N85-32733

D.L. Peterson: BIOGEOCHEMICAL CYCLING AND REMOTE SENSING

Research is underway at the NASA Ames Research Center that is concerned with aspects of the nitrogen cycle in terrestrial ecosystems. An interdisciplinary research group is attempting to corelate nitrogen transformations, processes, and productivity with variables that can be remotely sensed. Recent NASA and other publications concerning biogeochemical cycling at global scales identify attributes of vegetation that could be related or explain the spatial variation in biologically functional variables. These functional variables include net primary productivity, annual nitrogen mineralization, and possibly the emission rate of nitrous oxide from soils.

Leaf area index of temperate coniferous forests has been estimated using remote sensing. Leaf area index (LAI), the one-sided projected area of canopies to a unit of ground area, has been consistently identified as a key structural variable. Canopy radiation models show that increased leaf layers in a canopy produce increased reflectance in the infrared region and that this property is asymptotic at LAI=7-8 (Fig. I-20). The reflectance in the infrared region is measured by band 4 (0.90 microns) on the Thematic Mapper (TM) satellite or by simulated TM data obtained by the Daedalus scanner on the NASA U-2 aircraft. Photosynthetically active radiation, especially in the red region, is strongly absorbed by leaves. In fully developed forests, the reflectance in the red region is very low and asymptotic at only LAI=2-3. The red region measurements are complicated by radiance added due to atmospheric scattering and the variation due to transmittance as a function of path length through air masses. We are evaluating these effects with helicopter measurements directly above the canopies of our chosen research sites using a portable field radiometer. In addition, the lack of reliable atmospheric correction algorithms for land scenes force us to compensate by using only relative values or ratios. We use band 3 to normalize the band 4 measurements which compensate for small differences between sites. However, this ratio does not remove the influence on sensitivity that preliminary calculations show reduce the sensitivity to LAI by a factor of about four.

To obtain a range of LAI, we selected sites that follow a temperature-moisture gradient across west-central Oregon. Leaf development in Oregon coniferous forests respond to this gradient from mild and moist temperatures on the coast to hot temperatures and dry sites in the desert (Fig. I-21). Net primary productivity was related to LAI by Henry Gholz (Fig. I-22). Most of the forest stands (sites) are dense, mature forests with nearly closed canopies (a major source of variation in remotely sensed data). Dimensional measurements were made at each site and applied to allometric relations to derive stand level leaf biomass and area. The relationship of these LAI estimates to the ratio of bands 4/3 (infrared/red reflectance) is shown in

ORIGINAL PAGE IS
OF POOR QUALITY

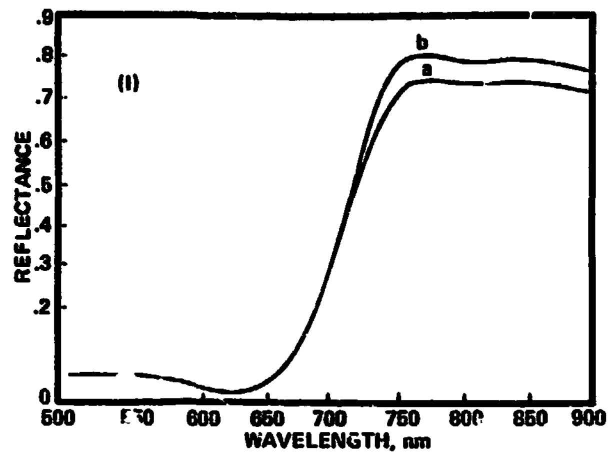

Figure I-20. Theoretical models of reflected radiation using deterministic methods for plant canopies. Courtesy of NASA Ames Research Center.

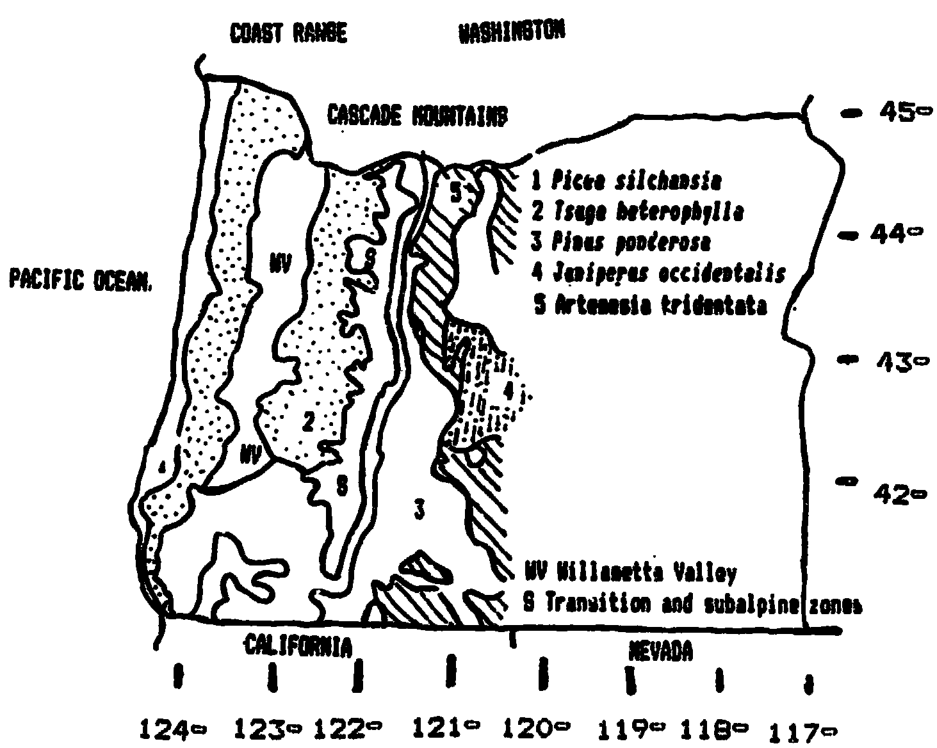

Figure I-21. Location of transect and vegetation zones in Oregon.

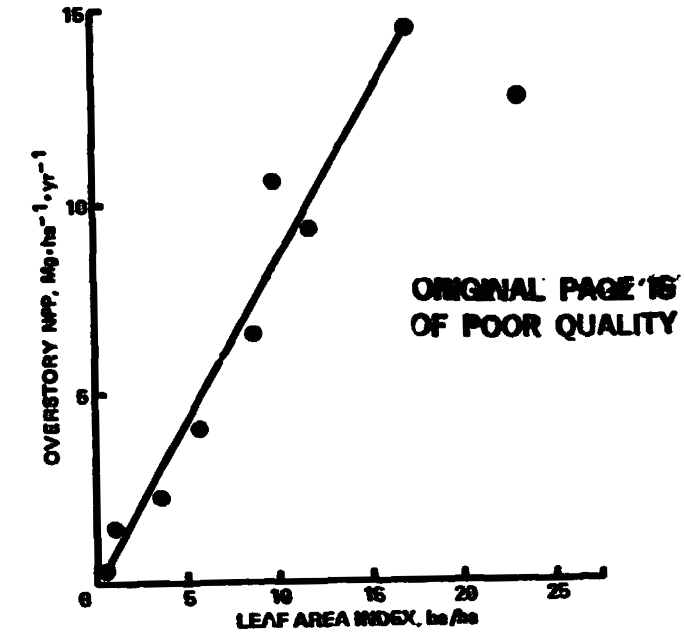

Figure I-22. Relationship between overstory net primary productivity (NPP in Mg/hectare/year) and leaf area (in hectare/hectare) for Oregon transect. Courtesy of Gholz, H.L., 1982.

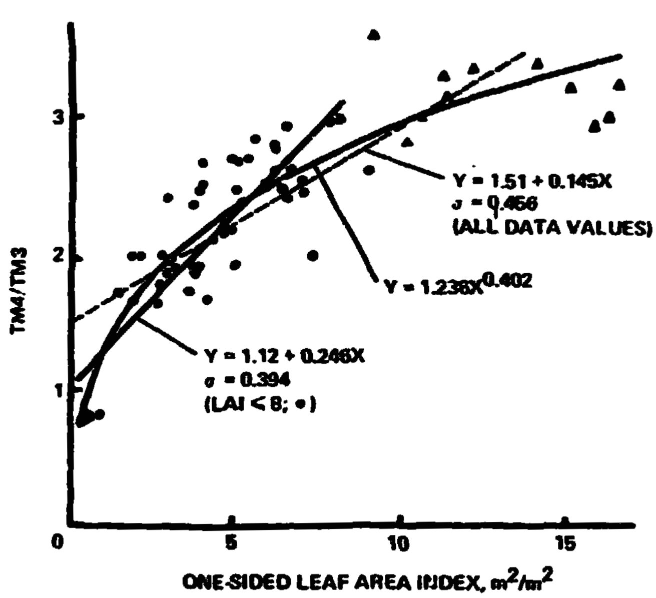

Figure I-23. Relationship of leaf area index (LAI) of secondary sample units to the ratio of thematic mapper (TMS) band 4/band 3.

Figure I-23. A good predictive relationship exists between both the linear and logarithmic curves. The log relationship appears to match the asymptotic behavior best, and this is more consistent with model expectations.

We are beginning to use high spectral resolution remote sensing data for deriving canopy biochemistry. Data are being synthesized from several well-established research sites in Alaska and Wisconsin and other areas for forests of different fertilities and contrasting environments. The synthesis will be used to develop and test a semi-mechanistic process-level model that combines plant-water relations, carbon assimilation-allocation, and nitrogen-phosphorus cycling. Estimates of total canopy nitrogen, phosphorus, and lignin content together with microclimate will be used to drive the model. This model is designed to use remotely sensed inputs, particularly leaf chemistry.

Total canopy nitrogen, phosphorus, and lignin content are the required inputs for remote sensing. Nitrogen, for example, is bound up primarily in chlorophylls and the proteins of leaves. Each organic constituent of leaves has unique absorption properties due to specific stretching frequencies of the chemical bonds. This fine spectral information cannot be observed with broad-band satellites such as the TM. However, new scanners are now available to make high spectral resolution (10 nm) between 1400 and 2400 nm (later from 400 to 2400 nm) measurements using the Airborne Imaging Spectrometer from JPL. The spectral curves for the four major leaf constituents - proteins, water, oils, and carbohydrates - are shown in Figure I-24. Through a combination of wet chemical and spectrophotometric analyses, we plan to develop multi-linear regressions and related corelation techniques which can be used to infer these biochemical variables from the scanner.

Chance, J.E. and LeMaster, E.W., 1977. Suits reflectance models for wheat and cotton: theoretical and experimental tests, Applied Optics, 16: 407-412.

Spanner, M.A., Peterson, D.C., Hall, M., Wrigley, R., and Running, S.W., 1984. Atmospheric effects on remote sensing of forest leaf area index. Proc. 18th International Symp. Remote Sensing of Environment, Paris.

Gholz, H.L. 1982. Environmental limits on above ground net primary production, leaf area, and biomass in vegetation zones of the Pacific Northwest, Ecology, 61:469-481.

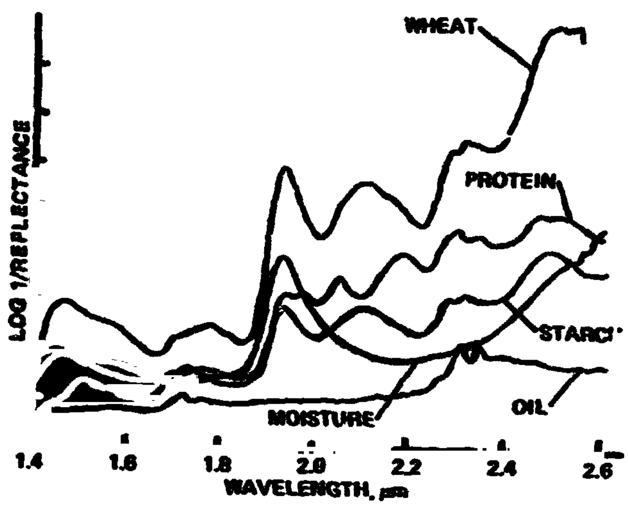

Figure I-24. Organic constituent spectra and typical composite spectra for grain (wheat berries).

Spanner, M. A., Teuber, K., Acevedo, W., Peterson, D. L., Running, S. W., and Card, D. H., 1984. Remote sensing of the leaf area index of temperate coniferous forests. Proc. 10th International Symp. Machine Processing of Remotely Sensed Data, pp. 362-370.

Hruschka, W. R. and Norris, K. H.. 1982. Least squares curve fitting of near-infrared spectra predicts protein and moisture contents of ground wheat, Applied Spectroscopy, 36:241-265.

Goetz, A. F. H., Rock, B. N., and Rowan, L. C., 1983. Remote sensing for exploration: An overview, Economic Geology. 78:573-590.