THE ln(a/tanß) INDEX: HOW TO CALCULATE IT AND HOW TO USE IT WITHIN THE TOPMODEL FRAMEWORK (1994)

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- **Leading researchers in the field of Digital Terrain Analysis (DTA)**
- **Beven developed TOPMODEL in 1979**

Presented by Chris Maio EEOS 383 Spring 2010

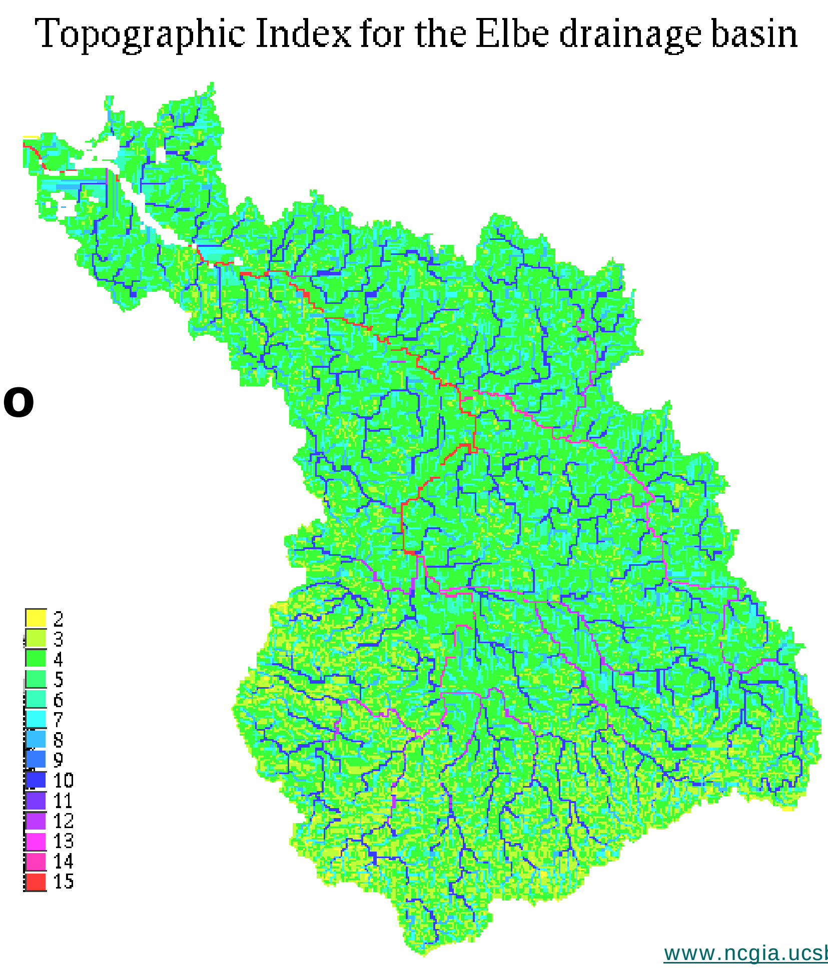
Digital Terrain Analysis (DTA)

- DTA has become a useful tool with many applications
- Enables for the calculation of topographic index distributions
- TOPMODEL and TAPES two widely used models

(Quinn, Bevan, and Lamb, 1995)

Topographical Indices:
Where is the River?

- **Used for functional representation of catchments**
- **No one "correct" way to calculate**
- **This study has defined some of the problems and possibilities for TOPMODEL application**

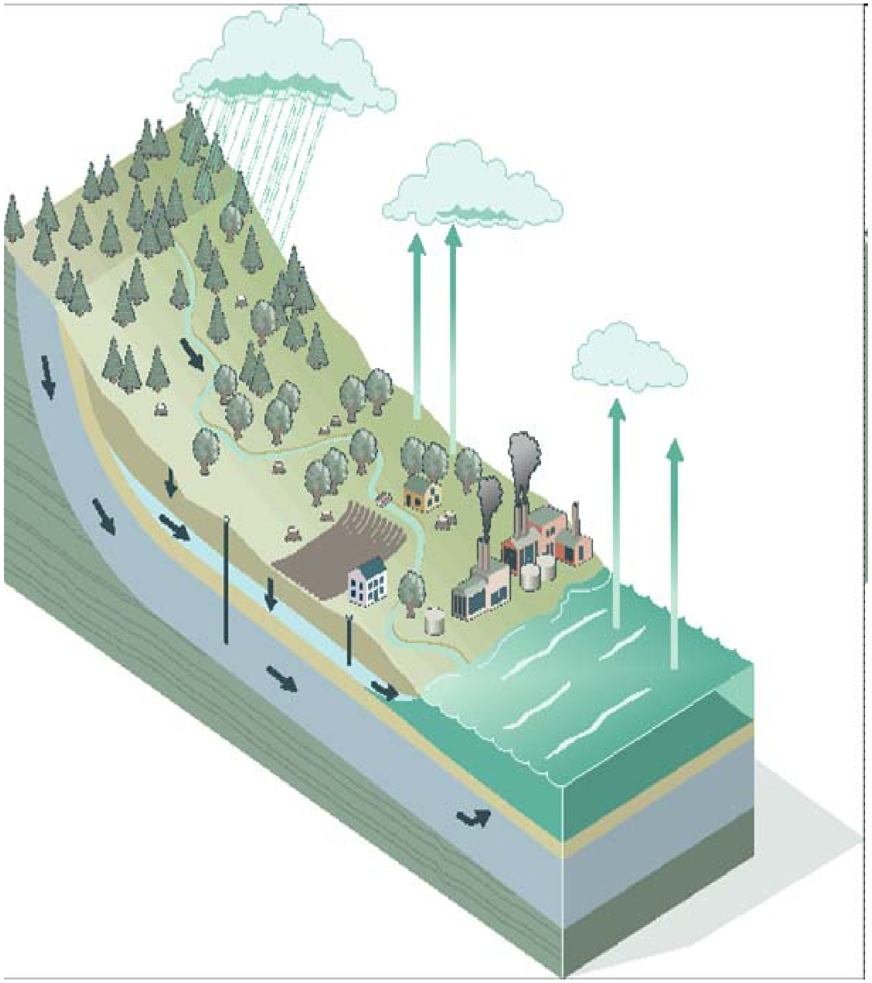


www.ncgia.ucsb.edu/.../
dmwpaper.html

(Quinn, Bevan, and Lamb, 1995)

TOPMODEL

- Bevin and Kirkby (1979)
- TOPMODEL is a rainfall-runoff model that bases its distributed predictions on an analysis of watershed topography
- Applied to the modeling variety of natural process including soil moisture fluxes, geochemical fluxes, evapotranspiration, erosion and sedimentation
- Numerous versions and techniques developed to 'optimize' model performance



(Quinn, Bevan, and Lamb, 1995)

ln(a/tanß)

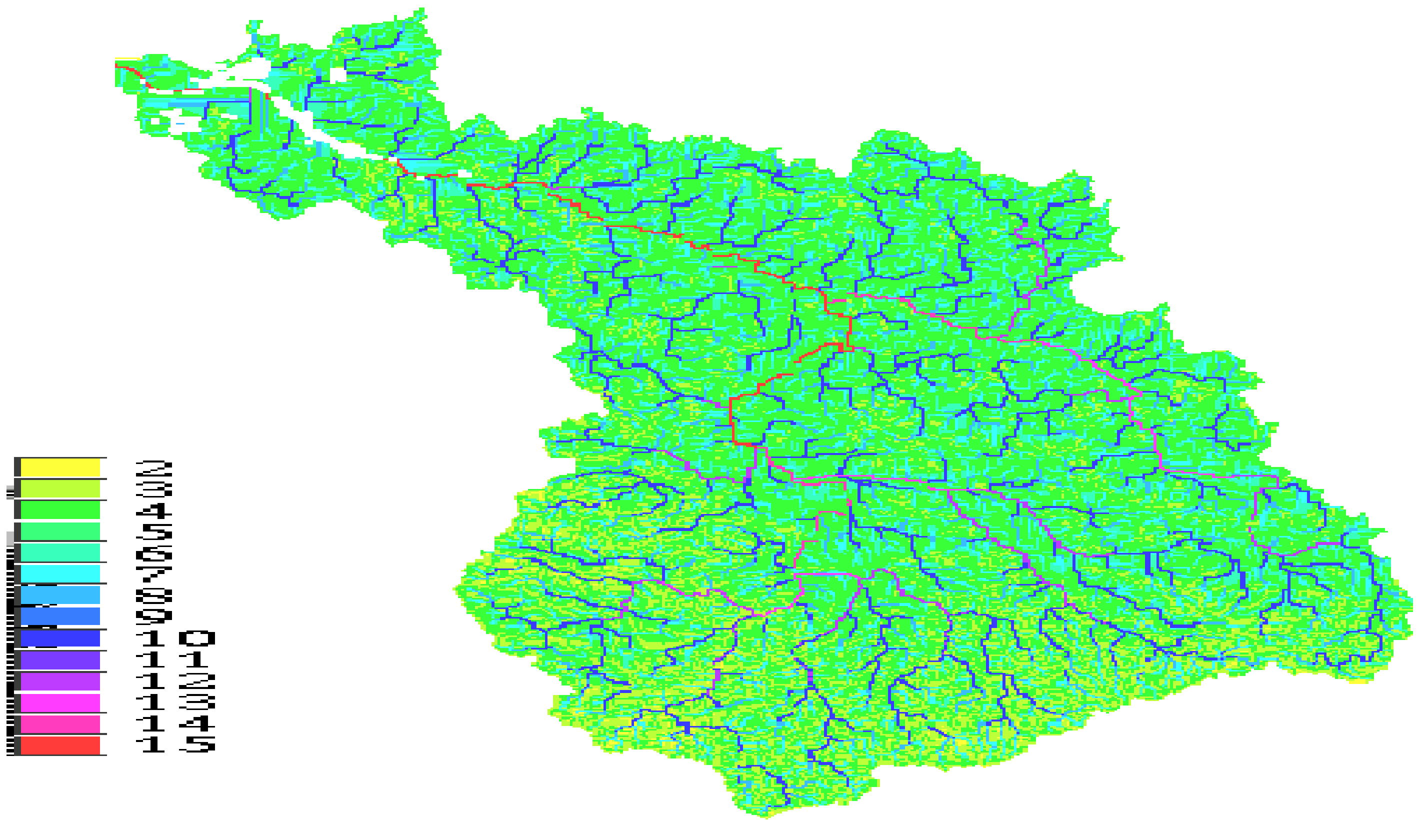
ln = Natural Log

a = upslope area per unit contour length

Tanß = local slope angle acting on a cell

(Quinn, Bevan, and Lamb, 1995)

ln(a/tanß)



Higher values associated with drainage networks

Lower values associated with ridges and upland areas

TOPMODEL

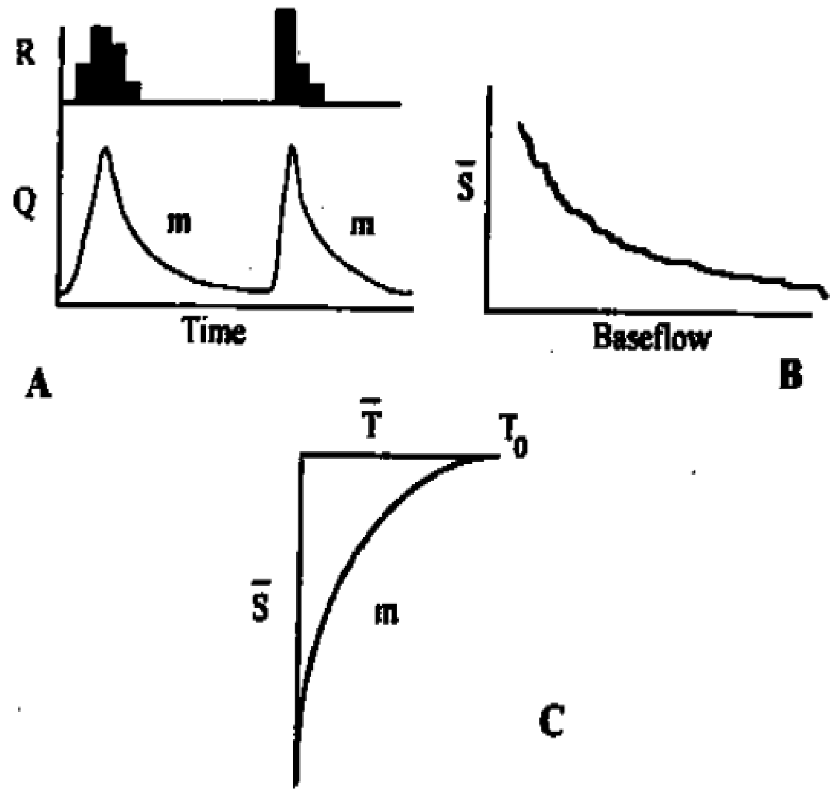


Figure 2. Temporal conceptualization of TOPMODEL. (A) Typical rainfall–runoff relationship where R is the rainfall intensity, Q is the discharge and m is the rate of change of the recession curve. (B) Relationship between the baseflow discharge and the average soil moisture deficit ($\bar{S}$) of the catchment. (C) Relationship of transmissivity with ($\bar{S}$) where $\bar{T}$ is the average operating transmissivity and T_0 is the transmissivity when saturated

(Quinn, Bevan, and Lamb, 1995)

Research Questions

- What effect does DTM grid resolution have on the calculation of the ln(a/tanß) index?
- Do different calculation procedures change results?
- Can TOPMODEL be optimized to account for data and processing limitations?

(Quinn, Bevan, and Lamb, 1995)

1. What effect does DTM grid resolution have on the value of the ln(a/tanß) index ln(a/tanß) index?

- **50 m DTM only shows downstream build up tending towards higher stream order**
- **Tends to ignore lower order channels**
- **Small channels are ‘hidden’ within large-scale grid cells**
- **Difficult to even define accurate catchment boundaries**
- **Changes value of ln(a/tanß)**

(Quinn, Bevan, and Lamb, 1995)

Impact of Resolution on Distribution Function

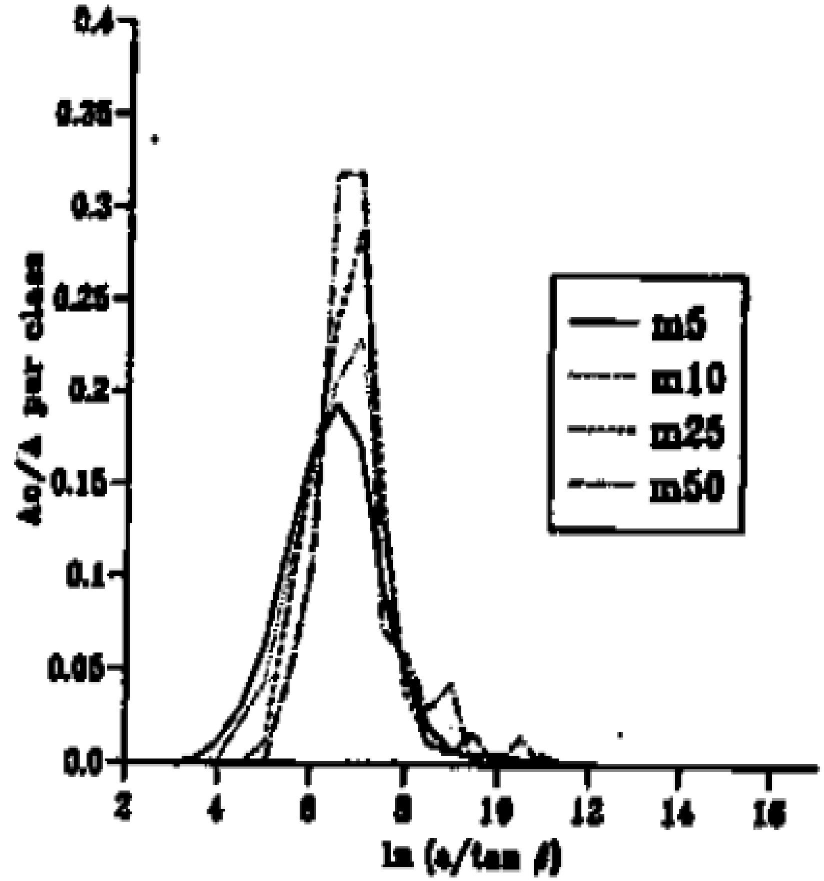
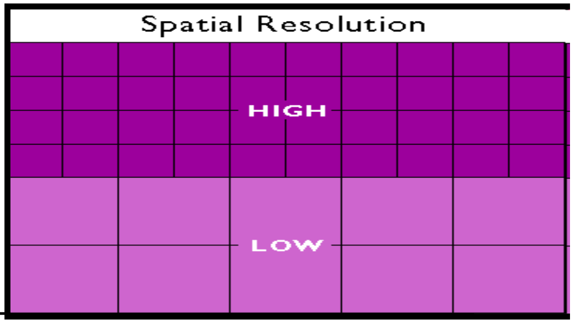


Figure 7. Effect of changing grid size on the distribution function based on the patterns of Figure 6

(Quinn, Bevan, and Lamb, 1995)

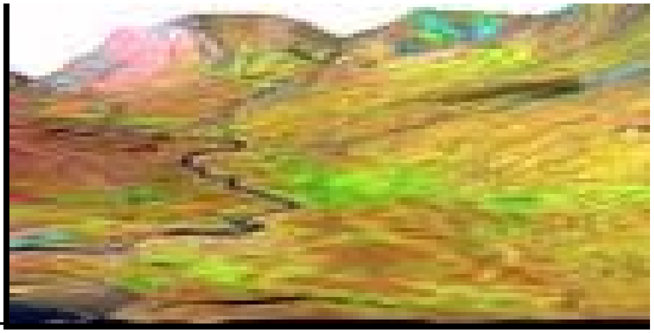
Grid Cell Size



- Large pixels are unrepresentative of detailed catchment form and validation but are still useful for macroscale interpretation of moisture flux and hydrograph predict*ion*
- ‘Optimum’ TOPMODEL parameter sets may be unique to the grid scale used in their derivation and should be set accordingly
- Large grid cells exhibit bias towards larger index values
- Smaller grid values give rise to lower index values as plan area of cells is much reduced
- Nested representative DTMs with fine resolution should be used to test internal state processes

(Quinn, Bevan, and Lamb, 1995)

Why not use ALL high resolution data?



- Fine grid scale DTM's are not available to most users
- Any reduction in grid size in even small catchments causes a huge increase in data
- Conversion or creation of fine grid scale DTMs for larger basins may introduce greater interpolation errors
- More pixels = more processing time

(Quinn, Bevan, and Lamb, 1995)

Channel Initiation Threshold (CIT)

Is there an optimum threshold for initiating a channel?

- CIT is an assumed value of upslope areas by which a permanent channel will be specified
- An ‘optimum’ channel initiation threshold (CIT) may be identified for positioning river headwaters in a raster DTM
- Dependent on DTM grid resolution
- CIT must be derived for each pixel resolution

(Quinn, Bevan, and Lamb, 1995)

2. Do different calculation procedures change ln(a/tanß) results?

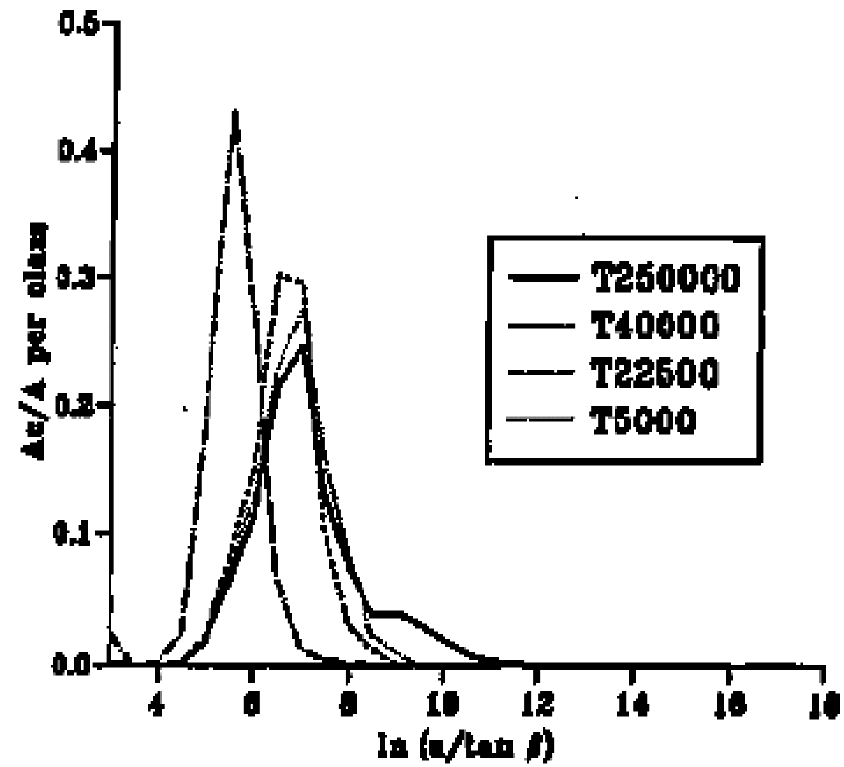


Figure 15. Change in the ln(a/tanβ) distribution function by introducing a successively lower CIT value

(Quinn, Bevan, and Lamb, 1995)

Changing CIT values Impacts ln(a/tanß)

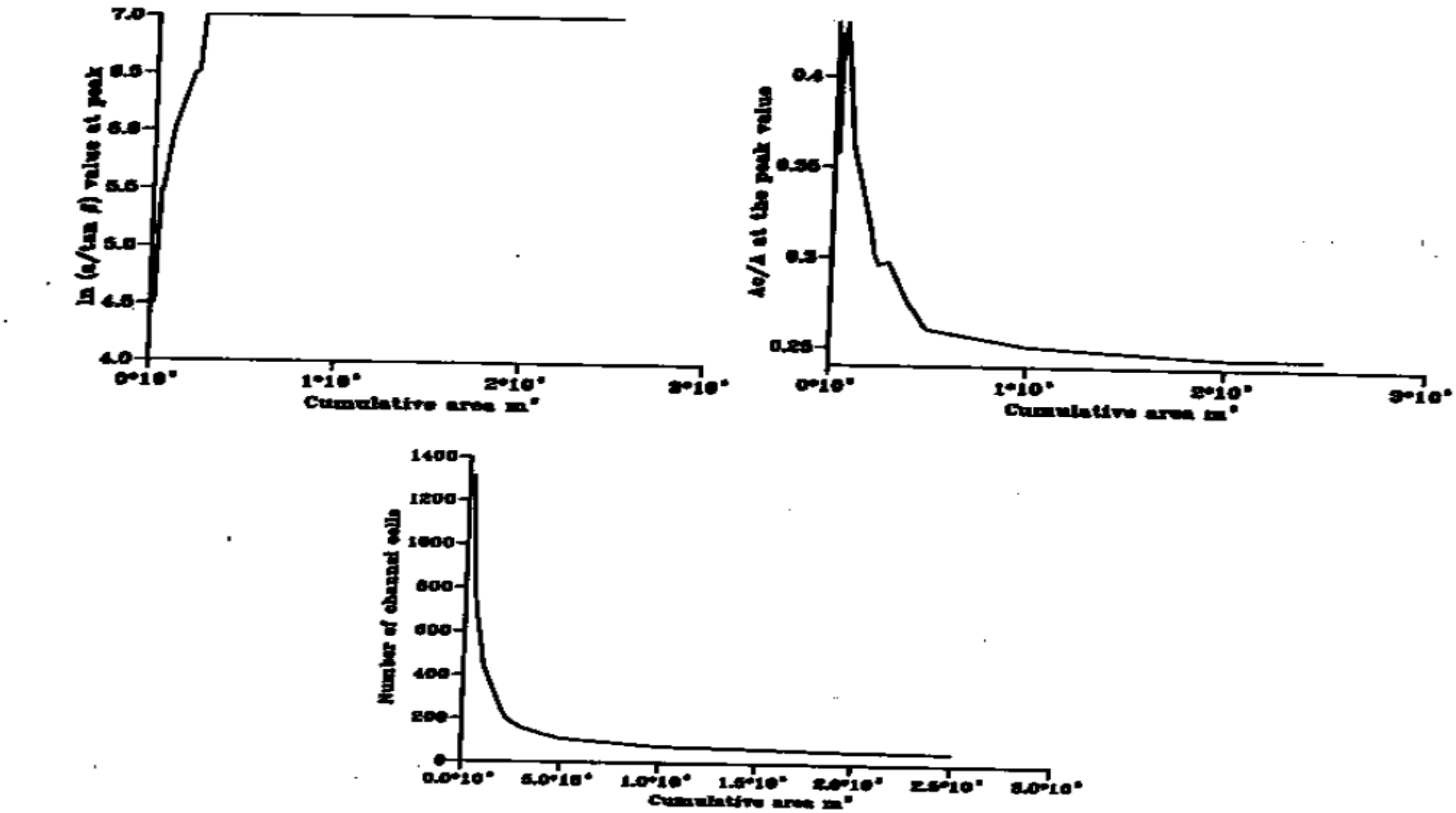


Figure 17. Changes in ln(a/tanβ) distribution function form by changing the CIT value. The optimum CIT for 50 m grid cells can be chosen in the zone just before the ln(a/tanβ) distribution changes rapidly

(Quinn, Bevan, and Lamb, 1995)

“h” Values and Distribution Function

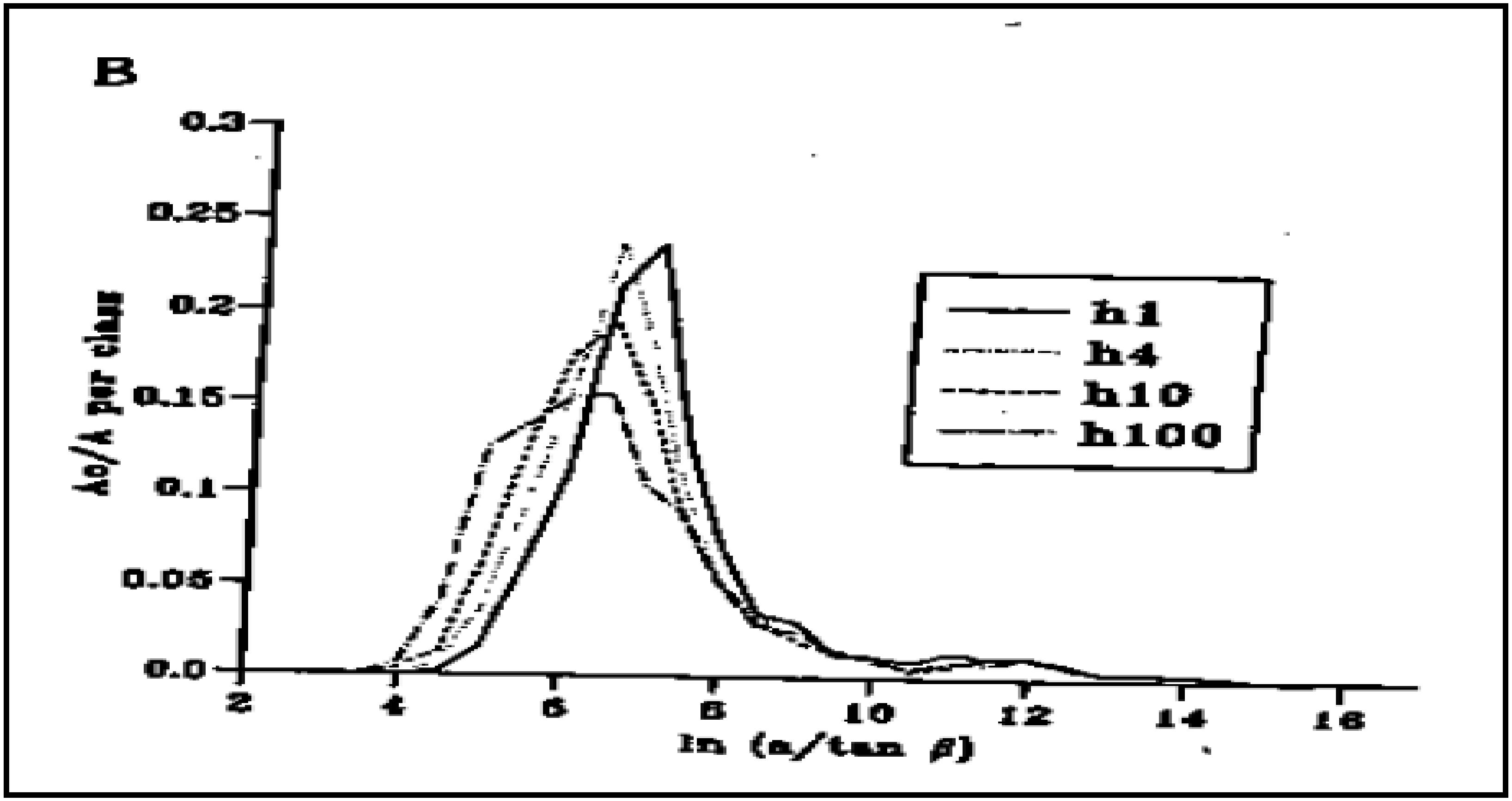


Figure 11. (A) Example map of the ln(a/tanβ) distribution for h = 10 for the control DTM. (B) ln(a/tanβ) distribution functions for a range of h values

(Quinn, Bevan, and Lamb, 1995)

3. Can TOPMODEL be optimized to account for data and processing limitations?

3 Options introduced for optimization

- **The "h" parameter of Holmgren (1994)**

- **The CIT can be optimized through accurate field observations**

  Needs to be close relationship between field hydrologist and model builders in order to 'optimize' model parameters

- **Above combination create 'feedback' version that converts multi-flow directions into single flow direction prior to entering permanent channel**

(Quinn, Bevan, and Lamb, 1995)

Conclusions

- There is no one solution for calculating the ln(a/tanß) index
- Grid Resolution does impact calculation of index
- 50 m DTM is to course a resolution for the internal validation of TOPMODEL (< 10 m required)
- Larger DTMs are able to achieve simpler goal of predicting hydrographs
- Combined CIT Index with h power variables will allow identification of permanent realistic channel
- CITs and other parameters are not transferable between grid resolutions
- Field hydrologists needed to optimize parameters of models

(Quinn, Bevan, and Lamb, 1995)

QUESTIONS?