Excess Water in Prairie Soils: Land Management in an Uncertain Climate

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SUMMARY

Excess soil moisture occurs when a soil is unable to transmit water present on top of and within the soil prior to the onset of conditions harmful to soils and crops. The economic cost of excess soil moisture conditions can be very high – in 2006 the crop insurance claims in Saskatchewan alone for unseeded acres due to excess soil moisture exceeded $61 million.

Three main sets of controls exist for excess soil moisture. The first controls are the hydrological ones, which control the delivery of water to the soil surface. The second controls are those that determine the partitioning of water between runoff and infiltration. The third controls are those that determine the transmission of water through the soil and sediment, including those that control the elevation of the groundwater table. Our focus in this paper is on controls that can be influenced by management and development of Beneficial Management Practices to achieve these management goals.

The effects of excess soil moisture on soil chemical properties can cause both short- and long-term damage to soils. Recharge of water to the groundwater can cause an increase in the elevation of the groundwater table and the introduction of saline or sodic conditions into the rooting zone of crops. Decomposition and release of nutrients from crop residues is greatly slowed, and very high gaseous losses of nitrogen can occur through denitrification.

Excess moisture can influence crop yield in two ways: 1) the inability to access the field and plant the crop at the right time (i.e., trafficability) and 2) damage to the crop due to lack of sufficient O_2 and biochemical processes triggered by the absence of O_2 (Figure 1).

Trafficability issues most commonly arise in spring after snowmelt, and the inability to access the field early enough in the short growing season decreases the number of frost-free days available for plant growth and grain ripening.

Seed germination, the earliest stage of plant growth, can be inhibited or even prevented by excess moisture because cell division and growth require O_2 to proceed. Where plant growth is established, excess moisture can have a significant negative impact on both root and shoot growth, eventually leading to the senescence of roots. Low O_2 concentrations limit root respiration and drastically reduce the energy available from the oxidation of glucose, with up to 95% reductions in ATP production, where ATP is the fuel for most cellular processes. Photosynthesis in waterlogging-sensitive plants also decreases rapidly under excess moisture. For many species, there is an interacting effect between the timing of excess moisture and plant growth stage, with

young, actively growing seedlings generally being most vulnerable to damage and dormant plants, with their much lower respiration rates, being least vulnerable.

The incidence of weeds and other pests also increases under excess soil moisture conditions. Where flooding and excess moisture lead to late planting or to no crop being seeded at all, weeds have a competitive advantage and can become increasingly problematic for several years if allowed to go to seed. Floodwaters may also introduce new weed species into affected areas. Many of the waterlogging stresses on root physiology make plant roots more susceptible to soil-borne pathogens, including fungi, bacteria, nematodes, and viruses.

Given the range of conditions that can lead to excess soil moisture it is very difficult to develop generic solutions that can apply to all situations. Instead BMPs must be tailored to specific combinations of soil and landscape conditions where the likelihood of excess soil moisture conditions occurring are high.

There are two main soil management goals to control excess soil moisture. The first goal is to maintain the structure of the soil in a condition where infiltration rates and within-soil transmission rates are as high as possible for that soil. This can be accomplished by maintaining a good aggregation state in the upper soil through tillage and residue management. The gains in infiltration and permeability that can be made through these practices are the lowest, however, in fine textured soils, which are typically the most susceptible to waterlogging (Tables 1 and 2).

The second soil management goal is to remove water from the soil profile as quickly as possible to allow the highest possible infiltration and within-soil transfer of water. This is true whether the source of excess water is a high groundwater table or water added through precipitation or flooding. This can be accomplished through drainage by lined or unlined subsurface drains or by the adoption of high water use plants such as alfalfa, which increase water losses through transpiration. Both types of measures have negative environmental or agronomic tradeoffs associated with them.

Changes to the overall cropping system to address yield losses due to excess soil moisture can also be made. Within each of the crop and forage classes planted in the Prairies a range of sensitivity to waterlogging has been documented (Tables 3 and 4). Seed treatments incorporating hormones (or hormone-suppressants) that encourage development of waterlogging-tolerant traits may be a useful consideration for some crops. Timing fertilizer application to correspond with maximum plant uptake is of particular importance in landscapes at risk of flooding and increased moisture due to the greater likelihood of nutrient loss through denitrification and leaching. Incorporating crops that reduce soil moisture into the crop rotation can alleviate some of the issues associated with waterlogging and salinity without permanent infrastructure or other engineering solutions. Recent work from Australia suggests that management of complex problems like high groundwater levels and salinity requires a multi-disciplinary approach.

Summary and attached Figures and Tables compiled for PFRA in the following report:

Pennock, D.J. and A. Bedard-Haughn. 2006. Management of Flooded Soils and Excess Soil Moisture: A Compilation of Research and Identification of Beneficial Management Practices. © HER MAJESTY THE QUEEN IN RIGHT OF CANADA 2001 as represented by the Minister of Agriculture and Agri-Food Canada.