiltration tests on frozen soil in cultivated fields indicated an infiltrability considerably less than the typical snowmelt rate. Enhanced infiltrability in perennial forages was attributed to the development of macropores, such as root holes, desiccation cracks, and animal burrows (van der Kamp et al., 2003). The results demonstrated that the model simulations presented here were able to capture the increased infiltration in frozen soils due to macropore formation under forage.

Higher soil moisture content for perennial forages in some years (i.e., 1994-1996, 2002-2006, and 2011) is contrary to the trends reported by field investigations in the Canadian Prairies (Christie et al., 1985; van der Kamp et al., 2003) where grasses had lower soil moisture than cultivated fields. Such contrasts could be due to the more western and drier locations and short period of field investigations [1990 and 2000 by van der Kamp et al. (2003) and seemingly 1975 and 1981 by Christie et al. (1985)], which may not cover the full range of climate conditions including very dry and wet years experience in Manitoba. Thus, the impact of perenial forages on soil moisture may not be unequivocal as suggested by previous short-term field research, and this land cover may show variation between periods of low and high soil moisture dictated by antecedent conditions. These differences in soil moisture may also be a result of differences in ET calculation, although the mean annual precipitation in the present study (560 mm) is larger than those reported by Christie et al. (1985) for Lethbridge, Alberta (350-400 mm) and van der Kamp et al. (2003) for the St. Denis National Wildlife Area, Saskatchewan (358 mm).

Recent field studies in the western Canadian Prairies indicated that differences in annual ET values between cropland and bromegrass land were attributed to their differences in phenological response to precipitation and air temperature (Morgan et al., 2019). In the present study, differences in ET between annual crop and perennial forages were mainly caused by differences in the length of the growing season, plant height, and growth rates in the CRHM models, which were parameterized by the Penman-Monteith (PM) method (Monteith, 1965), with a Jarvis-style resistance formulation (Verseghy et al., 1993). The PM method estimated stomatal and aerodynamic resistances that represent the diffusion path lengths through vegetation and boundary layer, respectively, and both resistances controlled the water vapour transfer to the atmosphere. Noteworthy, the fixed value of stomatal resistance does not account for seasonal variations in biophysical properties of vegetation (leaf area index, plant height) and for effects of environmental stress factors (i.e., light limitation, vapour pressure deficit, soil moisture tension or air entry pressure, and air temperature), which leads to uncertainties in the PM method for this study. The initial stomatal resistance value represents the minimum unstressed vegetation resistance and is difficult to measure. Moreover, there is no consensus of accepted approach to estimate four environmental stress factors, and they are determined from correlation and regression analysis (Verseghy et al., 1993). Thus, these uncertainties in the PM method could affect the ET flux estimations and should be considered when interpreting the results. Further investigations on canopy resistance formulation and field campaign to measure canopy resistance are needed to improve the ET estimations for a number of vegetation types in the Canadian Prairies.

The changes in the water balance described in this study are conducive to reductions in nutrient export from agricultural lands. Previous studies indicated that reductions in sediment and nutrient transport are closely associated with the reduction in surface runoff (Aksoy and Kavvas, 2005; Chen et al., 2016; Corriveau et al., 2013; Sharpley and Williams, 1990). Previous modelling exercises in the region also corroborates this conclusion. For example, simulations of land use conversion from annual crop to perennial forages using the SWAT model conducted in the entire La Salle River subbasin (where the study area in the present study is located) reported reductions of 37%, 58%, and 72% in sediment, total nitrogen (TN), and total phosphorus (TP) loads, respectively (Yang et al., 2014). The lower reduction in sediment compared to TN and TP was due to the majority of cropland being in very flat terrain with clay soils, making soil erosion and sediment transport processes less significant in that basin (Yang et al., 2014). However, parameterization in the nutrient dynamics module of SWAT, not discussed in detail in the study, could also have influenced these results. A stepwise calibration of stream discharge and sediment, followed by calibration of TN and TP, was achieved using the sequential uncertainty fitting (SUFI-2) calibration algorithm in SWAT-CUP software. This calibration procedure implies a dependency of TN and TP on sediment transport, which is not usually the case in the Canadian Prairies, where most of nutrient transport from basins occurs in dissolved form (Cade-Menun et al., 2013; Liu et al., 2013; Tiessen et al., 2011). Another potential concern in that study was the SWAT version used in the simulations (i.e., SWAT 2012), which does not include modules for simulating nutrient release from vegetation. As discussed above, not accounting for the contribution of perennial forages to runoff nutrient concentration could underestimate the nutrient export from these landscapes. In fact, nutrient leaching from plant residues have not been represented in water quality models, which has led to the development of process-based algorithms in the Canadian Prairies to address this gap (Costa et al., 2019).

Despite the hypothetical positive water quality impacts due to land use conversion from annual crops to perennial forages, this conversion is challenged by current trends in agricultural lands. According to the 2021 Plowprint Report, over 1M ha of grasslands have been converted between 2018 and 2019 alone, mostly to crop agriculture (World Wildlife, 2021). Conversion to cropland is mostly driven by recent increases in grain prices due to increased demands created by the rapid economic development in Asian countries (Montossi et al., 2020). Grassland conversion in the US Upper Midwest in the past decade has resulted in substantial degradation of soil quality, with implications for air and water quality (Zhang et al., 2021). Such environmental impacts are likely related to hydrological alterations, as indicated by the analysis presented in this study.  However, these hypotheses should be validated though field and modelling research efforts in the future. In regard to the former, field monitoring investigating the interplay between hydrology and nutrient release is required, as stated previously. In regard to the latter, future model development to better represent the hydrological behaviour of perennial forages is needed. The methodology adopted in the present study (i.e., falsification of the 'fallstat' parameter) was meant as a 'proof-of-concept' approach, but a more rigorous model development based on field research is warranted.

Additionally, there are a number of parameters for which it seems that the authors have subjectively chosen numerical values (e.g. stomatal resistance, L. 331 - 332). Given that the water balance at the soil surface has a major impact on the model result I had expected to see a sensitivity analysis for parameters that the authors have selected based on their expert judgement.

**Reply:** While CHRM makes provision for expert knowledge during parameterization, an objective parameterization was used in the present study. Stomatal resistance, mentioned by the reviewer, was defined based on Beven (2011), which is within the range reported in the literature, as indicated in the manuscript. The major issue with this parameter is that it is dynamic in nature, while its representation in the model is static. We agree with the reviewer that this limitation creates some uncertainty in the ET estimates, as acknowledged in the manuscript. Therefore, a sensitivity analysis of stomatal resistance has been conducted in the revised manuscript. The stomatal resistance values used in the analysis were 25 (lower limit reported in the literature), 50 (Beven, 2011), 75 (equidistant value), and 100 s $m^{-1}$ (upper limit reported in the literature).

**Detailed comments:**

- L. 17: “resulting in lower water yield and concomitant export of nutrients”: From a nutrient balance perspective: where would the nutrients not lost end up in the system?

Reply: The nutrient would buildup in the soil and be potentially uptake by vegetation. Alternatively, nutrients could also be lost through other pathways depending on its form (e.g., N gaseous emissions).

- L. 17: A related aspect: what are the nutrient budgets for the two alternative crops (fertilization rates, yield export)? This is important for the long-term effect of any given crop choice.

Reply: It is expected that lower nutrient application to forage land would lead to reduced nutrient loss compared to annual crop land. The nutrient budget of perennial forages could also differ, depending on management (e.g., native, and tame pastures, which differ in nutrient inputs, for example). These aspects are complex and out of the scope of the manuscript. That said, CRHM is under continuous development and has been recently added a nutrient module (Costa et al., 2021). The authors expect to further investigate the nutrient balance of the two alternative land uses using the newly developed CRHM modules in the future.

- L. 29: Introduce abbreviation upon first use.

Reply: Correction has been made as suggested.

- L. 33: Which nutrients? N or P or both?

Reply: It indicates both N and P. We have included additional references (Mccullough et al., 2012; Schindler et al., 2012; Yates et al., 2012) that report the increasing trend of N and P loading to Lake Winnipeg in the past few decades.

- L. 35: Which kind of intensification took place?

Reply: Agriculture intensification has taken place in the Lake Winnipeg region since the early 1800s. In Manitoba, wheat and barley production has increased from ~$1\times10^9$ kg yr$^{-1}$ and 0.3-$0.5\times10^9$ kg yr$^{-1}$ in 1910s to $5\times10^9$ kg yr$^{-1}$ and $2\times10^9$ kg yr$^{-1}$ in the 1980s, respectively. Potato production has increased by almost 10-fold to $1\times10^9$ kg yr$^{-1}$ due to increased demand for processed food (Honey and Oleson, 2006; Bunting et al., 2016). Canola production has increased from $<1.2\times10^4$ ha in

1961 to 1.15×$10^6$ ha in 2004. Hog population has increased by 500% and fodder crops increased 275-1000% during 1981-2000 (Bunting et al., 2016).

- L. 37 – 38: The way of referencing is somewhat misleading. As written, the citation evokes the impression that Liu et al. (2014) proposed this conversion (based on their scientific findings). However, these authors describe that “Conservation initiatives on the Canadian Prairies are attempting … by promoting conversion of annual cropland to perennial forages” (Liu et al., 2014, p. 1645). Actually, the authors formulate based on their empirical findings some warnings regarding this suggested conversion: “When nutrients are released from plant residues by freezing, the introduction of perennial forages to a crop rotation may increase P losses in surface runoff during snowmelt.” (Liu et al., 2014, p. 1654). Such a framing puts this manuscript into quite a different perspective.

Reply: The introduction section has been expanded to reflect the balanced approach suggested by the reviewer in the general comment.

- L. 39: Agronomic practices are neglected.

Reply: Agronomic practices, namely, nutrient management, are now mentioned in a new paragraph added to the introduction section.

- L. 41 – 42: This sentence gives the impression that conversion to perennial crops were a better alternative than arable crops. However, given the findings cited above (Liu et al., 2014), this implicit assessment is not necessarily true.

Reply: The introduction section has been expanded to reflect the balanced approach suggested by the reviewer in the general comment. Specifically, the revised introduction now discusses both hydrology and nutrient dynamics as drivers of water quality issues.

L. 68 – 69: How is it possible to achieve “physical realism of hydrological processes without the need of parameter calibration to achieve accurate simulations.”? This holds especially true for parameters such as soil hydraulic parameters at the spatial scale of HRUs. The statement is also in contradiction with (He et al., 2021), which states: “… were initialized based on the soil textures in WGC basin, and then slightly adjusted using trial and error based on the NSE and logNSE values of the streamflow simulation in the calibration period." (He et al., 2021, p. 5).

Reply: The paradigm for development of CRHM has been to rely on parameterization based on knowledge of the basin. That said, parameter calibration can still be performed in CHRM. This statement has been removed in the revised version of the manuscript.

- L. 129: What are possible reasons for the poor performance under drier conditions?

Reply: The poor performance in simulating low flow is recognized as a common issue for many hydrological models. The reasons vary from region (location and/or size), season, to lead time (Nicolle et al., 2014). Cordeiro et al. (2017), studying the same basin, suggested that variable typological controls at the landscape level (e.g., preferential flow) could be one of reasons influencing the hydrological regime under the dry conditions, which are difficult to represent in model simulations. Those authors stress that these hypotheses remain to be investigated.

- L. 138 – 144: This seems to indicate that a major change was introduced apriori to the model structure!? Does this not lead to the situation that the model results simply reflect the initial hypothesis?

Reply: The module structures between annual crop and perennial forage models were the same. The introduction of the 'fallstat_correction' parameter was a technical way to mimic a hydrological premise of perennial forages observed in field research in the Canadian Prairies, namely, to reduce or prevent the formation of ice lenses in those landscapes and to increase infiltration through macropore formation. The objective of the manuscript was to assess the large-scale hydrological implications of this premise to other components of the water balance. We acknowledge that the extend of this hydrological premise depends on antecedent conditions and, therefore, we used an uncertainty framework to capture this uncertainty. We also acknowledge that the methodology adopted in the present study (i.e., falsification of the 'fallstat' parameter) was meant as a 'proof-of-concept' approach, but a more rigorous model representation of this process based on field research is warranted. This last sentence has been included in the discussion section of the revised manuscript.

L. 140: the use and motivation for the parameter “fallstat” is obscure to me. Should the degree of saturation of the soil not result from the water balance simulations of the antecedent period? “Defining” a degree of saturation will generally induce a water balance error, wouldn’t it? Please explain and clarify.

Reply: In the current representation of CHRM, replacing annual crops with perennial forages would change the hydrological effect of the above-ground vegetation cover (e.g., snow trapping), but would cause no difference in the subsoil hydrology. In order to mimic the known subsoil alterations (i.e., prevention of ice lenses formation), the parameter “fallstat” was falsified. This parameter handles the infiltration into frozen soil for the following spring as determined from soil properties and soil moisture variables (Gray et al., 2001). The value 0% of “fallstat” indicates the soil is cracked and the infiltration flow is unlimited. The value 100% of “fallstat” indicates the soil is completely saturated and infiltration is restricted. Intermediate values of this parameter characterized limited infiltration. The original range of “fallstat” values used in the simulations (i.e., 30%-70%) characterizes the limited infiltration range of infiltration (Gray et al., 2001). However, this range has been expanded to between 0% and 70%, as suggested by the reviewer.

- L. 145 – 146:] I suggest to extend the range between 0 and 70\%. This allowed to assess the vegetation effects on SWE separately from the effects on soil properties (i.e. infiltration capacity).

Reply: We have extended the range of fallstat from 30%-70% to 0-70%, as suggested. The results have been updated accordingly, while the conclusion remains similar after the expansion of scenarios.

- L: 174 - 180: How have the meteorological point data extrapolated in space?

Reply: The data was not extrapolated in space. Rather, a single weather file was applied to the entire area. This was due to the fact that the study area does not have a weather station within. Also, no single weather station had all the meteorological variables required to force the model. Therefore, we combined the data from nearby stations. As stated in section 2.4, we obtained temperature, wind speed, and relative humidity from the Portage Southport Airport station, while solar radiation was acquired from the station located at the Winnipeg International Airport, and precipitation was acquired from the weather station in Marquette. Precipitation was only available in a daily time-step and was disaggregated to an hourly time-step using the R package HyetosMinute (Kossieris et al., 2013; Koutsoyiannis and Onof, 2001).

- L. 210, Fig. 3 (and following): The figures differentiate between the two crops with green and red colors. Given that about 8% of the male population is color blind, I strongly recommend to change the color code and potentially also use different symbols to avoid readability problems.

Reply: Figures 3 through 9 were reformatted, as suggested.

- L. 235: Can the larger SWE for forage crops be fully explained by reduced sublimation? It seems that transport and wind erosion would not cause such differences because in a scenario with one land use only (arable crop or forage only), any transport and erosion would lead to snow deposition somewhere else in the catchment without a net change of the surface water balance. Can you comment on that?

Reply: The larger SWE in perennial forages is a result of the great ability of this vegetation cover to trap snow due to its increased height compared to crop land, which is harvested and has a shorter stubble height.

- L. 285: The assumption of constant nutrient concentrations contradicts the empirical findings by Liu et al., (2014) reporting substantial increase of several nutrients upon a change from arable crops to perennial forage. This puts the results in quite a different perspective.

Reply: The discussion section has been extensively revised and, as a result, this statement has been removed.

- L. 285 – 302: This section seems biased in that only results are reported that favor a transition from arable to forage crops. Conflicting findings are neglected despite the fact that one of such papers (Liu et al., 2014) is cited.

Reply: As stated above, the discussion section has been extensively revised and provides a more balanced argument highlighting the interaction between hydrology and nutrient release to water quality outcomes.

- L. 312 - 313: The mechanism of how the macropore flow is mimicked by the model is not very clear. Please provide more (technical) details.

Reply: As stated previously, the fallstat parameter was indented to mimic the hydrological effect of macropore flow (i.e., enhanced infiltration). This representation was meant as a 'proof-of-concept' approach to assess the overall implications to different water balance components, but a more rigorous model representation of this process based on field research is warranted.

- L. 330 - 340: These aspects should be investigated with a sensitivity analysis. This should be straightforward and would provide more robust information how relevant this parameter might be for the overall results.

Reply: As stated in the reply to the general comments, a sensitivity analysis has been conducted for the revised manuscript. The stomatal resistance values used in the analysis were 25 (lower limit reported in the literature), 50 (Beven, 2011), 75 (equidistant value), and 100 s $m^{-1}$ (upper limit reported in the literature).

- L. 348 - 349: This outcome seems rather trivial: empirical evidence at field scale has been conceptually be incorporated into the model and applied to a larger scale. Therefore, the model results are no independent test whether the local observations hold true if scaled up.

Reply: That particular sentence has been removed in the revised manuscript.

**References:**

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**Reviewer #2**

The authors conducted a modelling study to evaluate impact of a landuse change on a watershed-scale discharge. The study uses relatively established hydrological model (CHRM) originally designed for cold regions settings and, thus, already incorporating many relevant processes. Different model elements were evaluated in the multiple previous publications.

Overall, the paper is well-structured and well-written, however, it suffers from few issues. The authors fail to follow up on the hydrological data referred to in Methods (L181-186). These data are neither presented in Results, nor in Discussion. The absence of the observed discharge from the results is particularly puzzling, given that authors present simulation data only for the years when streamflow observations are available.

Reply: The objective of the manuscript was to assess the impacts of land-use conversion (i.e., annual crop to perennial forages) on several components of the water budget. As observations are not available for most of those variables, the comparison was made between the baseline model (i.e., annual crop) to the falsified model (i.e., perennial forage). The description of the hydrometric data in the methods section was an oversight . Besides, there were some days without stream discharge measurement within each of the study year, it might not be accurate to calculate the measurement cumulative and peak discharge under this situation. However, daily stream discharge and the calibration results of baseline model has been reported in Cordeiro et al. (2017) (Figure 3).

Furthermore, while utility of the CHRM in general was confirmed in the previous studies, authors changed the model to account for macropore development under perennial forages (L134-144). It is unclear from the article if adequacy of this change was properly evaluated.  This is particularly important given that authors report higher simulated water content under perennial forages than under crops in most years – an observation contradicting numerous previous studies throughout semi-arid grasslands in North America and Eurasia (and acknowledged by authors in Discussion – L314-324). Therefore, there is a clear need to compare model outputs with observations to confirm that completed model modification (‘fallstat_correction’) adequately captures effects of land use change.

Reply: In the current representation of CHRM, replacing annual crops with perennial forages would change the hydrological effect of the above-ground vegetation cover (e.g., snow trapping), but would cause no difference in the subsoil hydrology. In order to mimic the known subsoil alterations (i.e., prevention of ice lenses formation), the parameter “fallstat” was falsified. This parameter handles the infiltration into frozen soil for the following spring as determined from soil properties and soil moisture variables (Gray et al., 2001). As described in the manuscript, the approach to use the “fallstat” parameter was indented to *mimic the hydrological effect of macropore flow* (i.e., enhanced infiltration), not to represent macropore flow in fact. This representation was meant as a ‘proof-of-concept’ approach to assess the overall implications to different water balance components, but a more rigorous model representation of this process based on field research is warranted.

In fact, another reviewer suggested to expand the “fallstat” parameter from “30-70%” to “0-70%”. We have followed this advice and revised the results accordingly.

It must be noted that capturing observed discharge reduction may not be sufficient on its own, as it can be predicted based on the increased evapotranspiration after crop to grass conversion observed in the previous studies.

Reply: While ET certainly impacts stream discharge, the final result depends on the interaction between ET, runoff, infiltration, and soil moisture, which are influenced by soil texture and weather. In the Canadian Prairies, discharge is mainly contributed by runoff during the snowmelt season. The objective of the study was to quantify alterations in those variables at larger spatial scales. We agree that decreased stream discharge can be predicted as an expected outcome, but the actual quantification can only be effectively achieved through a modelling exercise. We don’t intend to claim that this study will answer all the questions, but it can certainly provide detailed insights about the hydrological contrasts between annual crops and perennial forages. It also provides evidence of processes that needs better representation in the model, such as soil moisture dynamics, which was mentioned by the reviewer.

I recommend this manuscript for publication after major revisions addressing the issues raised in the paragraph above.

Other notes:

L86 Typo: should be “Vertisols” instead of “Veritsols”

Reply: The word has been corrected.

L93 Please cite source of the shown land use file. Please add black line to the legend. Is it denoting borders of the 4 sub-basins referenced in L99?

Reply: Data source has been cited. Yes, it is the borders of the 4 sub-basins referenced in L99.

L99, L121 It is unclear why “four sub-basins” are mentioned. They are referred to just twice in the text and on Figure 1. Also, it adds confusion (there is a LS-05OG008 sub-basin that consists of four sub-basins).

Reply: The four subbasins are the result of the delineation of the watershed. We have rephrased the title of Figure 1 to improve clarity.

L105 Please consider spelling out most acronyms in the table (as was done at Cordeiro, 2017). Currently there are 22 acronyms in the making it nearly impossible to follow up.

Reply: The corrections have been made as suggested. It is not allowed to have landscape pages in the current version based on the journal requirements, we will make this change in the final typeset version.

**References:**

Cordeiro, M. R. C., Wilson, H. F., Vanrobaeys, J., Pomeroy, J. W., and Fang, X.: Simulating cold-region hydrology in an intensively drained agricultural watershed in Manitoba, Canada, using the Cold Regions Hydrological Model, Hydrol. Earth Syst. Sci., 21, 3483-3506, 10.5194/hess-21-3483-2017, 2017.

Gray, D.M., Toth, B., Zhao, L., Pomeroy, J. W., & Granger, R. J. Estimating areal snowmelt infiltration into frozen soils. Hydrological processes, 15(16), 3095-3111, 2001.