Overview of the Management Submodel in the Wind Erosion Prediction System

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Purpose

- Model cultural practices which affect a site's susceptibility to erosion
  - Surface conditions
  - Temporal soil properties
  - Vegetation/residue state
  - Soil/surface "amendments"
- Simulate all "typical" management operations
  - Primary/Secondary Tillage
  - Cultivation, Planting/Seeding
  - Harvesting, Burning, Irrigation

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Modeling Approach

- Simulate (almost) all types of "operations"
  - An "ordered" list of pre-defined processes
    - Number of processes in list is arbitrary
    - Processes can be repeated in the list

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Modeling Approach

- Processes defined based upon the "action" a specific physical effect has on the current soil/surface "state"
  - Surface modification (surface roughness)
  - Soil manipulation (breakage of aggregates)
  - Biomass manipulation (residue burial)
  - Addition/removal of amendments (manure applic.)




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Modeling Approach

- Processes consist of parameters defining the degree of impact the process has on the soil/surface "state"
  - Parameter values represent process specific behavior of an operation
  - Some processes may also be modified to reflect soil, speed, depth, residue, etc. impacts on the process' effects on the soil/surface "state"

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Modeling Approach/Goals

- Simulate processes via a physical basis if possible
- Incorporate conservation of mass concepts
- Minimize the number of parameters
- Use parameters with readily available/attainable values

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Classification of Actions Simulated

- Surface re-arrangement
- Soil manipulation
- Biomass manipulation
- Addition/removal of soil amendments

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Surface Re-configuration Effects

- Change soil surface characteristics
  - Crust
    - Destroy surface crust
  - Random Roughness
    - Smoothing or roughening surface
  - Oriented Roughness (Ridges/Dikes)
    - Creating, changing or destroying ridges/dikes

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Surface Re-configuration Effects

- Random Roughness (smoothing or roughening)

$$RR_f = \begin{cases} \zeta RR_{b_{adj}} + (1-\zeta) RR_o & RR_{b_{adj}} \geq RR_o \\ \zeta\left[\lambda RR_{b_{adj}} + (1-\lambda) RR_o\right] + (1-\zeta) RR_o & RR_{b_{adj}} < RR_o \end{cases}$$

where:

RR_f = Final tilled surface random roughness (mm)

RR_o = Pre tillage surface random roughness (mm)

$RR_{b_{adj}}$ = Implement assigned roughness after adj. for soil type and biomass (*mm*)

λ = Tillage intensity factor ($0 \leq \lambda \leq 1$)

ζ = Fraction of surface tilled ($0 \leq \zeta \leq 1$)

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Surface Re-configuration Effects

- Random Roughness (buried biomass adjustment)

$$RR_{b_{adj}} = \begin{cases} RR_{\min} + (RR_{impl} \cdot RR_{s_{adj}} - RR_{\min})(0.8(1.0 - \exp(-339.92 \cdot B_m)) + 2.0 & RR_{impl} \cdot RR_{s_{adj}} > RR_{\min} \\ RR_{impl} \cdot RR_{s_{adj}} \end{cases}$$

where:

$RR_{b_{adj}}$ = RR adj. for buried biomass (mm)

$RR_{s_{adj}}$ = RR adj. factor for soil type

RR_{impl} = Assigned nominal RR value for tillage operation (mm)

$RR_{\min}$ = 6.096 = Minimum RR value (mm)

B_m = Buried biomass density (dry basis) within soil tillage layer ($kg/m^2/mm$)

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Surface Re-configuration Effects

- Random Roughness (soil type adjustment)

$$RR_{s_{adj}} = \begin{cases} 0.16(siltf)^{0.25} + 1.47(clayf)^{0.27} & when\ RR_{s_{adj}} > 0.6 \\ 0.6 \end{cases}$$

where:

$RR_{s_{adj}}$ = RR adj. factor for soil type

clayf = Fraction of clay in soil

siltf = Fraction of silt in soil

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Soil Mass Manipulation Effects

- Change soil properties (by "layer")
  - Aggregate Size Distribution
    - break down soil aggregates
  - Bulk Density
    - loosen or compact soil
  - "Mix" soil layer properties
    - Re-distribute between soil layers
  - Invert soil layers
    - Moldboard plow

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Soil Mass Manipulation Effects

- Breakdown soil aggregates (change ASD)

$$\hat{w}[i]_{(1\times n)} = w[i]_{(1\times n)} P[i,j]_{(n\times n)}$$

where:

$\hat{w}[i]$ = post tillage array of aggregate size class fractions
$w[i]$ = pre tillage array of aggregate size class fractions
$P[i,j]$ = transition matrix
i,j = indices for soil aggregate size classes
n = maximum number of aggregate size classes

$$p_i = \frac{1.0}{1.0 + \exp\left(-\alpha + \beta \frac{gmd_i}{gmd_{\max}} \right)}$$

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Biomass Manipulation

- Change biomass properties
  - Flatten, Bury, Re-surface biomass
    - Transfer residue between standing, flat and buried locations
  - Cut or Thin standing biomass
    - Transfer fraction of standing to flat biomass on the surface
    - Reduce standing stem/stalk population
  - Kill or defoliate growing crop
    - Transfer crop biomass pools to decomposition

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Biomass Manipulation

- Flatten standing biomass

$$FL_f = FL_o + ST_o \gamma\zeta$$
$$ST_f = ST_o (1-\gamma\zeta)$$

where:

FL_f = Flat mass after operation (stem,leaf,store pools)

FL_o = Flat mass before operation (stem,leaf,store pools)

ST_f = Standing mass after operation (stem,leaf,store pools)

ST_o = Standing mass before operation (stem,leaf,store pools)

γ = Flattening coefficient $(0 \le \gamma \le 1)$

ζ = Fraction of surface tilled $(0 \le \zeta \le 1)$

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Biomass Manipulation

- Bury surface flat biomass

$$RES_{b_f} = RES_{b_o} + RES_{s_o}(B_{coef} D_{adj} S_{adj})\zeta$$
$$RES_{s_f} = RES_{s_o} - RES_{s_o}(B_{coef} D_{adj} S_{adj})\zeta$$

where:

RES_{b_f} = Buried biomass after operation (stem,leaf,store pools)

RES_{b_o} = Buried biomass before operation (stem,leaf,store pools)

RES_{s_f} = Flat surface biomass after operation (stem,leaf,store pools)

RES_{s_o} = Flat surface biomass before operation (stem,leaf,store pools)

B_{coef} = Burial coefficient for specified "toughness/size" residue class

S_{adj} = Speed adjustment factor for burial coefficient

D_{adj} = Depth adjustment factor for burial coefficient

ζ = Fraction of surface tilled ($0 \le \zeta \le 1$)

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Biomass Manipulation

- Bury surface flat biomass (tillage depth adj.)

$$D_{adj} = \frac{[1-(1-D_{act}/D_{max})^{2.7}]}{[1-(1-D_{ref}/D_{max})^{2.7}]} \qquad for\ D_{act} = \max[\min(D_{spec}, D_{max}), D_{min}]$$

where:

D_{adj} = Depth adjustment factor for burial coefficient

D_{spec} = Specified tillage (soil disturbance) depth (mm)

D_{act} = Actual soil disturbance depth (mm)

D_{ref} = Nominal (reference) soil disturbance depth (mm)

D_{max} = Maximum soil disturbance depth (mm)

D_{min} = Minimum soil disturbance depth (mm)

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Biomass Manipulation

- Bury surface flat biomass (tillage speed adj.)

$$S_{adj} = \frac{[0.6+0.4(S_{act}/S_{max})^{0.5}]}{[0.6+0.4(S_{ref}/S_{max})^{0.5}]} \qquad for\ S_{act} = \max[\min(S_{spec},S_{max}),S_{min}]$$

where:

S_{adj} = Speed adjustment factor for burial coefficient

S_{spec} = Specified operation speed (m/s)

S_{act} = Actual operation speed (m/s)

S_{ref} = Nominal (reference) operation speed (m/s)

S_{max} = Maximum operation speed (m/s)

S_{min} = Minimum operation speed (m/s)

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Biomass Manipulation

- Bury flat biomass (distribution below soil surface)

$BurialDistribution_{flag} = 0 =$ Uniform burial distribution

$BurialDistribution_{flag} = 1 =$ Mixing plus Inversion burial distribution

$BurialDistribution_{flag} = 2 =$ Mixing burial distribution

$BurialDistribution_{flag} = 3 =$ Inversion burial distribution

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Biomass Manipulation

- Resurface buried biomass

$$RES_{s_f} = RES_{s_o} + RES_{b_o}(L_{coef})\zeta$$
$$RES_{b_f} = RES_{b_o} - RES_{s_o}(L_{coef})\zeta$$

where:

RES_{s_f} = Flat surface biomass after operation (stem,leaf,store pools)

RES_{s_o} = Flat surface biomass before operation (stem,leaf,store pools)

RES_{b_f} = Buried biomass after operation (stem,leaf,store pools)

RES_{b_o} = Buried biomass before operation (stem,leaf,store pools)

L_{coef} = Lift (resurface) coefficient for specified "toughness/size" residue class

ζ = Fraction of surface tilled ($0 \le \zeta \le 1$)

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Biomass Manipulation

- Kill or defoliate growing crop

$KILL_{flag}$ = 0 = No crop killed
$KILL_{flag}$ = 1 = Annual crop killed, perennial crop NOT killed
$KILL_{flag}$ = 2 = All crop types killed
$KILL_{flag}$ = 3 = Crop defoliation triggered

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Biomass Manipulation

- Change biomass properties
  - Biomass removal (harvest)
    - Remove biomass from system by
      - class (crop/residue)
      - type (stem/leaves/roots/grain)
      - location (standing, flat, buried)
  - Planting/seeding/transplant
    - Initiate plant growth

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Biomass Manipulation

- Biomass removal (harvest)

$SelectPosition_{flag}$ = 0 = No crop components removed
$SelectPosition_{flag}$ = 1 = Standing and root components
$SelectPosition_{flag}$ = 2 = Flat component
$SelectPosition_{flag}$ = 3 = Standing, root and flat components
$SelectPosition_{flag}$ = 4 = Buried component
$SelectPosition_{flag}$ = 5 = Standing, root and buried components
$SelectPosition_{flag}$ = 6 = Flat and buried components
$SelectPosition_{flag}$ = 7 = Standing, root, flat and buried components

$SelectPool_{flag}$ = 0 = No changes to any biomass pools
$SelectPool_{flag}$ = 1 = Crop pool
$SelectPool_{flag}$ = 2 = Temporary crop pool
$SelectPool_{flag}$ = 3 = Crop and temporary crop pools
$SelectPool_{flag}$ = 4 = Residue pools
$SelectPool_{flag}$ = 5 = Crop and residue pools
$SelectPool_{flag}$ = 6 = Temporary crop and residue pools
$SelectPool_{flag}$ = 7 = All biomass pools

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Biomass Manipulation

- Planting/seeding/transplant (initiate plant growth)

$PlantingType_{flag}$ = 0 = Broadcast seeding
$PlantingType_{flag}$ = 1 = Use implement ridge spacing for row spacing
$PlantingType_{flag}$ = 2 = Use specified row spacing

$SeedPlacement_{flag}$ = 0 = Seed row placed in furrow bottom
$SeedPlacement_{flag}$ = 2 = Seed row placed on ridge top

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Amendment Effects

- Application of materials to surface/soil
  - Water (irrigation)
  - Residue, Manure
  - Plastic mulches

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Assumptions/Limitations

- Properties avg. when fraction of surface tilled
  - Slot planters, row cultivators, etc.
- Tillage zone water content changes not simulated
  - Evaporation routines expected to handle this
- Individual operations can have speed and depth effects applied to “adjust” tillage results
  - Faster speed, more breakage of aggregates
- Soil water content has no effect on tillage events
  - Typical soil wetness conditions assumed

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Assumptions/Limitations

- Tillage operations currently have no effect below tillage depth
  - No tillage "compaction layer" simulated
- No provisions for "scheduling" operations (except irrigation)
  - Emergency tillage
  - Can't shift operation date if soil is too wet or crop is not yet mature for harvesting
- Soil tillage depths adjusted to nearest soil layer boundary

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Summary

- Represent all current management practices
- Simulate an operation as an ordered list of processes
- Simulate processes via a physical basis if possible
- Incorporate conservation of mass concepts
- Use minimum number of parameters with readily available and/or attainable values

Thank You