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

1938 – Calibrating gauging station W-2
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
  – Rainfall excess estimated using SCS curve number method or 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$_2$ 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
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