ANNUAL REPORT
NASA CONTRACT NAS5-31368
FOR MODIS TEAM MEMBER STEVEN W. RUNNING
ASSOC. TEAM MEMBERS E.RAYMOND HUNT, RAMAKRISHNA R. NEMANI 15 JANUARY 1994

PRE-LAUNCH TASKS PROPOSED IN OUR CONTRACT OF DECEMBER 1991

We propose, during the pre-EOS phase to: (1) develop, with other MODIS Team Members, a means of discriminating different major biome types with NDVI and other AVHRR-based data. (2) develop a simple ecosystem process model for each of these biomes, BIOME-BGC based on the logic of the current FOREST-BGC; (3) relate the seasonal trend of weekly composite NDVI to vegetation phenology and temperature limits to develop a satellite defined growing season for vegetation; and (4) define physiologically based energy to mass conversion factors for carbon and water for each biome.

Our final core at-launch product will be simplified, completely satellite driven biome specific models for ET and PSN based on this modified NDVI logic. These algorithms will be in MODISDIS before launch. We will build these biome specific satellite driven algorithms using a family of simple ecosystem process models as calibration models, collectively called BIOME- BGC, and establish coordination with an existing network of ecological study sites in order to test and validate these products. Field datasets will then be available for both BIOME-BGC development and testing, use for algorithm developments of other MODIS Team Members, and ultimately be our first test point for MODIS land vegetation products upon launch. We will use field sites from the National Science Foundation Long-Term Ecological Research network, and develop Glacier National Park as a major site for intensive validation.

OBJECTIVES:

We have defined the following near-term objectives for our MODIS contract based on the long term objectives stated above.

1) Organization of an EOS ground monitoring network with collaborating U.S. and international science agencies.
2) Compiling a journal article summarizing the products planned by MODLAND during the EOS era, for distribution throughout the scientific community.
3) As development of the MODIS Surface resistance product, mapping the seasonal changes in surface moisture status over the continental US from NOAA/AVHRR.

4) Develop advanced logic for landcover classification using carbon cycle simulations from BIOME-BGC.
5) Develop improved algorithms for estimating LAI and FPAR for different biome types from AVHRR data.
6) Development of a generalized ecosystem process model, BIOME-BGC, for the simulation of the carbon, water and nitrogen cycles for different biomes.
7) Implementation of the Global Ecological Simulation System (GESSys).
8) Use GESSys to estimate continental net primary production (NPP) and for the globe.

WORK ACCOMPLISHED:

Algorithm Theroetical Basis Documents (ATBDs)

Ray, Rama and I produced ATBDs for our leaf area index (LAI) and fraction absorbed photosynthetically active radiation (FPAR) products, and our photosynthesis(PSN)-net primary production (NPP) products, and submitted these in Sept 1993.

OBJECTIVE 1: Organization of an EOS ground monitoring network with collaborating U.S. and international science agencies.

EOS-LTER

Plans are continuing with the LTER scientists, sponsored by the National Science Foundation, to use the LTER's in the United States as an EOS ground monitoring network. SWRunning attended the NSF LTER meeting in Estes Park, Colorado in Sept 1993. He chaired a workshop designing the protocol for a collective proposal from the LTER participants to establish the network of field validation sites for MODLAND products. The site sub-proposals were submitted to Warren Cohen of the HJAndrews LTER on December 1, for assembly into the final proposal, joint to NASA and NSF in Winter 1994.

Global Terrestrial Observing System (GTOS)

SWRunning has been nominated to the IGBP-GTOS. This newly proposed global monitoring network may prove to be an important avenue for developing a coordinated EOS ground monitoring network.

BOREAS project

We plan for BOREAS to provide us with a wealth of field data for MODLAND algorithm testing and validation. SWRunning attended the BOREAS Science Team meeting in October 1993 at

CoolFont Virginia. (Dorothy Hall and Allen Strahler also attended from MODLAND). SWR is organizing a modeling program as part of BOREAS science for February 7-9, 1994 in Missoula, Montana.

IGBP Biospheric Aspects of the Hydrologic Cycle (BAHC)

As vice-chair of BAHC, SWRunning has responsibility for developing and coordinating the science agenda of this core IGBP project. Many of the IGBP science objectives are tightly related to EOS science objectives, and are being executed by many of the same people. SWR visited the BAHC office in Berlin on July 5-6, 1993, and gave a seminar on global modelling.

IGBP Global Change and Terrestrial Ecosystems (GCTE)

ERHunt attended a GCTE meeting in Seattle, Washington (April 12-16, 1993) for the purpose of defining a new focus on forest ecosystems

OBJECTIVE 2: Journal article summarizing the products planned by MODLAND during the EOS era.

The MODLAND manuscript was accepted for publication in the International Journal of Remote Sensing in December 1993.

OBJECTIVE 3: Development of the MODIS Surface resistance product.

A journal article on our work appeared in the Journal of Applied Meteorology in March 1993.

OBJECTIVE 4: Develop advanced logic for landcover classification using carbon cycle simulations from BIOME-BGC.

During SWR's sabbatical leave at the University of Lund, Sweden with Dr. I. Colin Prentice, he spent considerable time developing a global landcover classification logic that can be remotely sensed. These ideas were written into a manuscript submitted to the journal, Ambio, as part of a special issue from the IGBP meeting in Ensenada, Mexico. A related manuscript was submitted for the ISLSCP Special Issue of Remote Sensing of Environment.

The utility of surface temperature observations from air and space borne sensors is being investigated in land cover classification. Surface temperature was found to be strongly controlled by fraction of vegetation cover. Different biomes with their inherent canopy geometric properties produce differential plant cover, which leads to large differences in observed surface temperature. Therefore, we believe surface

temperature observations can contribute substantial information in separating various land cover classes.

OBJECTIVE 5: Develop improved algorithms for estimating LAI and FPAR from AVHRR data.

Based on recent work from spectral-mixture models and radiative transfer models, NDVI may be more related to fraction of vegetation cover rather than LAI. By determining the maximum LAI for a vegetation class from other data, then LAI may be determined from fraction cover. Figure 2 shows our most recent version of a global LAI product.

Prototype versions of algorithms for deriving FPAR and LAI from MODIS data were developed for the ATBDs. A sensitivity analysis of various parameters in the algorithms is being undertaken using a 3-D canopy radiation model. We are also exploring the use of MODIS data from middle infrared wavelengths for extracting canopy biophysical parameters.

OBJECTIVE 6: Development of a generalized ecosystem process model, BIOME-BGC.

BIOME-BGC was revised with new variables and algorithms for soil biogeochemical processes and stable carbon isotope discrimination during photosynthesis. The isotopic ratio 13C/12C of vegetation may be one best parameters available for validating BIOME-BGC, because it integrates water use efficiency over a year. Also, 13C/12C may be used as an atmospheric tracer of the uptake and release of carbon by the oceans and terrestrial biosphere.

OBJECTIVE 7: Implementation of Global Ecosystem Simulation System, GESSys.

BIOME-BGC was revised to run under the UNIX operating system for workstations. The code was optimized and incorporated into the Global Ecological Simulation System (GESSys). C. David Keeling and Steve Piper providing 1987 daily climate data at a 1 latitude by 1 longitude resolution. Ralf Otto, visiting from the University of Frankfurt (now Johann Wolfgang Goethe Universitaet), generated data layers for soil water holding capacity from Zobler's dataset.

We have just finished the first annual global ecosystem simulations done at daily time resolution, at 1x1 deg spatial resolution. The results are summarized in the attached 7 figures. These simulations are important first prototypes of our MODIS products for global photosynthesis and net primary production.

OBJECTIVE 7: Use GESSys to estimate continental net primary production (NPP) from AVHRR-NDVI data.

We determined from GESSys that much of the variation in for forests may be attributed to the large mass of living wood. We are collaborating with Canadian scientists to determine if ERS-1 or JERS-1 synthetic aperture radar (SAR) may be used to determine woody biomass.

Activities of Assoc Team Member E.R.Hunt

E. Raymond Hunt's major activities were as follows. In collaboration with scientists from Canada, I studied the relationship between SAR backscatter and forest stand parameters to determine if SAR may provide important ancillary data for MODIS algorithms. I am also continuing to write up Mr. Agus Hidayat's thesis on combining AVHRR-NDVI data with BIOME-BGC simulations for a tropical forest, a globally important ecosystem. I also made two important presentations. One was to the Ecological Society of America and one was an invited seminar on my continuing work on BIOME-BGC development. Finally, I attended the FIFE Science Workshop in Manhattan, Kansas. Use of the FIFE data set to test BIOME-BGC is a high priority for MODIS algorithm development.

The invited seminar was at Oak Ridge National Laboratory, which is the site of the EOS Land-DAAC. Recently, I was appointed to the Oak Ridge Land DAAC Science Advisory Group. Some time was spent discussing possible historic data sets which may be saved by the DAAC. However, most of my time was spent discussing possible collaboration with the Walker Branch Throughfall Displacement Experiment. This manipulation experiment may be our best opportunity to rigorously test BIOME-BGC for a deciduous broadleaf forest ecosystem.

ANTICIPATED FUTURE ACTIONS

The proposal for ground validation of our LAI and NPP products by the LTER network will be completed in the coming 6 months

The final ATBDs for our LAI, FPAR, PSN and NPP products will be completed by Feb 28.

A Boreas Modeling workshop will be held here in February.

MEETINGS ATTENDED in 1993 (attendee initials included) The Third IGBP Scientific Advisory Council and Symposium, Ensenada, Mexico, 25-29 January 1993. SWR

UNEP Classification Scheme Workshop, January 1993. LL Pierce
MODIS Science Team meeting, March 1993. SWR EOS/LTER Workshop, March 1993. SWR.
IGBP-GCTE New Focus on Forest Ecosystems, April 1993. ERH
SCOPE Model Comparison Workshop, London, April 1993. SWR.
SCOPE Global Change Workshop, Washington DC, May 1993. ERH
EPRI Global Model Comparison Workshop, Woods Hole, July 1993.
RRN 4th International CO2 conference, Sept 12-17, in Carquaraine, France. RRN
Workshop on Thermal Remote Sensing of the Energy and Water Balance over Vegetation, Sept 22-25, in La Londe Les Maures, France. RRN (Papers presented:"Influence of surface and atmospheric conditions on the Ts/NDVI relation at the watershed scale." R. Nemani and S.Running. and "Land cover classification using the combination of spectral vegetation indices and surface temperature from AVHRR." R.Nemani and SW.Running.
MODIS Science Team Meeting September 1993. SWR, RRN NSF LTER All-hands meeting, September 1993 SWR IGBP-DIS Global NPP Workshop, Paris, France. November 1993. SWR NASA EOS-IWG Meeting San Antonio, Texas January 1994. SWR FIFE Science Workshop: Manhattan, Kansas; October 13- 15, 1993. ERH
Ecological Society of America Annual Meeting: Madison, Wisconsin; July 31 - August 4, 1993. ERH
User Working Group for the Oak Ridge National Laboratory Distributed Active Archive Center (DAAC) of EOSDIS.ERH

PUBLICATIONS

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Nemani, R.R., L.L. Pierce, S.W. Running and S.N. Goward. 1993. Developing satellite derived estimates of surface moisture status. Journal of Applied Meteorology, 32: 548-557.

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Figure Captions

Figure 1. The data flowchart for our Global Ecosystem Simulation System, GESSys.

Figure 2. Global leaf area index estimates derived from long-term climate, soil texture and GVI data. First, leaf area index of a plant/clump/tree (LAIp) was derived using the hydrologic equilibrium between climate, soil and leaf area. Then, the LAIp was scaled to the canopy Leaf area index using estimates of fractional vegetation cover derived from the GVI data.

Figure 3. Estimated available soil water holding capacity from soil texture and potential vegetation. We assigned specific Soil Conservation Service texture classes to the Zobler soil texture database available from Kineman and Ohrenschall (1992 NOAA/EPA Global Ecosystems Database version 1.0 on CD-ROM). From texture, volumetric water content at field capacity was calculated. Soil depth was estimated from Matthews Vegetation Database (Kineman and Ohrenschall 1992). From soil depth and volumetric water content at field capacity, the available water content was estimated.

Figure 4. Global lifeform map from Matthew's potential vegetation and cultivation intensity maps (from Kineman and Ohrenschall 1992). We assigned Matthews vegetation classes to one of five lifeforms. When cultivation

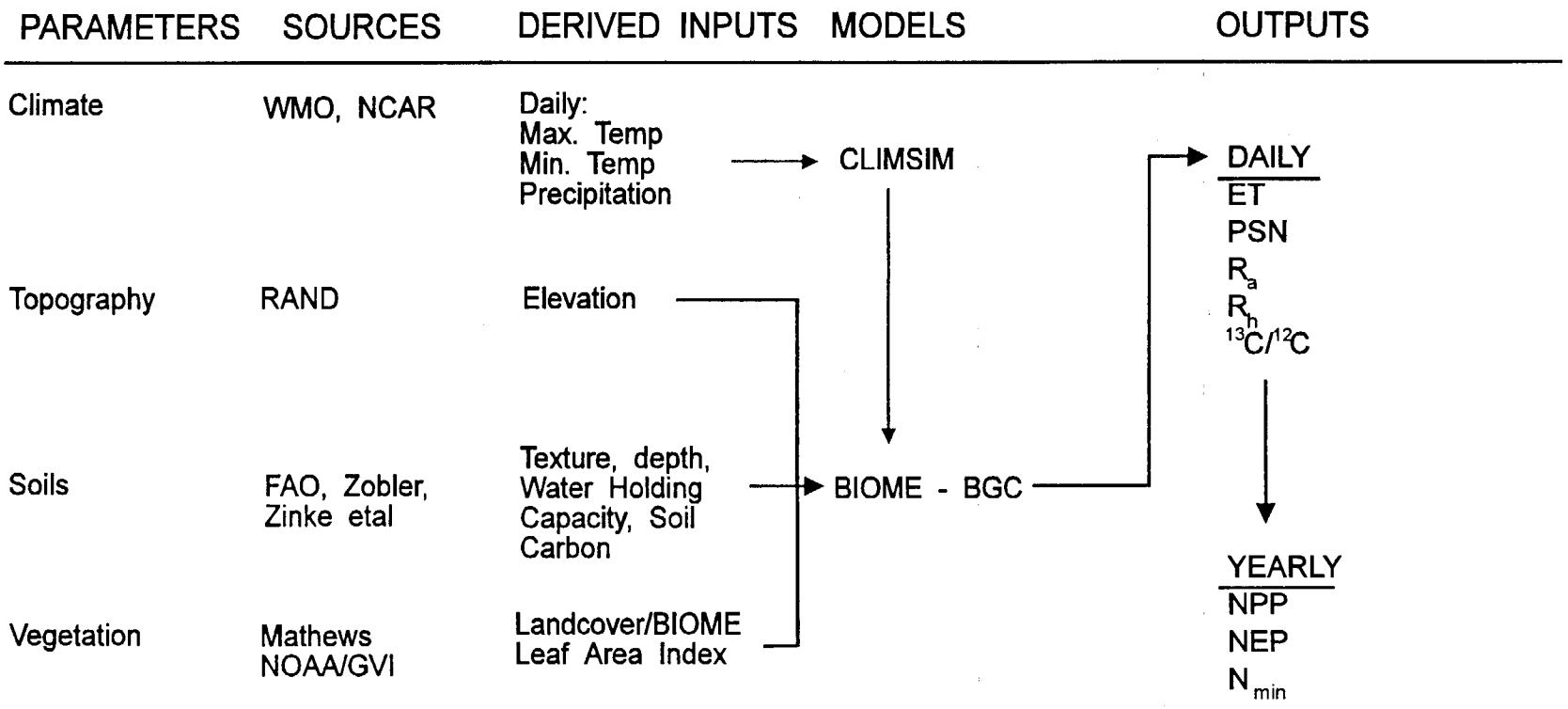
intensity was 50% or greater, we assigned that pixel as a C3 grassland, except for the US cornbelt region and African sorghum region, which were assigned as C4 grasslands.

Figure 5. Global net primary production estimated from a Global Ecosystem Simulation System (GESSys). GESSys is a modeling system, consisting of an ecosystem model (BIOME-BGC) and a climate simulation model (CLIMSIM), designed to compute and map daily carbon and water fluxes at 1x1 degree scales.

Figure 6. Global PAR use efficiency, or calculated from the daily GESSys simulation for 1987.

Figure 7. A first estimate of the possible change in midday surface temperatures that may have occurred resulting from landcover conversion since pre-human settlement times.

Global Ecosystem Simulation System (GESSys)



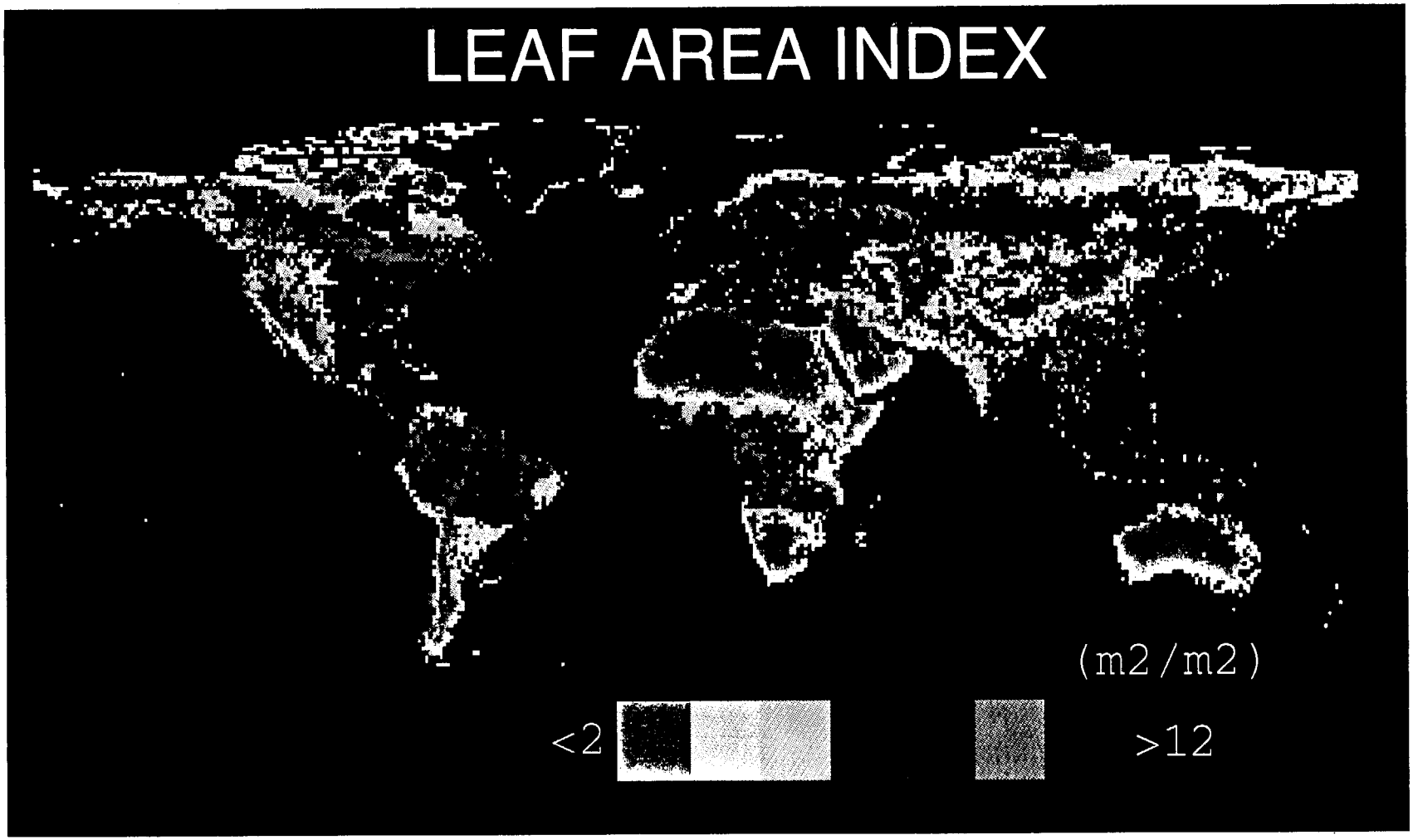
Climate:
Data collected at approximately 6000 weather stations around the globe, organized by WMO, archived at NCAR

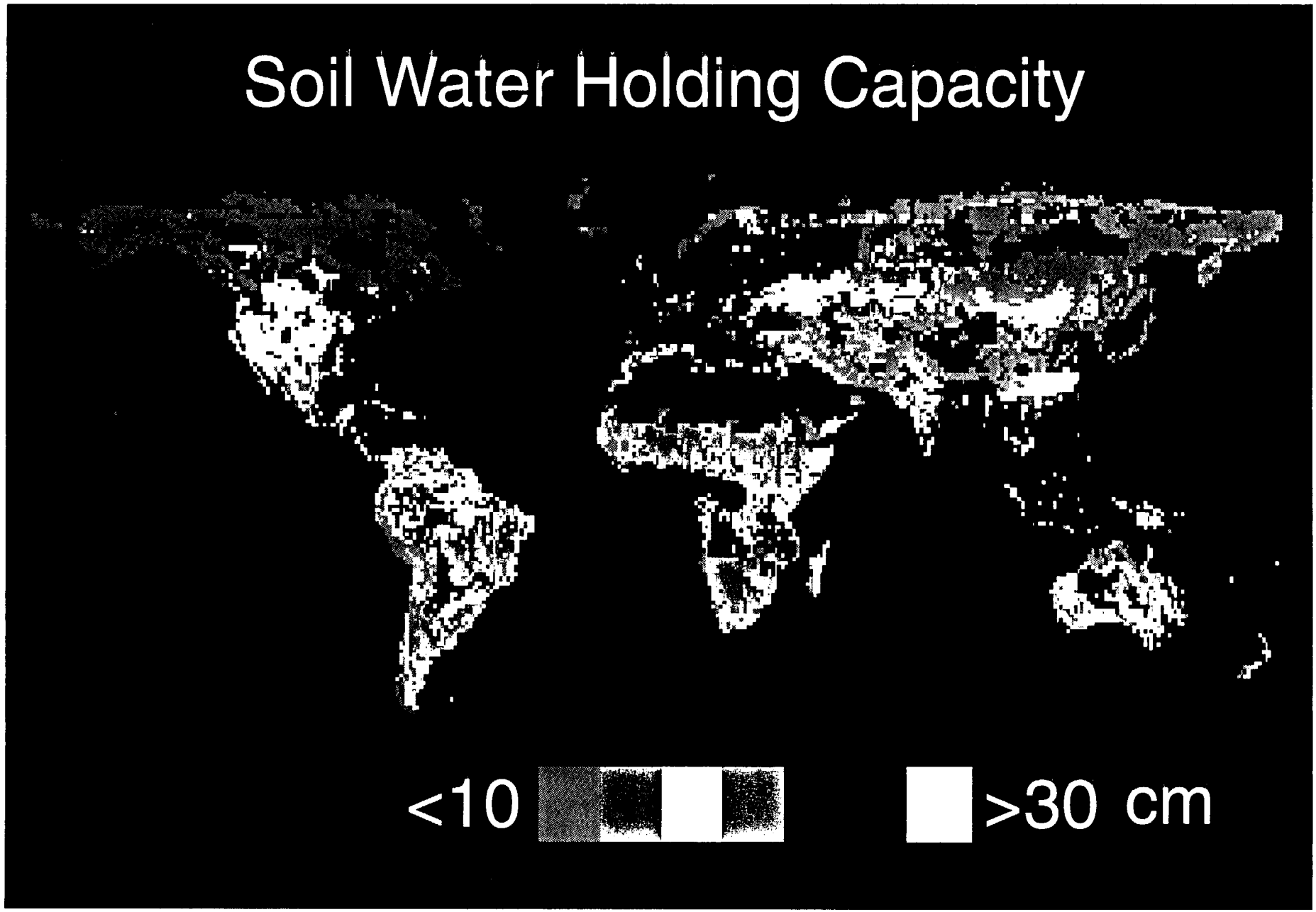
Vegetation: (source: NGDC)
Mathews (1983) potential vegetation map was combined with GISS cultivation map to produce Land Cover/Biome map. Maximum LAI was derived using NOAA/GVI and Land Cover map.

Soils: (source: NGDC)
Zobler's (1986) digitized and improved Soil Map of the world produced by the FAO.
Soil carbon data compiled by Zinke et al (1986) was mapped to Land Cover/Biome map.

CLIMSIM - Climate Simulation Model
BIOME-BGC - Biome Specific Ecosystem Simulation Model

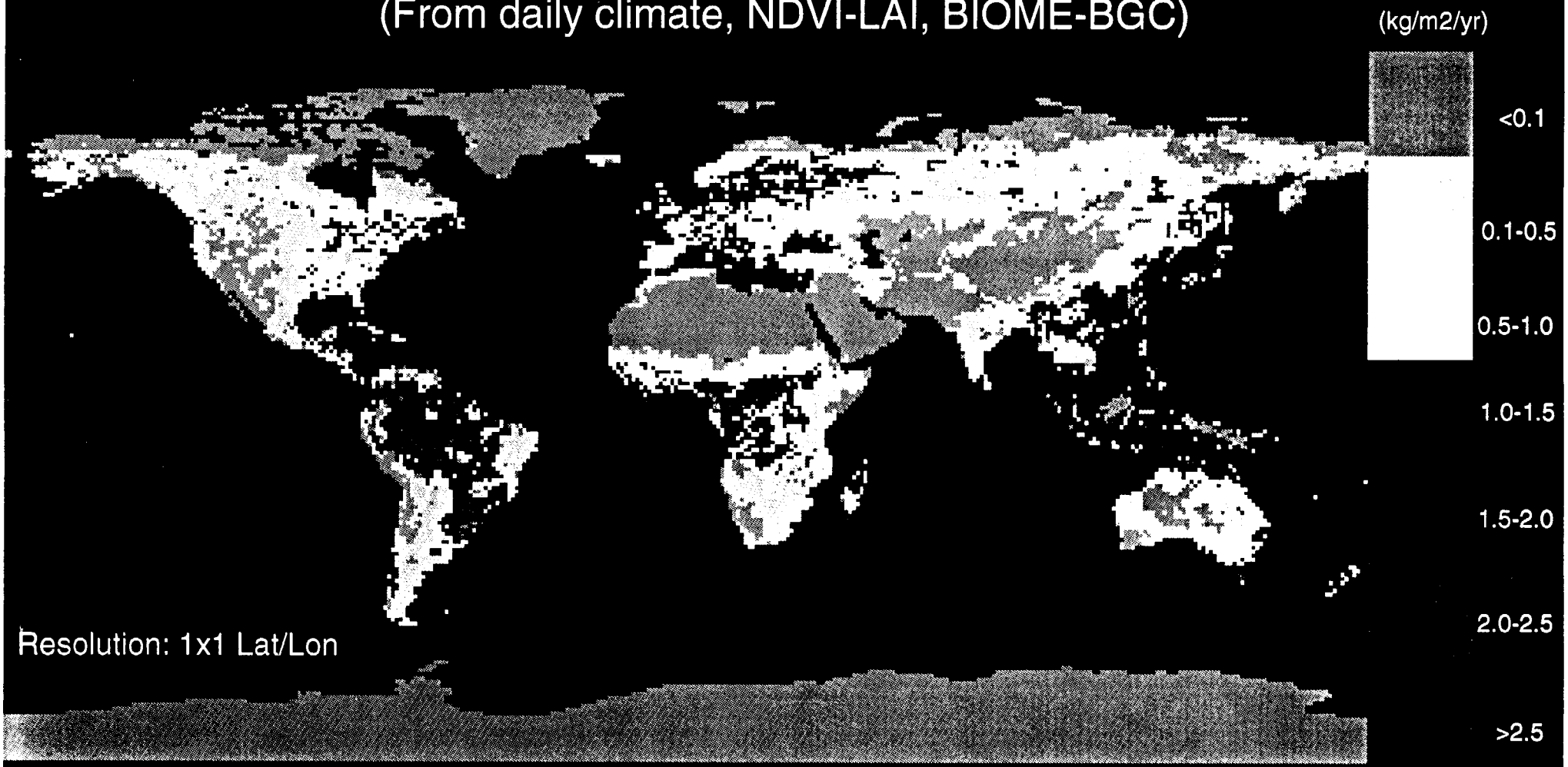
ET - Evapotranspiration, cm/day
PSN - Net Photosynthesis, kg C/ha/day
R_a - Autotrophic Respiration, kg C/ha/day
R_h - Heterotrophic Respiration, kg C/ha/day
$^{13}C/^{12}C$ - Carbon Isotopic Ratio, dim
NPP - Net Primary Production, kg C/ha/yr
NEP - Net Ecosystem Production, kg C/ha/yr
N_{min} - Nitrogen Mineralization, Kg N/ha/yr


LEAF AREA INDEX
(m2/m2)
<2
>12


Soil Water Holding Capacity
<10
>30 cm

GLOBAL NET PRIMARY PRODUCTION, 1987

(From daily climate, NDVI-LAI, BIOME-BGC)



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LIGHT USE EFFICIENCY, 1987
(From daily climate, NDVI-LAI, and BIOME-BGC)

nemani/hunt/running/NTSG

Resolution: 1x1 Lat/Lon

POTENTIAL CHANGES IN SURFACE TEMPERATURE RESULTING FROM CHANGES IN LAND COVER

Resolution: 0.5x0.5 Lat/Lon

nemani/running/NTSG