History of Model Development at Temple, Texas

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INTRODUCTION

• Model development at Temple
  ➢ A long history (1937-present)
  ➢ Many scientists participating in:
    Data collection
    Component construction
    Structural design
    Validation
    Application
INTRODUCTION

• Model construction—a small group at Temple
  – USDA-Agricultural Research Service (ARS)
  – Texas AgriLIFE Research
  – USDA-Natural Resources Conservation Service (NRCS)

• Components, equations, etc.
  – Contributed by many scientists worldwide
  – Worldwide Scientific link provided
  – Additional expertise needed to develop comprehensive models
INTRODUCTION

TEMPLE MODELS

• ALMANAC, EPIC, APEX, SWAT
  – Operate on spatial scales ranging from individual fields to river basins
  – Daily time step
  – Continuously updated and improved as a result of user interaction and feedback
DATA COLLECTION-
RIESEL

• Blackland Experimental Watershed-hydrological data collection program
  – Established in 1937 near Riesel, TX.
  – 57 rain gages and 40 watersheds
  – Established to analyze the impact of land use practices on:
    • soil erosion
    • flood events
    • water resources
    • agricultural economy
MODEL DEVELOPMENT

• Started with hydrograph development and flood routing research in 1965
  – Background
    • 2.5 years experience in SCS flood control
    • New TR-20 flood routing model
    • Data from Riesel used in developing & testing hydrological models
  – Early models were single event models used as building blocks for today’s models
    • Focused on surface water hydrology and sediment yield
SURFACE RUNOFF

- SCS curve number method
- Green & Ampt infiltration equation

Used in EPIC, APEX and SWAT
UNIT HYDROGRAPH MODEL

- Two parameter gamma distribution
  - Rising limb
  - Peak
  - Recession to inflection point

- Exponential recession limb
  - Inflection point to base flow or zero

- For simulating runoff hydrographs from small Texas Blackland watersheds

- (1968)
Tests showed recession limb depleted too rapidly in many cases.

Hydrograph modified:
- Two parameter gamma distribution
- Double exponential recession limb

(1973)
FLOOD ROUTING

• Variable travel time method (VTT)
• VTT converted to Variable storage coefficient (VSC)
  – Improve accuracy of storage flood routing
  – Convenience in computer solutions
  – Accounts for variation in travel time
  – Maintains correct water balance
  – Later included effects of water surface slope (Williams, 1975)
  – Included in APEX and SWAT

• (1969)
HYMO

• Problem oriented computer language
  – Consisted of
    • Runoff curve number
    • Unit hydrograph
    • VSC flood routing method
    • MUSLE (sediment yield)

• (1972)
MUSLE

- Single storm event sediment yield
- Introduced runoff energy factor
- Eliminated need for delivery ratio
  - Runoff factor represents energy used in detaching and transporting sediment
- (1975)
SEDIMENT ROUTING

• Based on
  – MUSLE
  – Exponential function of travel time and particle size
  – One routing coefficient determined for all sub-areas in a watershed
  – Provided estimates of sediment deposition from subarea outlet to watershed outlet
  – Did not locate deposition
  – Ignored degradation

• (1975)
SEDIMENT ROUTING

• Worked in conjunction with flood routing model
  – Transported sediment from reach to reach adding subarea contributions as flow was routed downstream
• Deposition similar to previous model
• Degradation component developed
  – Bagnold’s stream power equation
• Applies to individual routing reaches
• (1978)
SEDIMENT ROUTING

• Current model used in APEX and SWAT
• Modified Bagnold
  – Sediment concentration function of
    • Flow velocity
    • Sediment load
    • Particle size
    • Vegetative cover
    • Soil erodibility

• (2000)
WIND EROSION

• EPIC wind erosion model
  – Modified Manhattan, KS model (WEQ)
    • Converted annual to daily time step
      – Simulated
        » Vegetative cover
        » Tillage effects

• (1984)
WIND EROSION

• Current EPIC/APEX model
  – Wind Erosion Continuous Simulation (WECS)
  – Revised original model
    • Driven by daily wind speed
      – Bagnold’s equation
    • Function of daily wind run
      – Wind direction
      – Field orientation

• (1995)
CROP GROWTH

- CERES model
  - Simulated crop growth and yield in uniform field
  - Maize and wheat
  - Simulates effect on development, growth & yield as a function of:
    - Cultivar
    - Plant population
    - Weather
    - Soil

- (1986)
CROP GROWTH

• EPIC crop model
  – Used some concepts from CERES
  – Generic model simulates 100+ crops
    • Annuals/perennials
    • Field crops/pastures
    • Legumes
    • Trees/shrubs
    • Unique parameters for each crop

• (1989)
CROP GROWTH

• ALMANAC crop model
  – Based on EPIC crop model
  – Plant competition (up to 10 crops)
    • Assess impact of weeds on crop yields
    • Grown in same space
    • Compete for
      – Water
      – Nutrients
      – Light
WEATHER SIMULATION

• WGEN
  – Simulated daily
    • Precipitation
    • Temperature (max and min)
    • Radiation
    • Wind speed and direction

• (1981)
WEATHER SIMULATION

• WXGN
  – Combination of WGEN and CLIGEN
  – Used in all Temple Models
  – Simulates daily
    • Precipitation
    • Temperature (max and min)
    • Radiation
    • Relative humidity
    • Wind speed and direction

• (1984)
WATER YIELD MODEL

- Developed to estimate water yield from agricultural watershed
- Based on SCS curve number
- Continuous daily time step
- Soil moisture accounting
  - Driven by pan evaporation
  - One parameter optimized to match average annual water yield
- (1976)
CREAMS

• Designed to evaluate non-point source pollution from field-size areas

• Components
  – Hydrology
  – Erosion
  – Nutrients
  – pesticides

• Daily time step hydrology
  – Surface runoff estimation
    • Based on SCS water yield model
    • Infiltration approach
  – Added ET and percolation

• Later revised to become GLEAMS
  – Emphasized pesticide fate

• (1980)
SWRRB

• Based on CREAMS daily hydrology
• Watershed scale
  – Subdivided
  – Spatial weather generator (CLIGEN)
  – Water and sediment yield (MUSLE)
  – Water & sediment balances for ponds and reservoirs
• Provided the basis for SWAT

• (1985)
SWRRB APPLICATIONS IN U.S. – 1980’S

- National Oceanic and Atmospheric Administration (NOAA) National Coastal Pollutant Discharge Inventory
- U.S. Environmental Protection Agency Pesticide Registration Model
EPIC
ENVIRONMENTAL POLICY INTEGRATED CLIMATE MODEL

• Designed to define the erosion-productivity relationship throughout the U.S.
• Field scale
• Components
  – Weather simulation
    • Weather generator
  – Hydrology
    • Runoff (CN or Green and Ampt)
  – Erosion-sedimentation
    • Wind and water
  – Nutrient cycling
• (1984)
EPIC

• Components continued
  – Plant growth
  – Tillage
  – Soil temperature
  – Economics
  – Management

• (1984)
EPIC

• Applications
  – Used to evaluate soil erosion impacts for 135 U.S. land resource regions
  – AUSCANE model (spin-off of EPIC) created to simulate Australian sugarcane production
  – Assessed the impacts of future climate change on U.S. corn, soybean, alfalfa, and wheat yields
  – Assessed impacts of typical Mayan culture agricultural cropping systems and practices on erosion and development of Mayan civilization
  – Assessed irrigation timing and amount strategies for sunflower in Southern Italy to determine critical growth stage for irrigation application
APEX
AGRICULTURAL POLICY / ENVIRONMENTAL EXTENDER MODEL

• Whole farm/watershed scale
• Subarea component (EPIC)
• Routing (water, sediment, nutrients, pesticides)
• Groundwater & reservoir
• Feedlot dust distribution
• Daily time step
• Capable of simulating 100’s of years
• (2000)
• Management capabilities
  – Irrigation
  – Drainage
  – Furrow diking
  – Buffer strips
  – Terracing
  – Waterways
  – Fertilization
  – Manure management
  – Lagoons

  – Reservoirs
  – Crop rotation and selection
  – Pesticide application
  – Grazing
  – Tillage
APEX

• Applications
  – Evaluate effects of global climate/CO\textsubscript{2} changes
  – Design environmentally safe, economic landfill sites
  – Design biomass production systems for energy
  – Livestock farm and nutrient management (manure and fertilizer)
  – Forest management
  – Evaluate effects of buffer strips nationally
  – Simulate runoff, erosion/sediment yield, nutrient and pesticide losses from cropland in the U.S. (CEAP)
SWAT
SOIL AND WATER ACCESSMENT TOOL

- Basin scale
- Based on SWRRB
- Readily available input—physically based
- Comprehensive-Process interactions
- Simulates streamflow (not just water yield),
  - subsurface flow (tile drainage)
  - groundwater flow
  - lateral flow

Upland Processes

Channel/Flood Plain Processes
SWAT

- **Upland Processes:**
  - Weather
  - Sedimentation
  - Plant Growth
  - Nutrient Cycling
  - Hydrology (impoundment, irrigation, subsurface)

- **Continuous Time**
  - Daily Time Step (sub-hourly)
  - 1 Day to 100s of Years

- **Links with APEX, EPIC, ALMANAC**

- **AVSWAT-X interface**
  (SSURGO soils, splitting tools, auto-calibration and uncertainty tools)

- **Pesticide Dynamics**
- **Soil Temperature**
- **Management (Agricultural & Urban)**
- **Bacteria**
SWAT

• Applications
  – Simulated hydrologic and/or pollutant loss impacts of agricultural & municipal water use, tillage and cropping systems trends (HUMUS)
  – Assess benefits of different conservation practices at scale national scale (CEAP)
  – Perform U.S Environment Protection Agency Total Maximum Daily Load (TMDL) analyses for impaired waters
  – Quantify the impacts of climate change
  – U.S. Environmental Protection Agency HAWQS National Environmental Assessment
PARTICIPATION IN OTHER MODEL DEVELOPMENT

• GLEAMS
• SPUR
• WEPP
• WEPS
• NLEAP