Geospatial
Laboratory *for*
Environmental
Dynamics

Geospatial Site Types: Opportunities

Intermountain Forest Tree Nutrition Cooperative
2010 Annual Meeting

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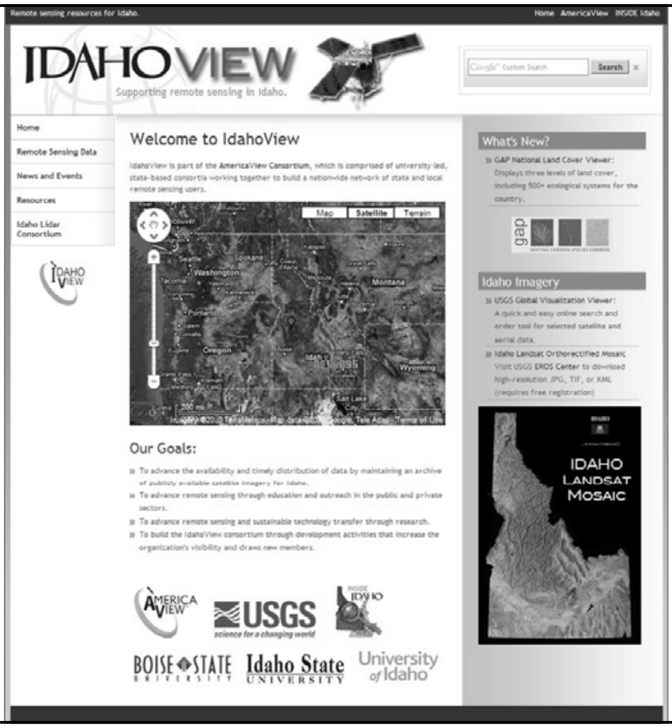
University of Idaho



Welcome to IdahoView

IdahoView is part of the **AmericaView Consortium**, which is comprised of university-led, state-based consortia working together to build a nation-wide network of state and local remote sensing users.

Our Goals:

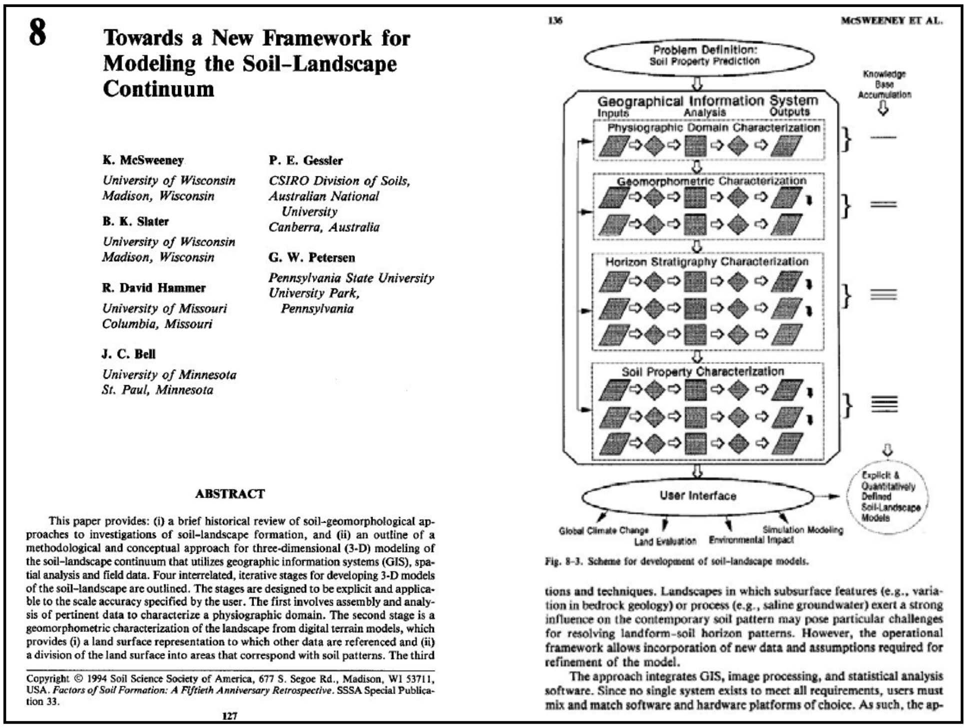
- To advance the availability and timely distribution of data by maintaining an archive of publicly available satellite imagery for Idaho.
- To advance remote sensing through education and outreach in the public and private sectors.
- To advance remote sensing and sustainable technology transfer through research.
- To build the IdahoView consortium through development activities that increase the organization's visibility and draws new members.

What's New?

- GAP National Land Cover Viewer: Displays three levels of land cover, including 500+ ecological systems for the country.

Idaho Imagery

- USGS Global Visualization Viewer: A quick and easy online search and order tool for selected satellite and aerial data.
- Idaho Landsat Orthorectified Mosaic: Visit USGS **EROS Center** to download high-resolution JPG, TIF, or KML (requires free registration)



8 Towards a New Framework for Modeling the Soil–Landscape Continuum

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ABSTRACT

This paper provides: (i) a brief historical review of soil-geomorphological approaches to investigations of soil-landscape formation, and (ii) an outline of a methodological and conceptual approach for three-dimensional (3-D) modeling of the soil–landscape continuum that utilizes geographic information systems (GIS), spatial analysis and field data. Four interrelated, iterative stages for developing 3-D models of the soil–landscape are outlined. The stages are designed to be explicit and applicable to the scale accuracy specified by the user. The first involves assembly and analysis of pertinent data to characterize a physiographic domain. The second stage is a geomorphometric characterization of the landscape from digital terrain models, which provides (i) a land surface representation to which other data are referenced and (ii) a division of the land surface into areas that correspond with soil patterns. The third

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Factors of Soil Formation: A Fiftieth Anniversary Retrospective. SSSA Special Publication 33.

Fig. 8–3. Scheme for development of soil–landscape models.

tions and techniques. Landscapes in which subsurface features (e.g., variation in bedrock geology) or process (e.g., saline groundwater) exert a strong influence on the contemporary soil pattern may pose particular challenges for resolving landform–soil horizon patterns. However, the operational framework allows incorporation of new data and assumptions required for refinement of the model.

The approach integrates GIS, image processing, and statistical analysis software. Since no single system exists to meet all requirements, users must mix and match software and hardware platforms of choice. As such, the ap-

Conceptual Quantitative Soil-landscape Model

(empirical)

$$s_{i\,(1\ldots n)} = f_{\;i\,(1\ldots n)}(x_1, x_2, x_3, \ldots x_n)$$

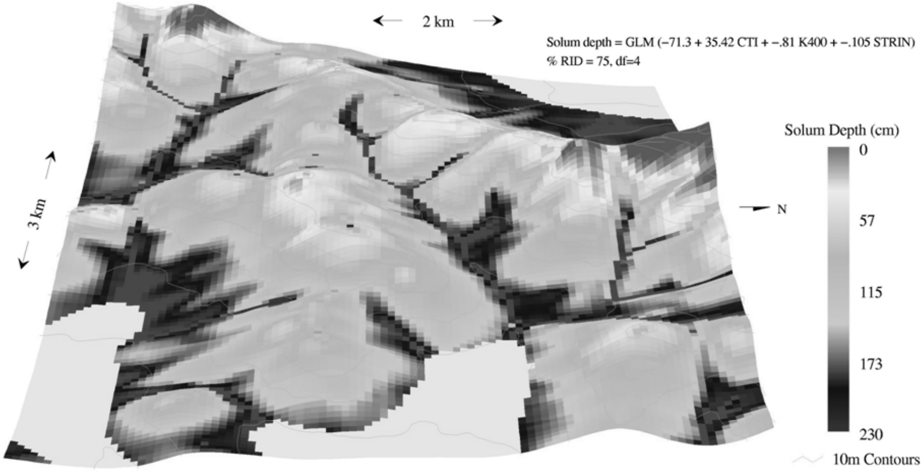
where:

s is a response soil attribute (e.g. A horizon depth, profile total carbon, B hor clay %)

i_n represents the explicit definition of the model domain or scope using available environmental variables (e.g. a region defined using climate, geology, landform)

f is the statistical model (e.g. generalized linear, generalized additive, tree-based, geostatistical, fuzzy…)

x_n are predictor environmental variables (e.g. slope, hillslope position, flow accumulation, solar radiation…)



Solum depth = GLM (−71.3 + 35.42 CTI + −.81 K400 + −.105 STRIN)
% RID = 75, df=4

Figure 3.7 Drape of Predicted Solum Depth Using a GLM Model

3-23

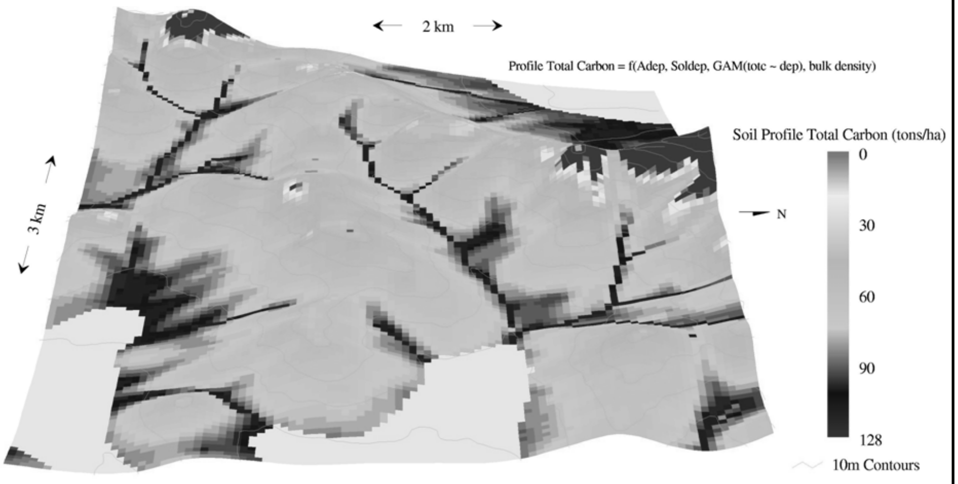
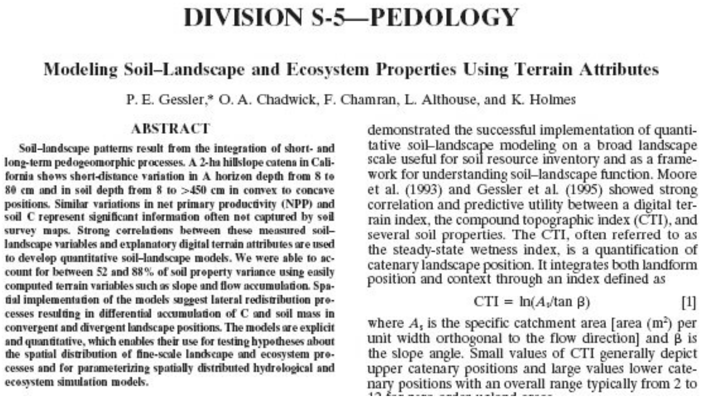


Figure 3.14 Drape of Predicted Soil Profile Total Carbon

3-34



DIVISION S-5—PEDOLOGY

Modeling Soil–Landscape and Ecosystem Properties Using Terrain Attributes

P. E. Gessler,* O. A. Chadwick, F. Chamran, L. Althouse, and K. Holmes

ABSTRACT

Soil–landscape patterns result from the integration of short- and long-term pedogeomorphic processes. A 2-ha hillslope catena in California shows short-distance variation in A horizon depth from 8 to 80 cm and in soil depth from 8 to >450 cm in convex to concave positions. Similar variations in net primary productivity (NPP) and soil C represent significant information often not captured by soil survey maps. Strong correlations between these measured soil–landscape variables and explanatory digital terrain attributes are used to develop quantitative soil–landscape models. We were able to account for between 52 and 88% of soil property variance using easily computed terrain variables such as slope and flow accumulation. Spatial implementation of the models suggest lateral redistribution processes resulting in differential accumulation of C and soil mass in convergent and divergent landscape positions. The models are explicit and quantitative, which enables their use for testing hypotheses about the spatial distribution of fine-scale landscape and ecosystem processes and for parameterizing spatially distributed hydrological and ecosystem simulation models.

demonstrated the successful implementation of quantitative soil–landscape modeling on a broad landscape scale useful for soil resource inventory and as a framework for understanding soil–landscape function. Moore et al. (1993) and Gessler et al. (1995) showed strong correlation and predictive utility between a digital terrain index, the compound topographic index (CTI), and several soil properties. The CTI, often referred to as the steady-state wetness index, is a quantification of catenary landscape position. It integrates both landform position and context through an index defined as

$$\mathrm{CTI} = \ln(A_s/\tan\beta) \qquad [1]$$

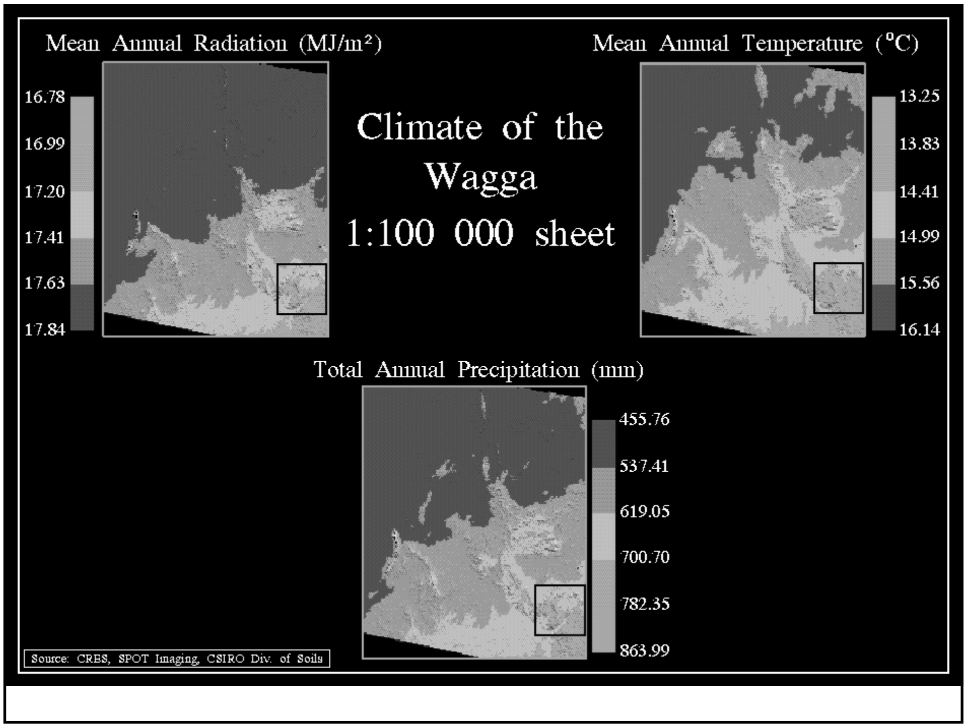
where A_s is the specific catchment area [area (m^2) per unit width orthogonal to the flow direction] and β is the slope angle. Small values of CTI generally depict upper catenary positions and large values lower catenary positions with an overall range typically from 2 to

Gessler, P.E., O.A. Chadwick, F. Chamron, K. Holmes, and L. Althouse. 2000. Modeling soil-landscape and ecosystem properties using terrain attributes. *Soil Science Society of America Journal* 64:2046-2056.

Gessler, P.E., I.D. Moore, N.J. McKenzie, and P.J. Ryan. 1995. Soil-landscape modeling and spatial prediction of soil attributes. Special issue: Integrating GIS and Environmental Modeling. *International Journal of Geographical Information Systems*, Volume 9, 4:421-432.

Hutchinson, M.F., and P.E. Gessler. 1994. Splines - more than just a smooth interpolator. Proceedings Pedometrics - 92: Developments in spatial statistics for soil science. September 1-3, 1992. Wageningen, Netherlands. *Geoderma* 62(1-3):45-67.

Moore, I.D., P.E. Gessler, G.A. Neilsen, and G.A. Petersen. 1993. Soil attribute prediction using terrain analysis. *Soil Science Society of America Journal*. 57:443-452. 3



Climate of the Wagga 1:100 000 sheet

Source: CRES, SPOT Imaging, CSIRO Div. of Soils

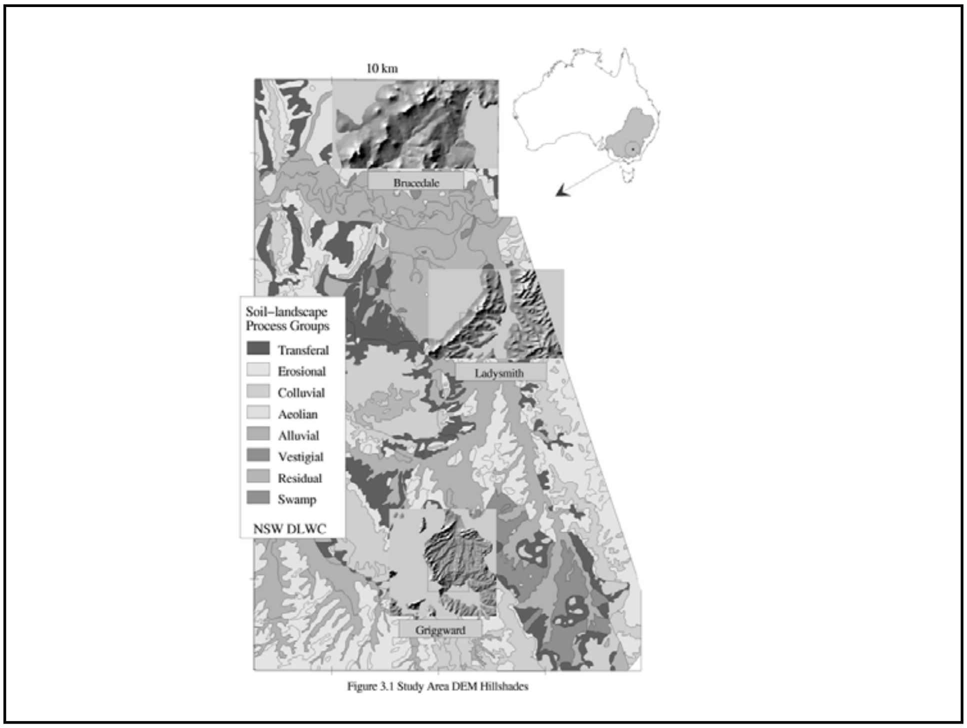
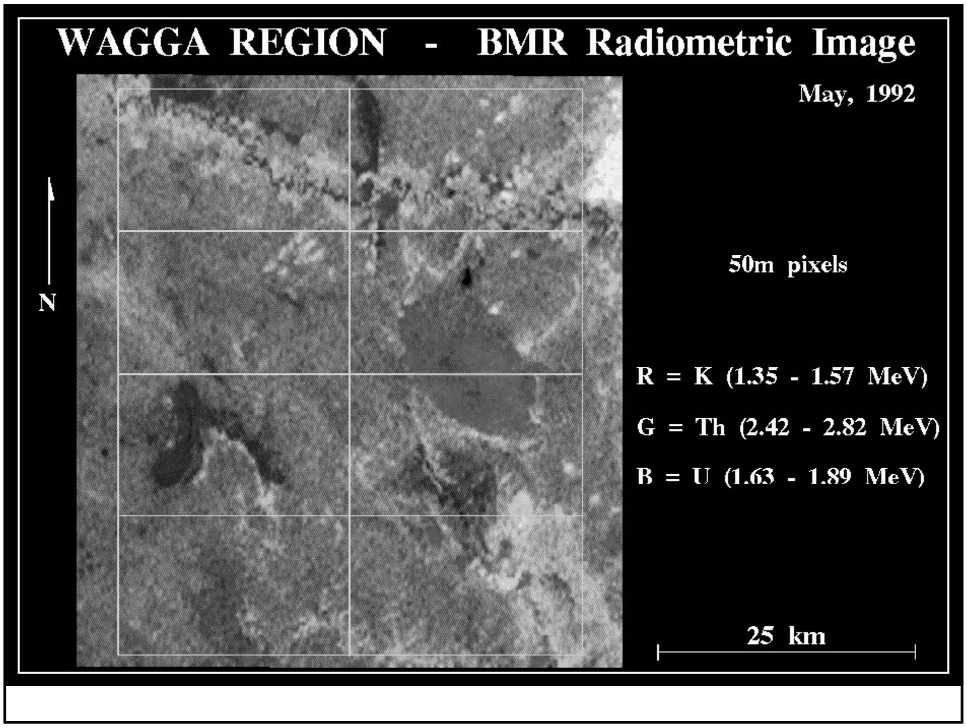


Figure 3.1 Study Area DEM Hillshades



WAGGA REGION - BMR Radiometric Image

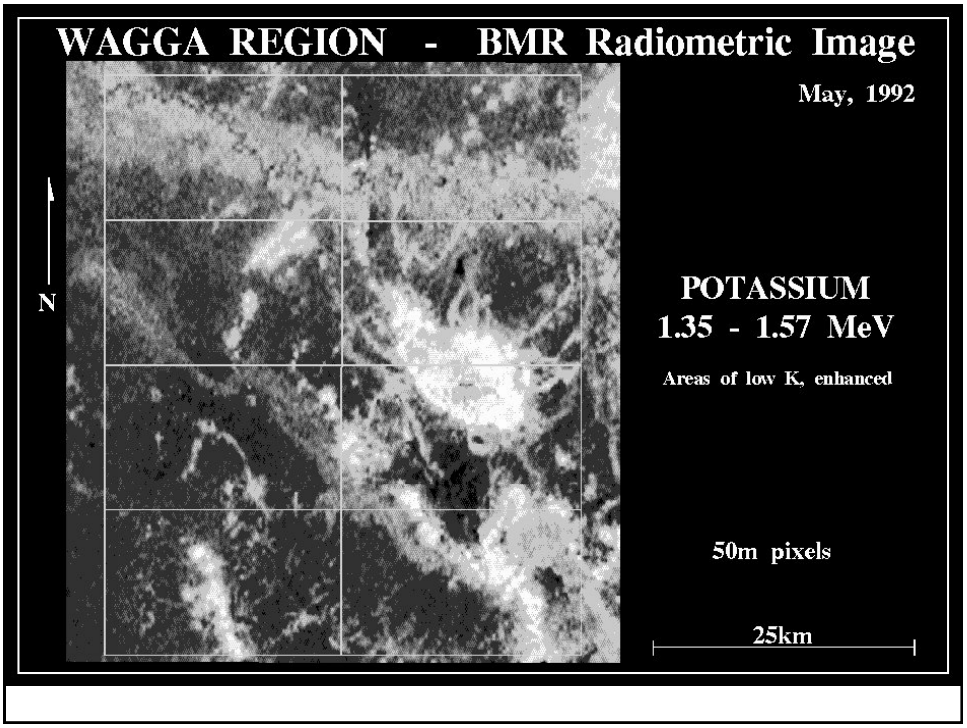
May, 1992

50m pixels

R = K (1.35 - 1.57 MeV)

G = Th (2.42 - 2.82 MeV)

B = U (1.63 - 1.89 MeV)



WAGGA REGION - BMR Radiometric Image

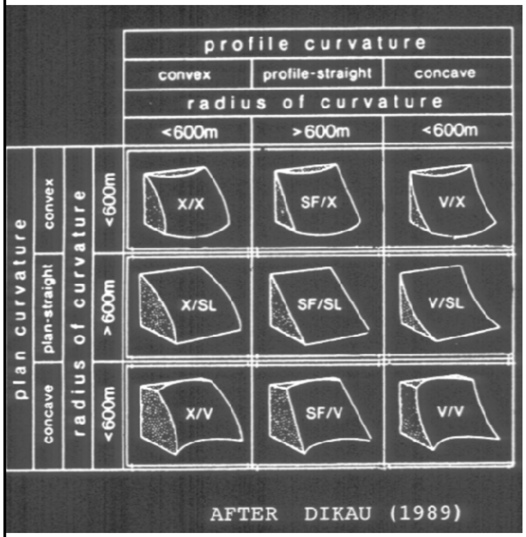
May, 1992

POTASSIUM
1.35 - 1.57 MeV

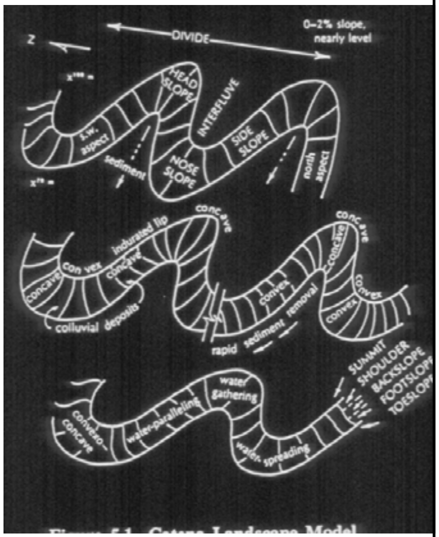
Areas of low K, enhanced

50m pixels

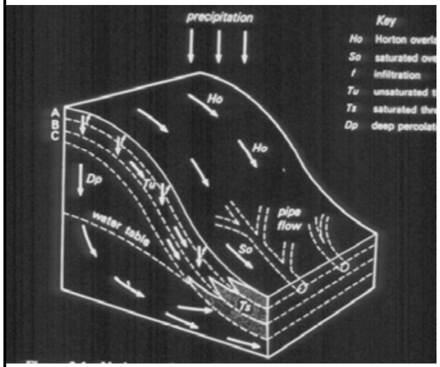
Quantitative Terrain Attributes - geomorphometry

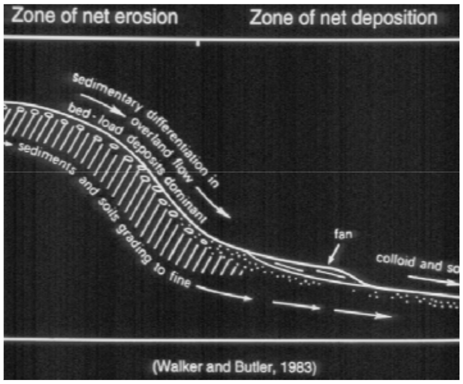


AFTER DIKAU (1989)

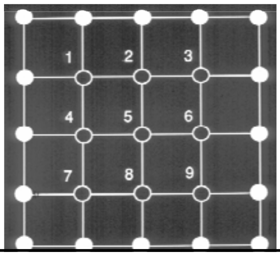


Quantitative Terrain Attributes - geomorphometry





(Walker and Butler, 1983)



Quantitative Terrain Attributes - geomorphometry

Primary terrain attributes: calculated directly from a DEM (slope, aspect, plan & profile curvature, flow accumulation)

Secondary terrain attributes: calculated from combinations of primary terrain attributes (wetness, streampower, sediment transport indices, solar radiation indices, upslope slope – contextual combinations)

Opportunities for sampling – ensuring that we collect samples that represent the population we are attempting to understand, model and map

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Compound Topographic Index

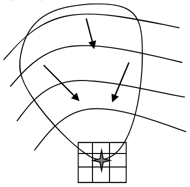
(or steady-state wetness index)

(Speight, 1974; Bevan & Kirkby, 1979; Moore et al. 1991; 1993)

$$CTI = \ln(A_s / \tan B)$$

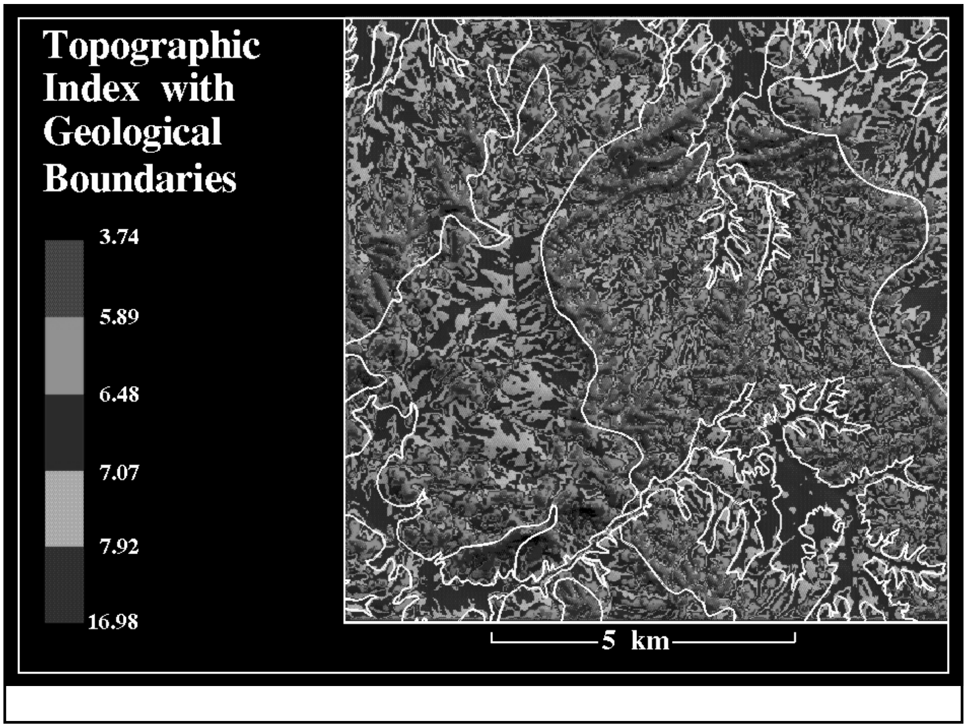
where:

A_s is the specific catchment area (contributing area (m^2) per unit width of contour orthogonal to the flow direction)

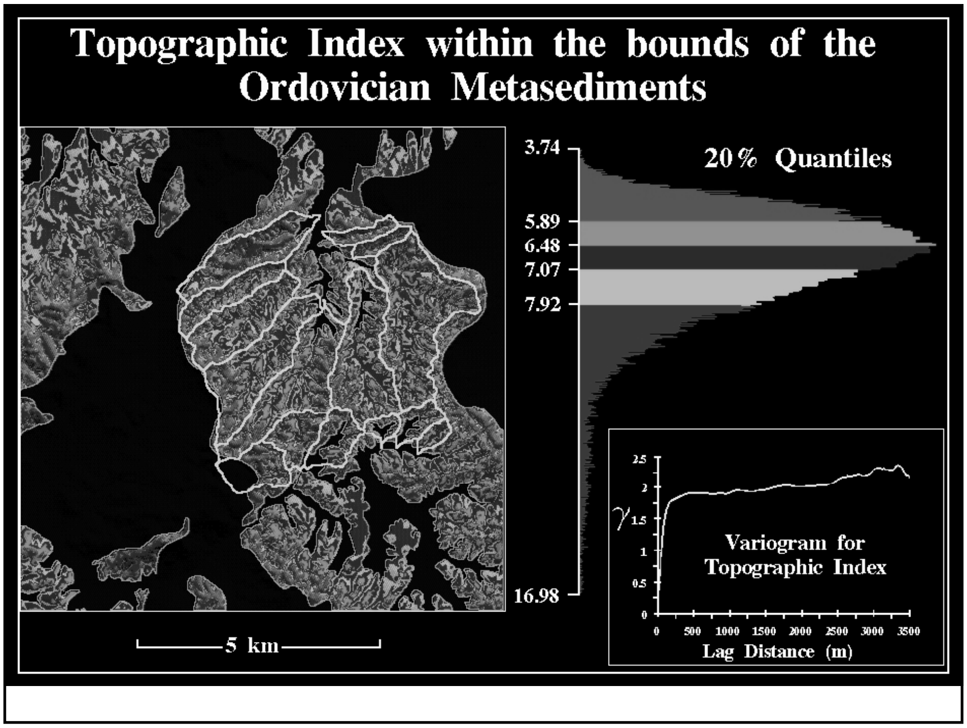


B is the slope angle in degrees

“a quantification of catenary landscape position”

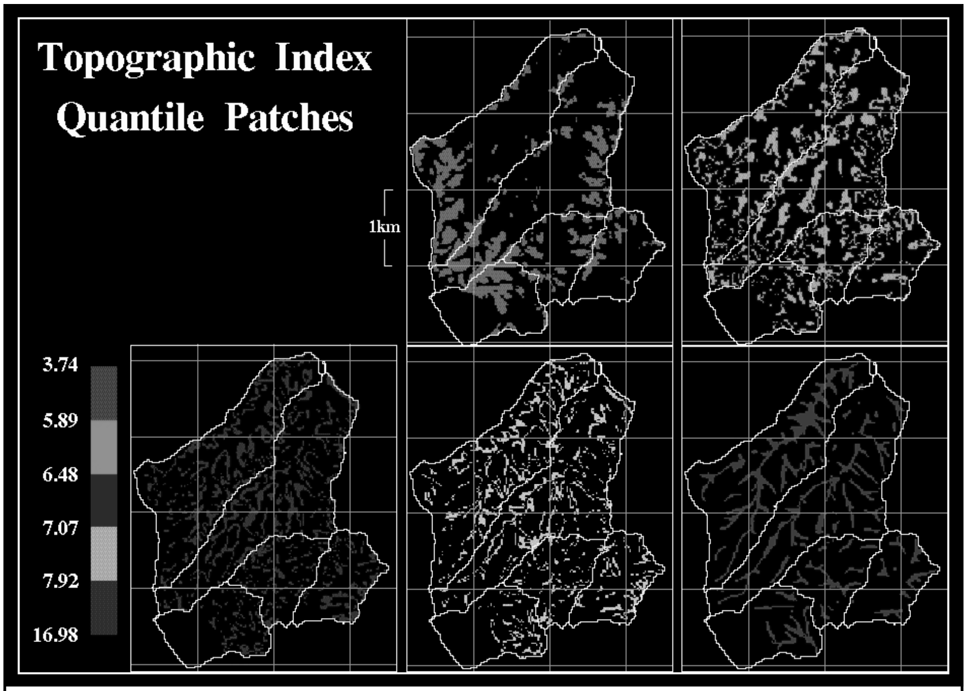


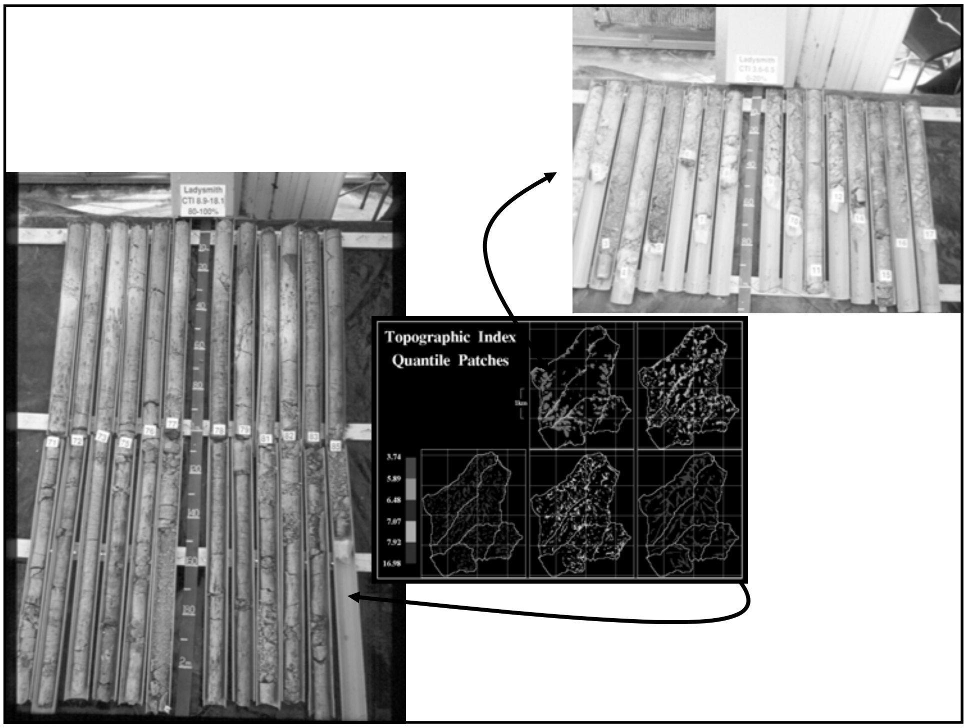
Topographic Index with Geological Boundaries



Topographic Index within the bounds of the Ordovician Metasediments

Topographic Index Quantile Patches

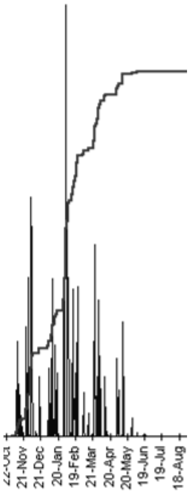


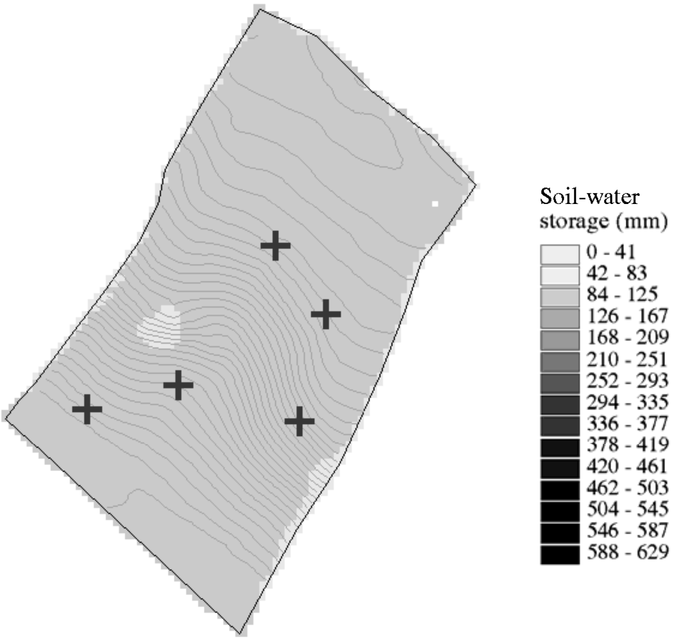


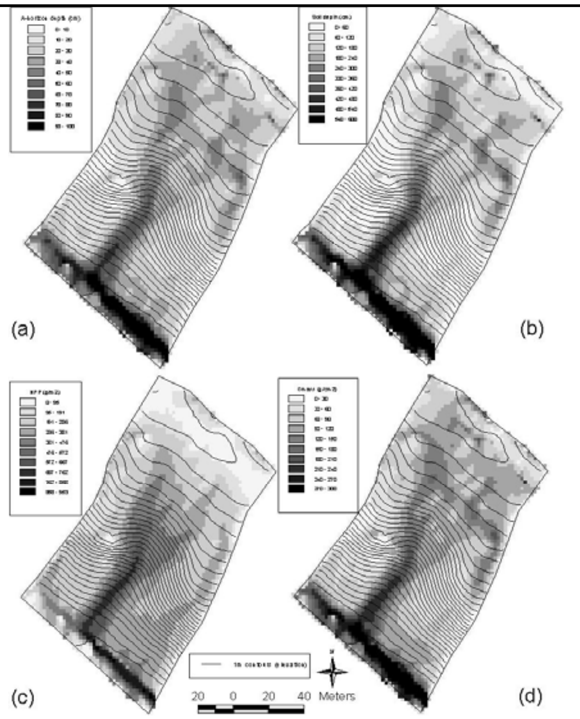
El Niño - 1998

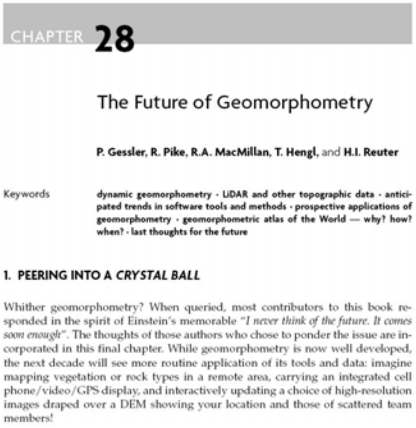
January to May weekly time steps

June to August monthly time steps









CHAPTER **28**

The Future of Geomorphometry

P. Gessler, R. Pike, R.A. MacMillan, T. Hengl, and **H.I. Reuter**

Keywords **dynamic geomorphometry · LiDAR and other topographic data · anticipated trends in software tools and methods · prospective applications of geomorphometry · geomorphometric atlas of the World — why? how? when? · last thoughts for the future**

1. PEERING INTO A *CRYSTAL BALL*

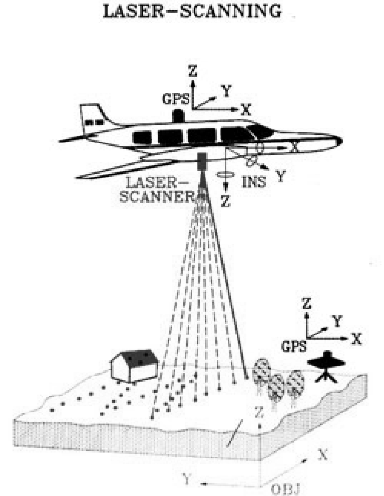
Whither geomorphometry? When queried, most contributors to this book responded in the spirit of Einstein's memorable *"I never think of the future. It comes soon enough"*. The thoughts of those authors who chose to ponder the issue are incorporated in this final chapter. While geomorphometry is now well developed, the next decade will see more routine application of its tools and data: imagine mapping vegetation or rock types in a remote area, carrying an integrated cell phone/video/GPS display, and interactively updating a choice of high-resolution images draped over a DEM showing your location and those of scattered team members!

Gessler, P., R. Pike, T. Hengl, R.A. MacMillan and H.I. Reuter. 2009. The future of geomorphometry. Chapter 28 In: Hengl, T., Reuter, H.I. (eds.), *Geomorphometry: concepts, software, applications*. Developments in Soil Science, Vol. 33, 637-651. Elsevier.

Nelson, A., H.I. Reuter and P. Gessler. 2009. DEM production methods and sources. Chapter 3 In: Hengl, T., Reuter, H.I. (eds.), *Geomorphometry: concepts, software, applications*. Developments in Soil Science, Vol. 33, 65-86. Elsevier.

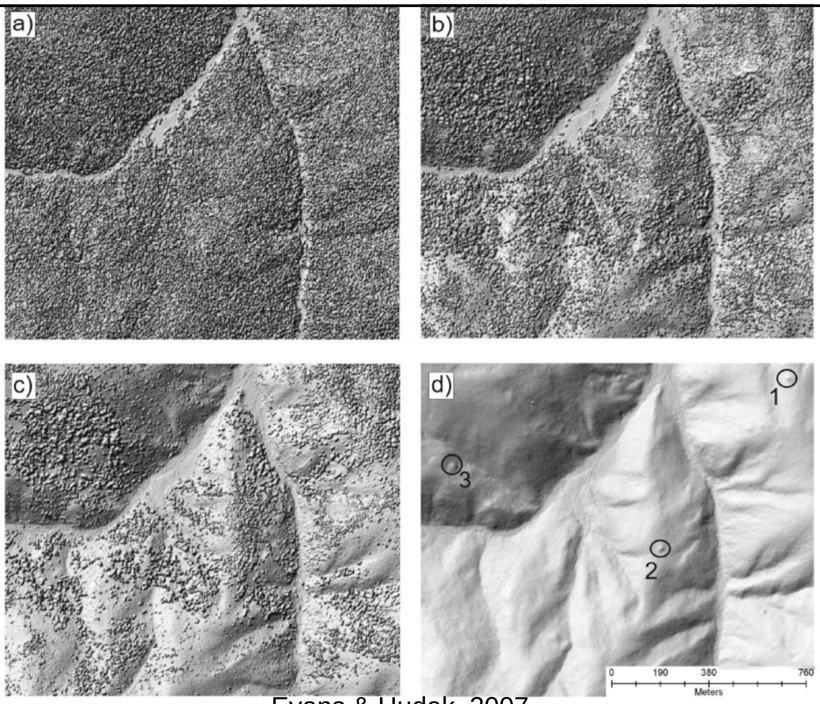
Reuter, H.I., T. Hengl, P. Gessler and P. Soille. 2009. Preparation of DEMs for geomorphometric analysis. Chapter 4 In: Hengl, T., Reuter, H.I. (eds.), *Geomorphometry: concepts, software, applications*. Developments in Soil Science, Vol. 33, 87-120. Elsevier.

LIDAR

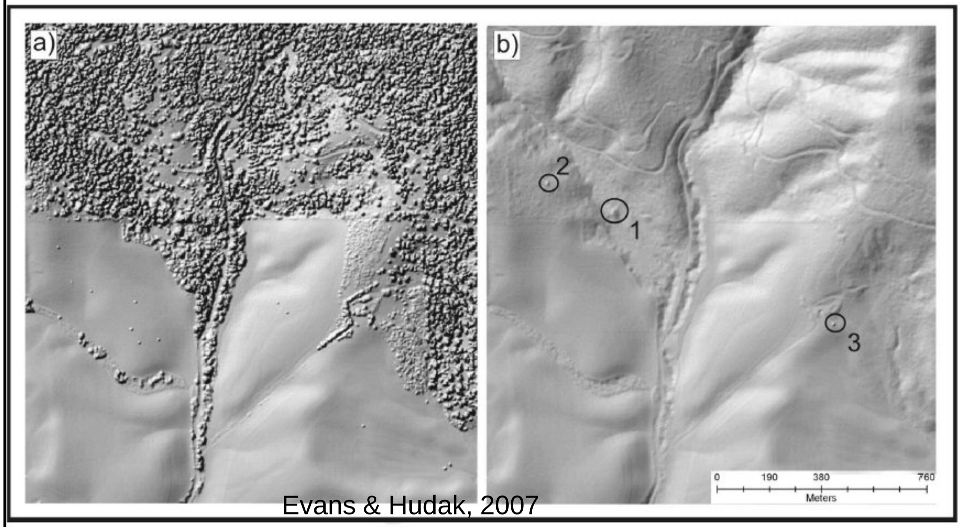


(Source: http://www.sbgmaps.com/lidar.htm)

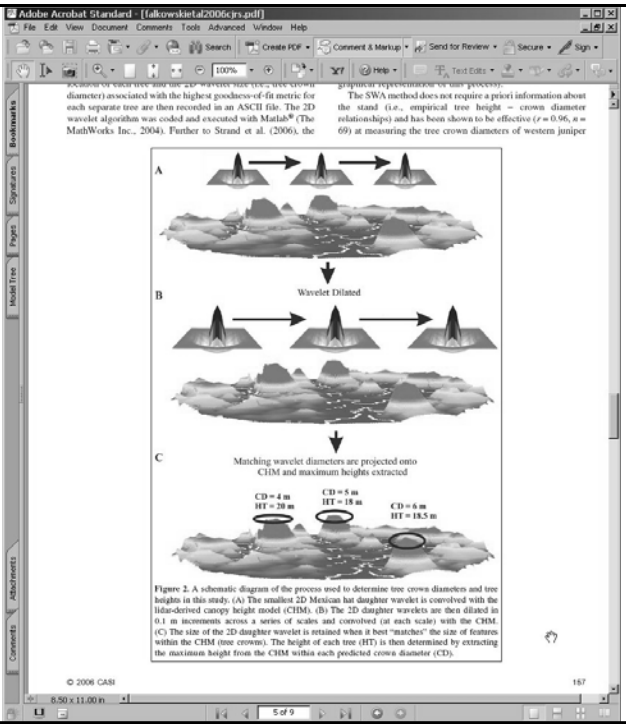
- Lidar – Light Detection and Ranging
- 1st developed in 1960 by Hughes Aircraft inc.
- Modern computers and DGPS make it practical: requires extremely accurate timing
- Measures distance to surfaces by timing a laser pulse and it's corresponding return(s)
- Lidar data are the X, Y, Z positions of each return
- Typically used in very accurate mapping of topography



Evans & Hudak, 2007



Evans & Hudak, 2007



diameter) associated with the highest goodness-of-fit metric for each separate tree are then recorded in an ASCII file. The 2D wavelet algorithm was coded and executed with Matlab® (The MathWorks Inc., 2004). Further to Strand et al. (2006), the

The SWA method does not require a priori information about the stand (i.e., empirical tree height – crown diameter relationships) and has been shown to be effective ($r = 0.96$, $n = 69$) at measuring the tree crown diameters of western juniper

Figure 2. A schematic diagram of the process used to determine tree crown diameters and tree heights in this study. (A) The smallest 2D Mexican hat daughter wavelet is convolved with the lidar-derived canopy height model (CHM). (B) The 2D daughter wavelets are then dilated in 0.1 m increments across a series of scales and convolved (at each scale) with the CHM. (C) The size of the 2D daughter wavelet is retained when it best "matches" the size of features within the CHM (tree crowns). The height of each tree (HT) is then determined by extracting the maximum height from the CHM within each predicted crown diameter (CD).

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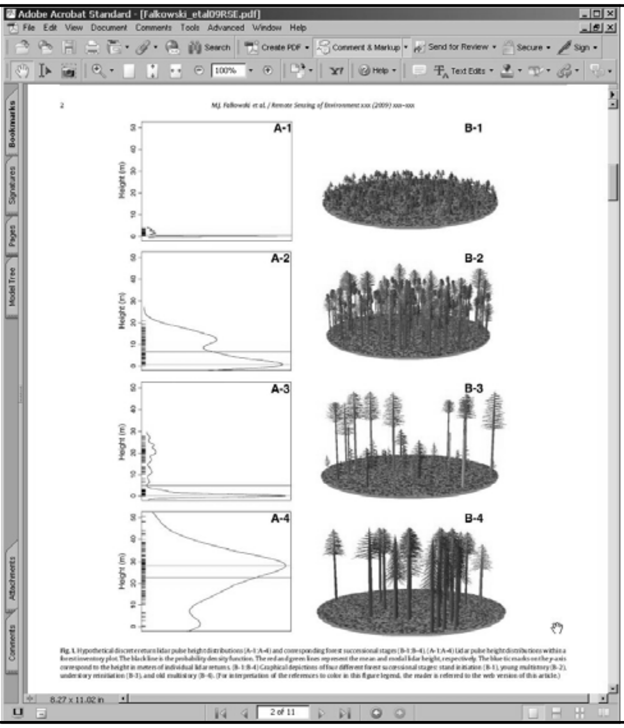

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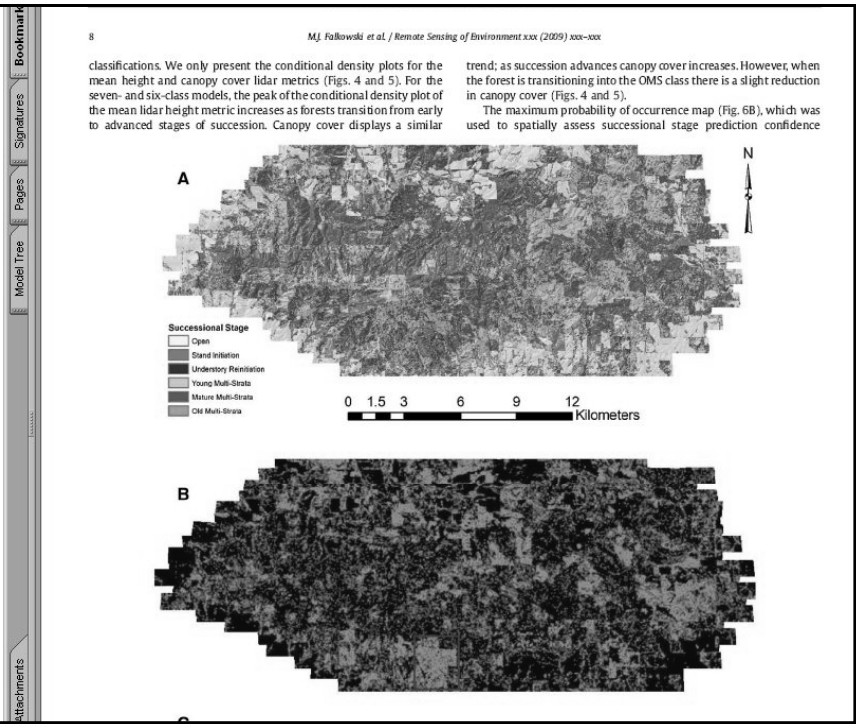
Fig. 1. Hypothetical discrete return lidar pulse height distributions (A-1:A-4) and corresponding forest successional stages (B-1:B-4). (A-1:A-4) Lidar pulse height distributions within a forest inventory plot. The black line is the probability density function. The red and green lines represent the mean and modal lidar height, respectively. The blue tic marks on the y-axis correspond to the height in meters of individual lidar returns. (B-1:B-4) Graphical depictions of four different forest successional stages: stand initiation (B-1), young multistory (B-2), understory reinitiation (B-3), and old multistory (B-4). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)



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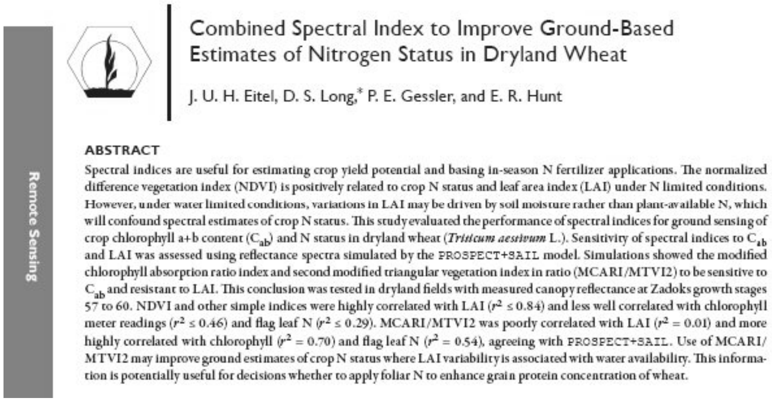
classifications. We only present the conditional density plots for the mean height and canopy cover lidar metrics (Figs. 4 and 5). For the seven- and six-class models, the peak of the conditional density plot of the mean lidar height metric increases as forests transition from early to advanced stages of succession. Canopy cover displays a similar trend; as succession advances canopy cover increases. However, when the forest is transitioning into the OMS class there is a slight reduction in canopy cover (Figs. 4 and 5).

The maximum probability of occurrence map (Fig. 6B), which was used to spatially assess successional stage prediction confidence



Remote Sensing

Combined Spectral Index to Improve Ground-Based Estimates of Nitrogen Status in Dryland Wheat

J. U. H. Eitel, D. S. Long,* P. E. Gessler, and E. R. Hunt

ABSTRACT

Spectral indices are useful for estimating crop yield potential and basing in-season N fertilizer applications. The normalized difference vegetation index (NDVI) is positively related to crop N status and leaf area index (LAI) under N limited conditions. However, under water limited conditions, variations in LAI may be driven by soil moisture rather than plant-available N, which will confound spectral estimates of crop N status. This study evaluated the performance of spectral indices for ground sensing of crop chlorophyll a+b content (C_{ab}) and N status in dryland wheat (*Triticum aestivum* L.). Sensitivity of spectral indices to C_{ab} and LAI was assessed using reflectance spectra simulated by the `PROSPECT+SAIL` model. Simulations showed the modified chlorophyll absorption ratio index and second modified triangular vegetation index in ratio (MCARI/MTVI2) to be sensitive to C_{ab} and resistant to LAI. This conclusion was tested in dryland fields with measured canopy reflectance at Zadoks growth stages 57 to 60. NDVI and other simple indices were highly correlated with LAI ($r^2 \leq 0.84$) and less well correlated with chlorophyll meter readings ($r^2 \leq 0.46$) and flag leaf N ($r^2 \leq 0.29$). MCARI/MTVI2 was poorly correlated with LAI ($r^2 = 0.01$) and more highly correlated with chlorophyll ($r^2 = 0.70$) and flag leaf N ($r^2 = 0.54$), agreeing with `PROSPECT+SAIL`. Use of MCARI/MTVI2 may improve ground estimates of crop N status where LAI variability is associated with water availability. This information is potentially useful for decisions whether to apply foliar N to enhance grain protein concentration of wheat.

Eitel, J.U.H., D.S. Long, P.E. Gessler and E.R. Hunt. 2008. Combined spectral index to improve ground-based estimates of nitrogen status in dryland wheat. *Agronomy Journal*. 100:1694-1702.

Eitel, J., D.S. Long, P.E. Gessler, E.R. Hunt, and D. Brown. 2009. Sensitivity of ground-based remote sensing estimates of wheat chlorophyll content to variation in soil reflectance. *Soil Science Society of America Journal*. 73(5): 1715-1723.

Eitel, J.U.H., D.S. Long, P.E. Gessler, and A.M.S.Smith. 2007. Using in-situ spectroradiometry to evalue RapidEye satellite data for prediction of wheat nitrogen status. *International Journal of Remote Sensing*. Vol. 28.(18):4183-4190.

Celebrating 100 Years of Forestry Education

Geospatial
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Dynamics

Geospatial Site Types: Opportunities

- integrating geospatial data layers to develop and explore/ define site types useful for forest management & sustainable growth
- gamma radiometric remote sensing – biogeochemistry & nutrient distribution – complement to foliar sampling
- geomorphometry – landform quantification, sampling in landscapes, quantitative/ explicit models
- LiDAR – key tool for forested and rugged settings, measuring trees/productivity and characterizing

landforms/landscapes - productivity and nutrient distribution & movements in landscapes

Thanks - paulg@uidaho.edu