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Assessment of soil trafficability across the agricultural region of the Canadian Prairies with the gridded climate data set

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ABSTRACT

The frequency of days with poor soil trafficability across the Canadian Prairies was determined from simulated soil moisture at soil polygon level during the growing season (April to September) with the Versatile Soil Moisture Budget (VSMB) model. Each soil polygon had a pre-determined critical soil moisture threshold in the first layer (0–5 cm) to trigger poor trafficability. The assessment of soil trafficability was limited to those polygons with good suitability rating for growing grain crops. For each of May, July and September, the polygon modelled soil moisture values were boot strapped into three percentile categories to reflect the highest risk (25th percentile), average conditions (50th percentile) and better than average conditions (75th percentile) for the entire climate period (1971 to 2000). We found that on average, soils with higher clay content (mostly those from eastern Manitoba, the northern fringes of the agricultural zone coinciding with the boreal forest zone and the Alberta Peace River region) had 5 to 9 days of poor trafficability at seeding time (May). In July, the zone with poor soil trafficability (close to two weeks) expanded northward to the Peace River Region of Alberta, northern Saskatchewan and eastern Manitoba. At harvest time (September), poor soil trafficability (> 10days) was concentrated in eastern Manitoba which also had the most days with poor soil trafficability at the start and mid-season months. The wet phase represented by the 75th percentile category showed that 10–14 days of poor trafficability can be expected on soil polygons with heavy textures. There were fewer days (1–4) with poor trafficability during dry years (the 25th percentile binned values). The soil trafficability maps generated from this study are a baseline for comparing trafficability levels under climate change scenarios and for planning agricultural activities.

1. Introduction

Periods of high soil moisture occur across Canada during every cropping season. High soil moisture not only damages crops, it also restricts field operations at critical times on the agricultural calendar. An issue that poor soil trafficability brings about is the inability of field equipment to traverse the soil surface without negatively impacting the soil physical properties (e.g. destruction of soil structure from compaction) and general disturbance of field conditions (seedbed and field roughness) necessary for crop production. The number of days that a soil can withstand field traffic is referred to as soil trafficability or field working days. According to Reeve and Fausey (1974), trafficability is "the ability to perform the required field operations in such a way as to create beneficial soil conditions or to complete a required operation expediently." Activities which are affected when a field is not trafficable include delays in seeding, spraying or harvesting. Poor soil trafficability especially at the start of the growing season can result in delayed or no seeding at all and leading to crop failure as was the case in parts of the prairie provinces in 2010 (Bonsal et al., 2017). When seeding is delayed, the growing season can become too short for the majority of the crops grown on the Canadian Prairies due to onset of frost in the autumn.

Soil trafficability can be related to specific soil properties and their interaction with soil moisture. As such, a soil has a critical soil moisture

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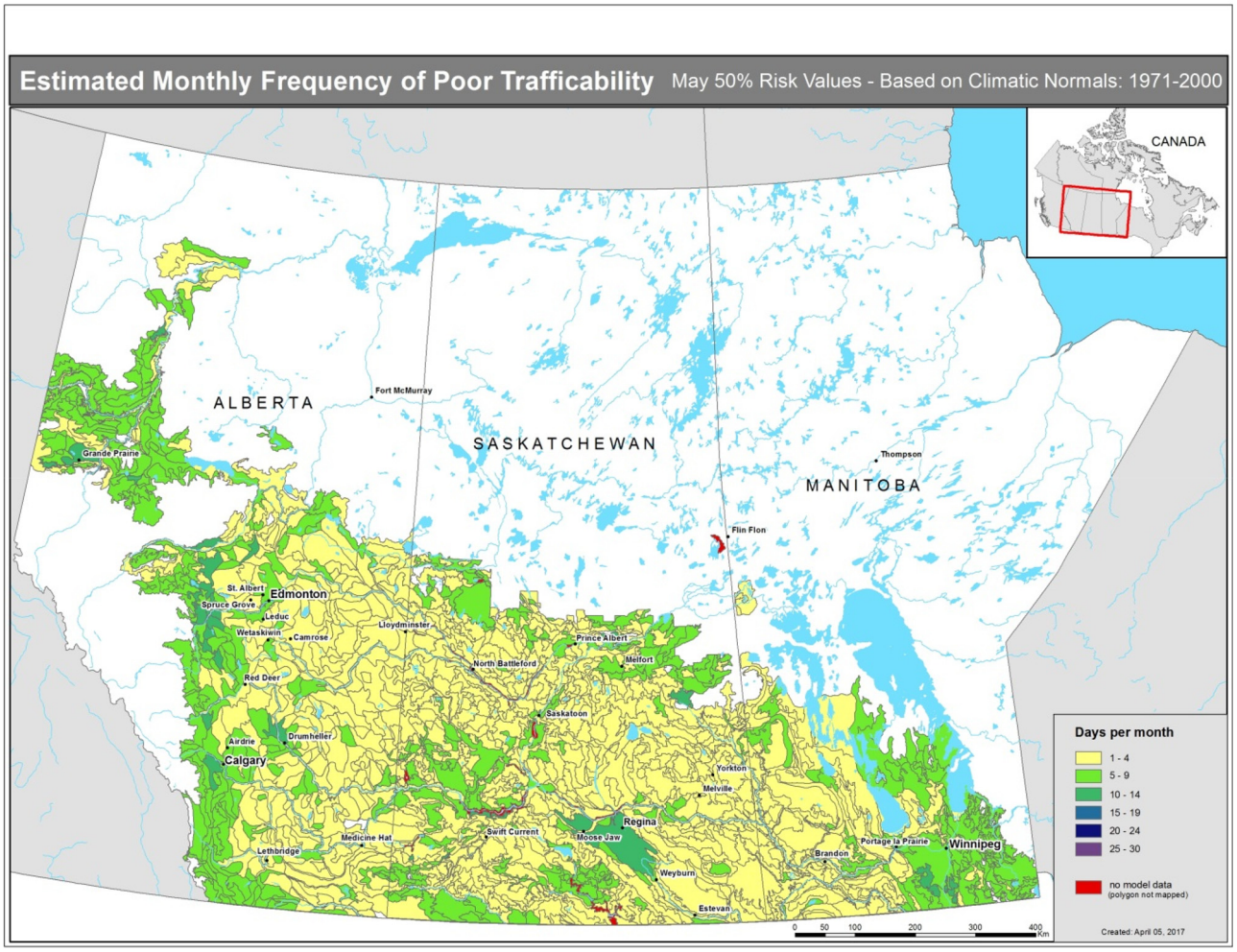

Fig. 1. The frequency of days with poor soil trafficability at seeding time (May) across the Prairie Provinces at the a) 50th Percentile b) 75th percentile and c) 25th percentile levels. Maps do not reflect local or regional changes to soil drainage such as tile, modified surface and regional drainage systems. Soil trafficabilty was not assessed in polygons where the areal extent of the suitable classes for growing crops was less than 20%.
a) 50th Percentile. The map shows the frequency of days with poor soil trafficability on average (1:2). Higher categories such as 10 to 14 days indicate that polygons in this category can experience poor soil trafficability up to two weeks during the month of May. A desirable outcome is fewer number of days (1-4) with poor trafficability in any given month to allow vehicular traffic to traverse the land.
b) 75th Percentile. The map shows the frequency of days with poor soil trafficability under conditions which are relatively wetter than average. These conditions come about due to excessive rain and snow melt in the spring.
c) 25th Percentile. The map shows the frequency of days with poor soil trafficability under relatively dry conditions (1:4). Under dry conditions the majority of the polygons are trafficable.

content beyond which the ability to safely travel on the soil is no longer feasible. A variety methods have been used to define the critical soil moisture content for soil trafficability. Most studies use soil moisture content relative to a specific soil property. Early work in Canada on trafficability/workdays used the critical soil moisture level of less than 97.5% of field capacity for heavy machinery and deep cultivation and greater than 90% of field capacity for lighter equipment and shallow cultivation (Baier, 1973). Other investigators have used values relative to a percent of available water holding capacity (Maton et al., 2007), or the plastic limit of the soil (Mueller et al., 2003; Tomasek et al., 2015). Paul and De Vries (1979) defined trafficability in relation to a critical soil water tension of 35 to 27 cm for a silty clay soil. A survey of the literature on thresholds for defining soil trafficability in Canada (Shaykewich, 2006, Pers. Comm) recommended a value slightly above field capacity for sandy soils and below 90% field capacity for clay oils. These recommendations were used by Sheppard et al. (2007) who found out that poor work days in the spring and fall resulted in more ammonia emission from manure than in the other seasons. The result from Sheppard et al. (2007) is an example of how delayed management of manure due to lack of soil trafficability can bring about unintended consequences. Shifts in trafficability may be introduced by tillage practices resulting in changes of the physical and productive capacity of the soil. In a study by Ozpinar and Cay (2005), three tillage practices (conventional, shallow and double discing) on a sandy loam soil from Turkey introduced changes in aggregate size distribution especially under double discing with positive effects on organic carbon accumulation

In Canada, the Versatile Soil Moisture Budget (VSMB) has been used successfully to estimate soil moisture levels in agricultural soils for a variety of applications such as irrigation scheduling, crop yield