Modeling fate and transport of *Cryptosporidium parvum* oocysts in overland flow

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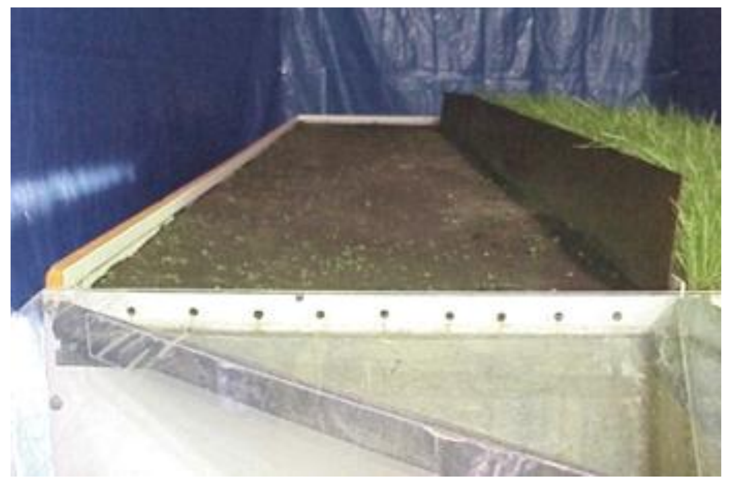
Introduction

❖ Public health concerns for contamination of soil and water due to the presence of pathogens in the surface and subsurface system.
❖Water-related diseases : the main cause of death in developing countries which accounts for 98% of the total death.
❖Worldwide: 250 million cases, 10 million deaths per year.
❖ In USA, 870 outbreaks were associated with drinking water during the period of 1920 to 2002 causing 883,806 illnesses.
❖ Understanding pathogen transport pattern is important for developing best management practices for limiting contaminant transport to water resources and preventing health hazards.
❖ Modeling can help understanding pathogen transport pathways. Accordingly, best management practices (BMP) can be developed.
❖ Although the prediction of fate and transport of pathogens has the great practical importance, the mathematical modeling of the phenomenon has been illustrated in few literatures only.

Why *Cryptosporidium*?

❖ *Cryptosporidium* - one of the most common causes of waterborne disease in USA.
❖ About 300,000 cases of diarrhea annually resulting from cryptosporidiosis in the United States.
❖ About 403,000 people were infected from a massive outbreak of *Cryptosporidium parvum* at Milwaukee in 1993 with more than 100 fatalities, the largest waterborne disease outbreak in USA.
❖ About 25-35% of the population in developed countries (including the United States) has had cryptosporidiosis at some time in their lives.
❖ Reason: Common treatment provided for drinking water (Chlorine disinfection) could not kill *Cryptosporidium*.

Experimental setup



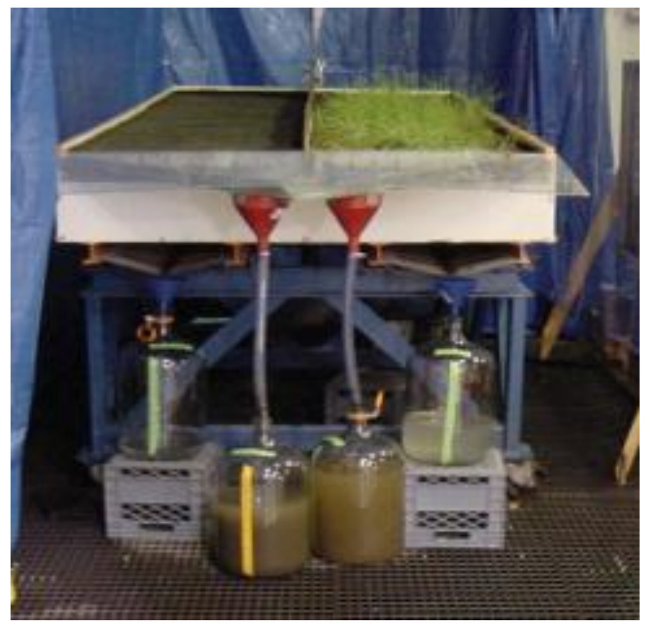
❖ Soil bed dimension: 3.6 m (L) x 0.75 m (W) x 0.3 m (H)

❖ 1.5, 3.0 and 4.5% slope conditions

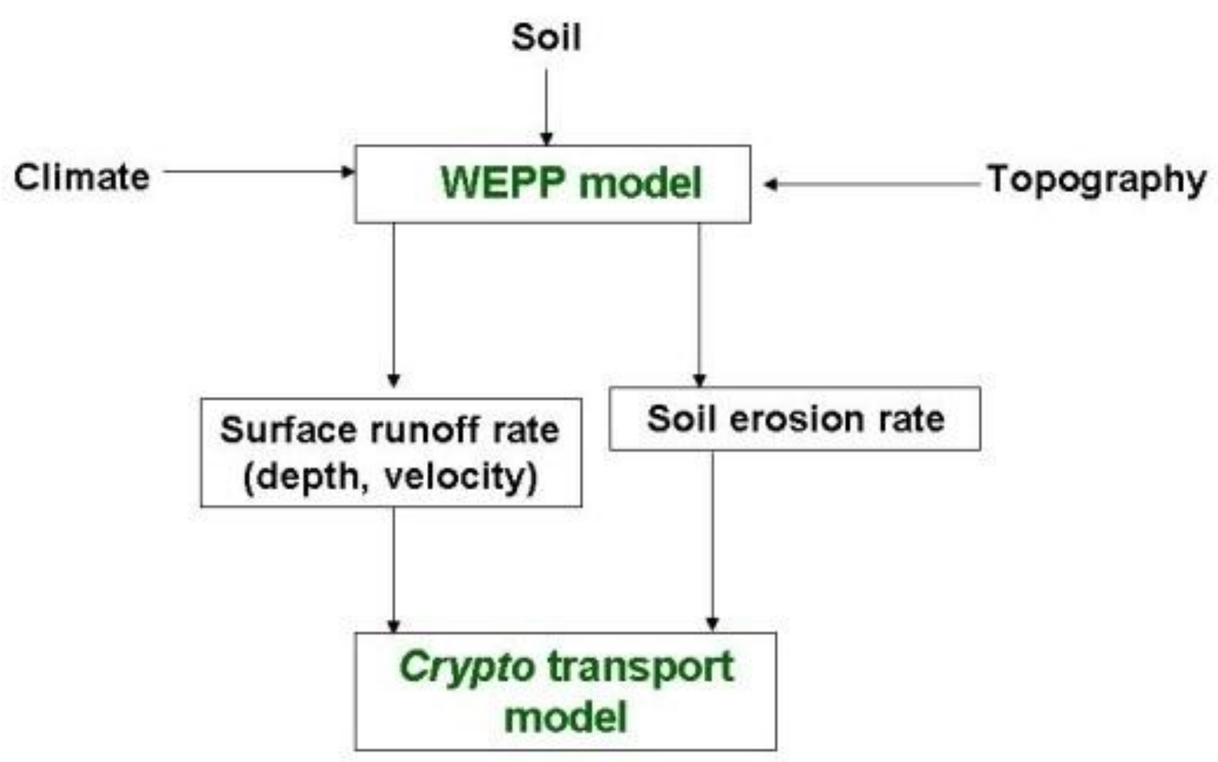
❖ 1.0 and 2.5 in/hr rainfall intensities

❖ Catlin and Newberry soils

❖ Bare and vegetated (Brome grass) cover



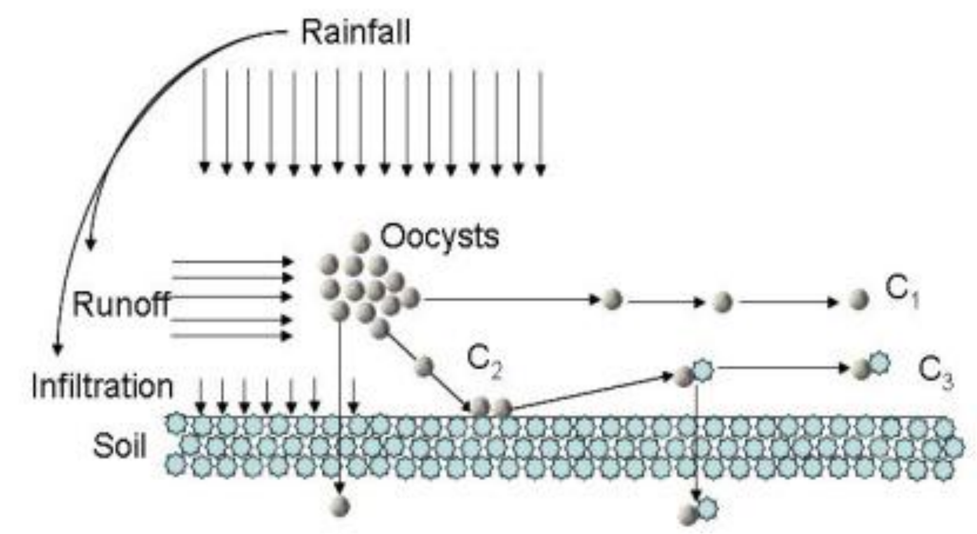
Model overview



Crypto Oocysts transport modeling

The following possible states of oocyst fate and transport are considered in overland flow:

(1) Oocysts attach to soil particles with attachment rate k_{12}
(2) Oocysts attached to mobile soil particles are removed surface flow with rate constant k_{23}
(3) Oocysts become inactivated with inactivation rate k_d
(4) Oocysts are removed by infiltration with the rate equal to *f/D* (*f* is hydraulic conductivity, and *D* is flow depth)



Concentrations of oocysts in water (C_1), attached to immobile soil particles (C_2), attached to mobile soil particles (C_3) can be calculated using the set of following mass balance equations:

$$\frac{\partial C_1}{\partial t} + u\frac{\partial C_1}{\partial x} = -(k_{12} + k_d + \frac{f}{D})C_1$$

$$\frac{\partial C_2}{\partial t} = k_{12}C_1 - k_{23}C_2$$

$$\frac{\partial C_3}{\partial t} + u\frac{\partial C_3}{\partial x} = k_{23}C_2 - (k_d + \frac{f}{D})C_3$$

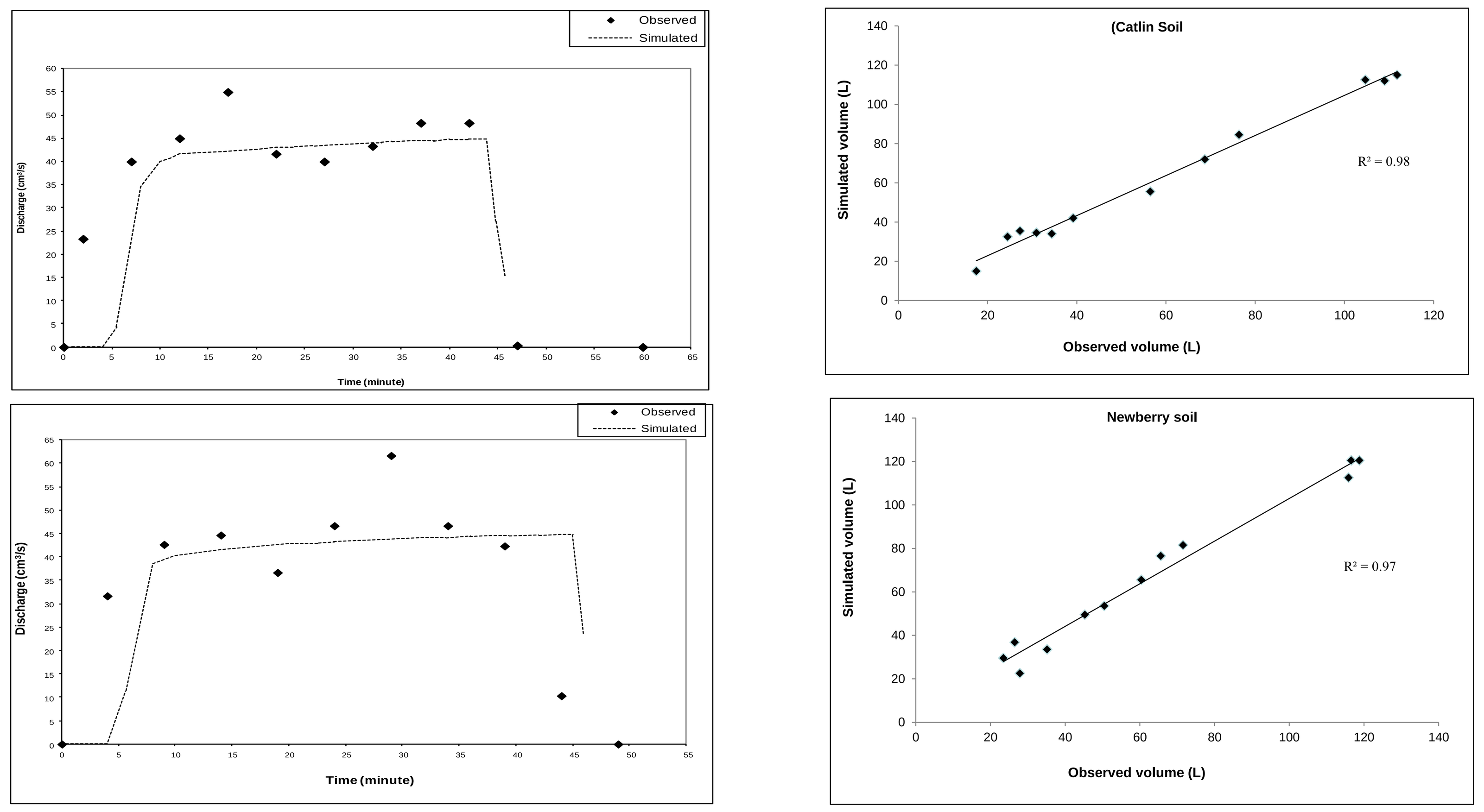
Initial conditions: $C_1^0 = C_1(0,x)$; $C_2(0,x) = C_3(0,x) = 0$

where C_1^0 is the concentration of oocyst applied to the system

Boundary conditions: $C_1(t,0) = C_2(t,0) = C_3(t,0) = 0$

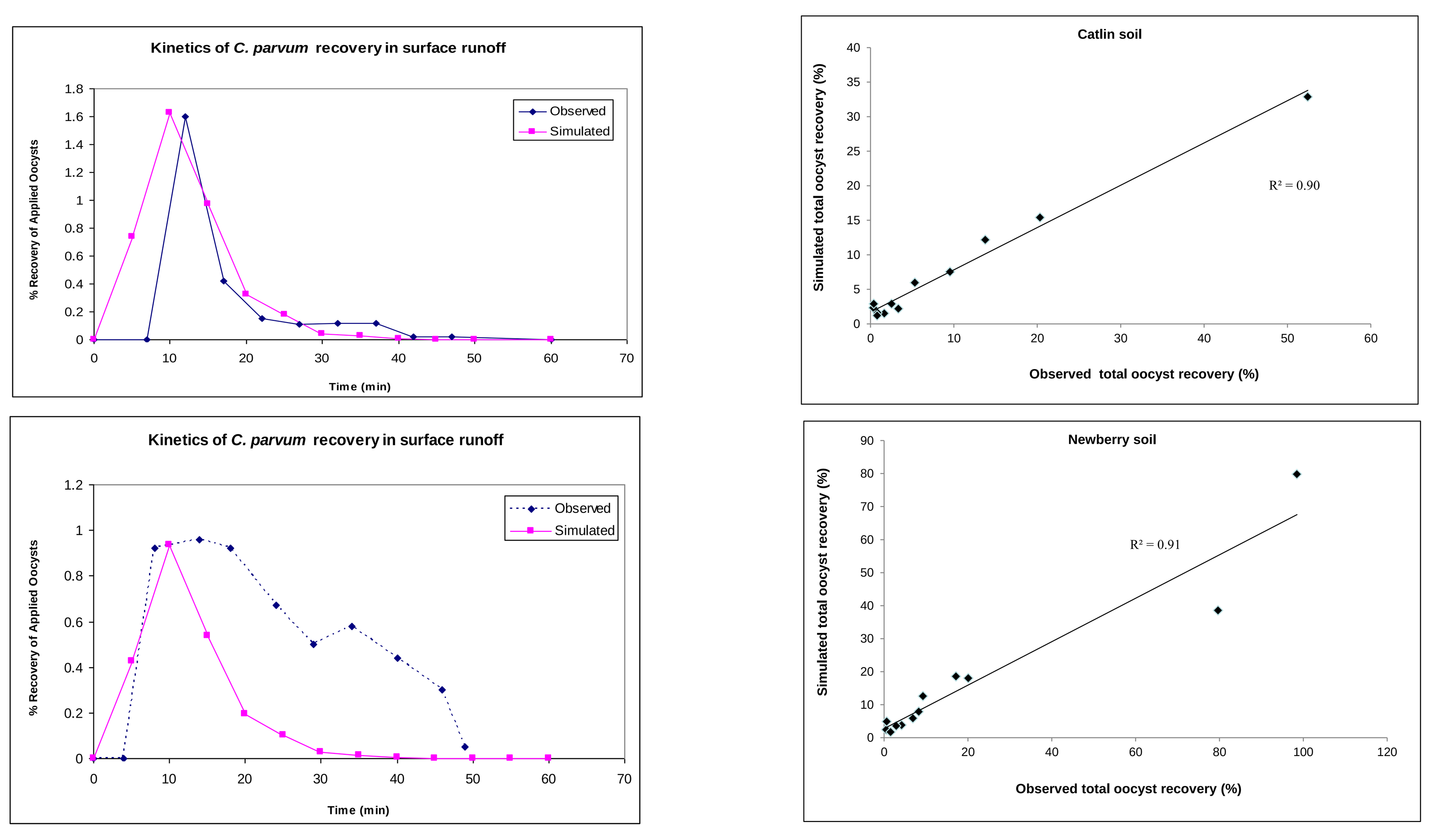
At time zero the oocysts are unattached and freely moving in the water, and there is no continuous source of oocysts exists at x = 0

WEPP model calibration



Catlin soil, Rainfall intensity - 2.5 inch/hr, slope – 1.5 and 3.0%

Cryptosproridium oocysts transport model result



Catlin soil, Rainfall intensity - 2.5 inch/hr, slope – 1.5 and 3.0%

Summary

❖ An approach for modeling *C. parvum* fate and transport in surface flow has been presented.
❖ Deterministic descriptions of the process have been employed and a correspondence between them has been established.
❖ A feature of the model is the incorporation of an erosion model (WEPP) into the microorganism transport model, thereby establishing a link between the sediment and microbial transport, and highlighting the capability of the suspended sediment to transport microbes in the overland flow.
❖ Model simulations have produced very good agreement between observed and predicted results in most cases.