Lesson 4

LAI, NDVI, Biomass

Plot-count and

Point-center-quarter methods

Possible Tasks for Class Projects

- Classification of bicycle bumps forest
- Analysis of the soil-vegetation relationships
- Indirect ordination analysis
- Direct ordination
- Forest structure (density, height, diameter, age, frequency of trees, canopy cover, LAI) (possibly two papers here)
- History of the site, and succession
- Flora of our site in relation to boreal forest flora of Alaska and circumpolar region
- Vegetation of our site in relation to Rivas-Martinez's Braun-Blanquet classification of North American boreal forests
- Classification and ordination of the Kolyma River, Russia data
- Other ideas?

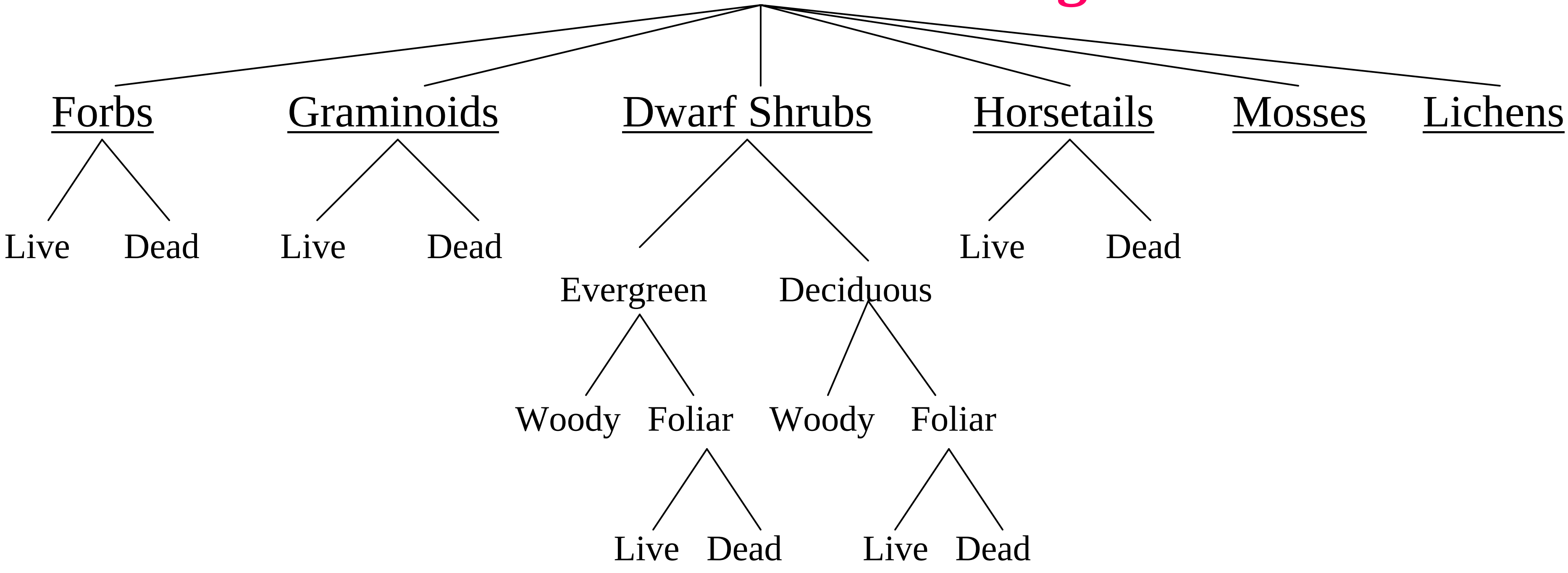
Cover, leaf area, LAI, and biomass

- Biomass: The mass per unit area of vegetation. **Destructive**, requires harvesting vegetation.
- Cover: The vertical projection of the plant parts on the ground surface per unit area of ground. Usually expressed as a percent. No species can have more than 100% cover.
- Leaf Area Index: The ratio of the area of leaves and green vegetation in the plant canopy per unit area of ground surface. LAI can exceed 1.
- The only way to get true leaf area is to strip all the leaves off the plants and measure their area. All other methods provide an "index" of this value (e.g. inclined point frame, LICOR-2000).
- LAI is a **nondestructive**, relatively fast method of obtaining an estimate of total leaf area.
- Normalized Difference Vegetation Index (NDVI): An index of *vegetation greenness* derived from remote sensing methods. Often used as an index of biomass.

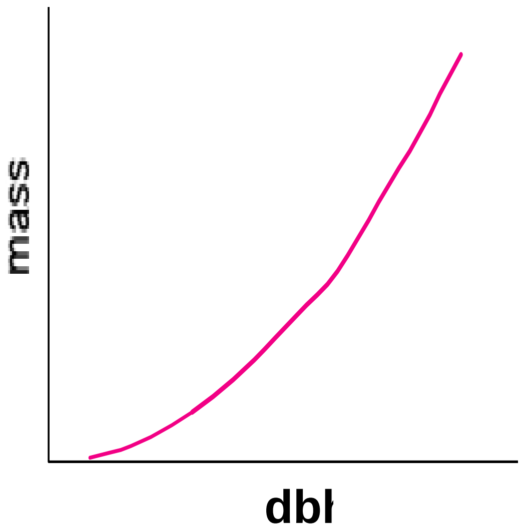
Biomass: Clip Harvest

- Normally, several small representative areas (e.g. 0.1 m^2 for graminoid communities) are clipped.
- Normally it is desirable to provide more detail from clip harvests than total mass per unit area.
- Sorting of the harvest can be by any of several criteria, or combination thereof, for example:
    1. Species
    2. Growth forms
    3. Live vs. dead
    4. Foliar vs. woody (useful for determining green biomass)
    5. Plant parts (flowers, stems, leaves, seeds, etc.).
- Once sorted, the components are oven dried (105° C) and weighed, and biomass expressed as mass/unit area

Alaska Biomass Sorting



Dimension analysis: Harvest and Regression Method for Trees



- In forests, it is difficult to clip representative areas, so it is necessary to use a statistical approach of relating tree diameter to tree mass.
- This is done by harvesting a few trees and then developing a regression of mass vs. diameter for each species
- Biomass of a stand can then be calculated by measuring the diameters of all trees and then determining the biomass from the regressions.

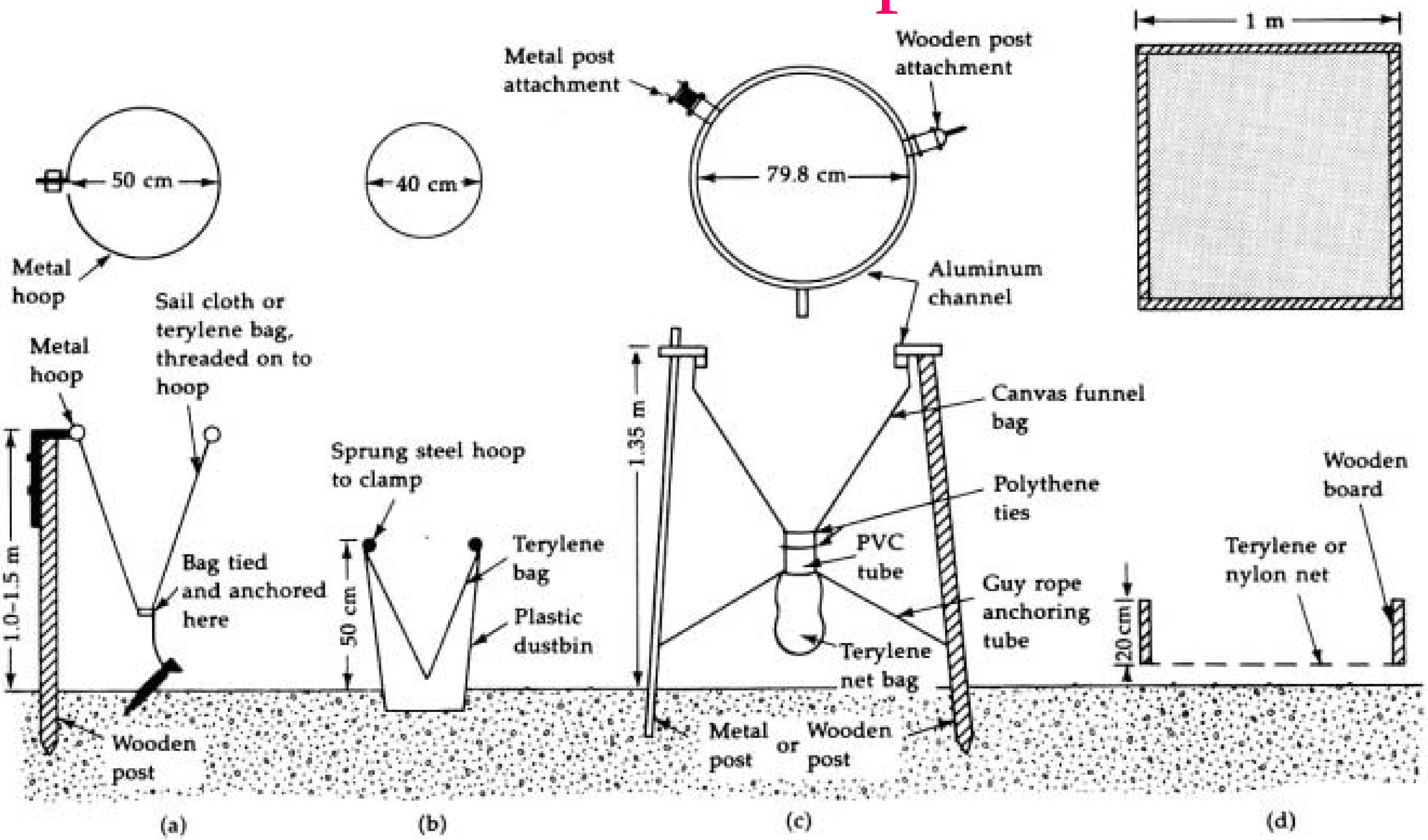
Belowground biomass

- **Below ground harvest**
  - Much more difficult to obtain.
  - In herbaceous vegetation several cores are take by taken by pressing a coring tube (e.g., 10-cm diameter) into the soil and extracting soil containing roots.
  - The cores are washed to remove the soil.
  - Live from dead roots can sometimes be determined by color of the roots, or application of tetrazolium salts.
  - Woody root systems may require excavation and exposure of the root system *in situ*.
- **Root ingrowth bags**
  - Used to determine annual belowground productivity.
  - Numerous small nylon mesh bags of known diameter and volume are filled with soil and inserted into the ground.
  - These are retrieved at intervals, and the ingrown roots are removed and weighed.
- **Minirhizotrons**
  - Photos taken at regular intervals along a tube inserted into the ground. Patterns of fine roots are photographed at several times during the summer, and root growth is recorded on video.
  - Still must obtain
  - Growth is obtained by taking periodic photos.

Minirhizotron apparatus

Photo of roots through the minirhizotron apparatus

Litter traps



Litterfall for major ecosystems

Table 12-2 Rate of litter production in various forest, perennial herb, and grass ecosystems. From data compiled by Jordan 1971. Reprinted by permission of *American Scientist*, magazine of Sigma Xi, The Scientific Research Society.

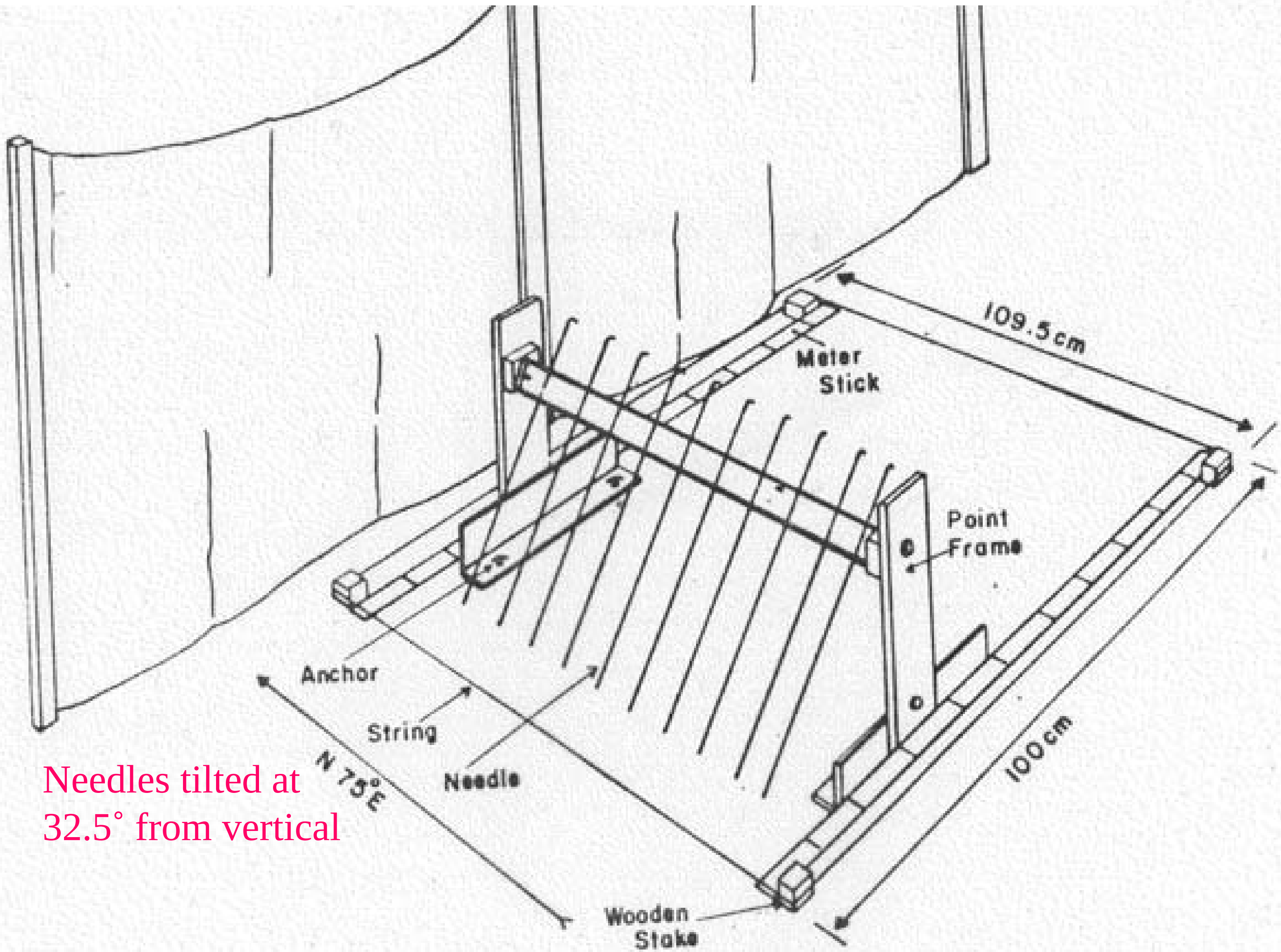
Community	Location	Litterfall ($g\ m^{-2}\ yr^{-1}$)	Source
Tropical rain forest	Thailand	2322	Kira et al. 1967
Tropical rain forest	Average of several	1600	Rodin and Basilevic 1968
Subtropical forests	Average of several	1200	Rodin and Basilevic 1968
Dry savanna	Russia	290	Rodin and Basilevic 1968
Oak forest	Russia	350	Mina, cited in Rodin and Basilevic 1968
Fir-taiga	Russia	250–300	Rodin and Basilevic 1968
Oak-pine forest	New York	406	Whittaker and Woodwell 1969
Pine forest	Virginia	490	Madgwick 1968
Tropical seasonal forest	Ivory Coast	440	Muller and Nielsen, cited in Kira et al. 1967
10 Angiosperm forests	Europe	280	Bray and Gorhman 1964
10 Angiosperm forests	Tennessee	320	Whittaker 1966
13 Gymnosperm forests	Tennessee	267	Whittaker 1966
Old-field upland	Michigan	312	Wiegert and Evans 1964
Old-field swale	Michigan	1003	Wiegert and Evans 1964
Perennial herbs	Japan	1484	Iwaki et al. 1966
Tallgrass prairie	Missouri	520	Kucera et al. 1967, Dahlman and Kucera 1965
Mesic alpine tundra	Wyoming	162	Scott and Billings 1964

Leaf Area Index (LAI)

- LAI is a **nondestructive**, relatively fast method of obtaining an estimate of biomass.
- An index of the ratio of the area of leaves and green vegetation in the plant canopy per unit area of ground surface
- The only way to get true leaf area is to strip all the leaves off the plants and measure their area. All other methods provide an “index” of this value (e.g. inclined point frame, LICOR-2000).
- Regression methods are used to relate biomass to leaf area.

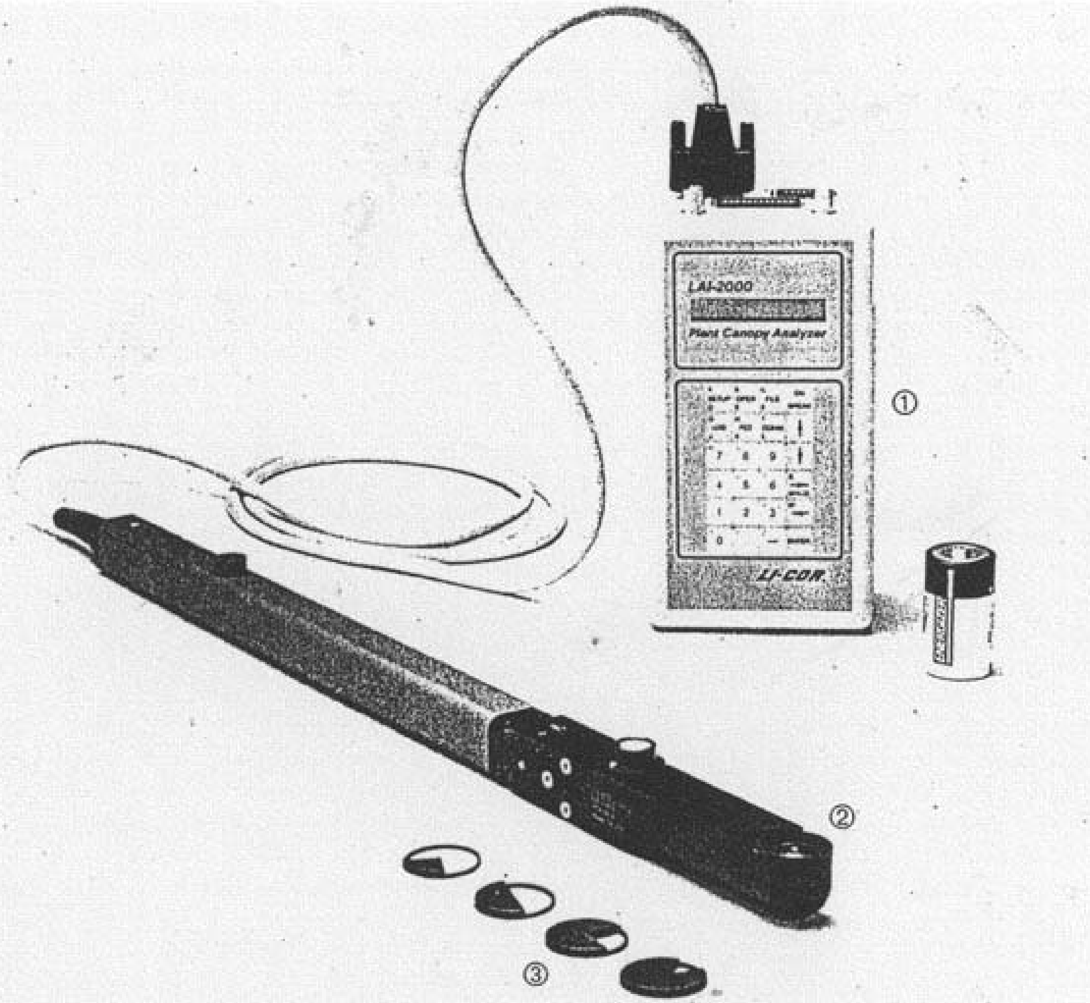
Inclined Point Frame for measuring LAI

Warren Wilson, J. 1959. Analysis of the distribution of foliage area in grassland. In: J. D. Ivins (Ed.), *The measurement of grassland productivity*. Butterworths Scientific Publications, London, pp. 51-61.



Needles tilted at 32.5˚ from vertical

LAI-2000 Plant Canopy Analyzer



The LAI-2000 Plant Canopy Analyzer includes 1) The LAI-2070 Control Unit; 2) LAI-2050 Optical Sensor; 3) View Caps for the LAI-2050.

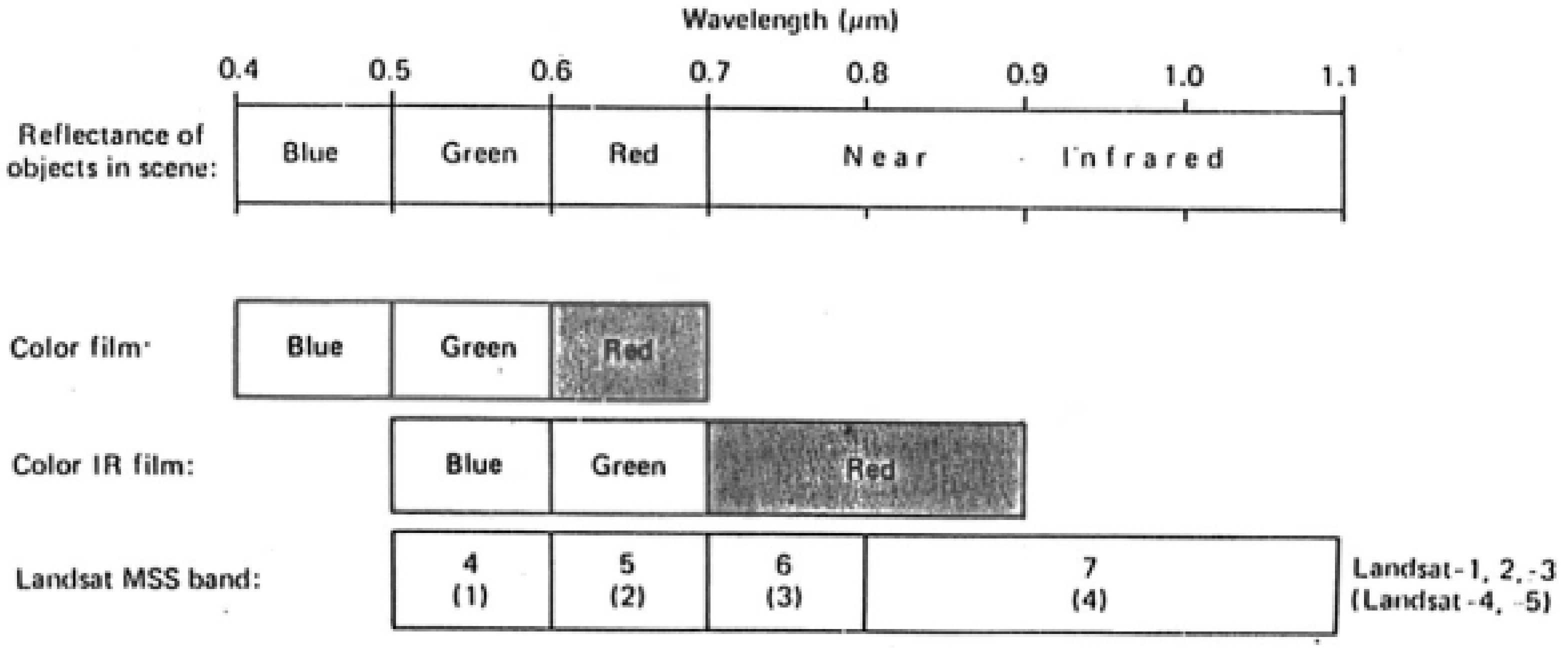
Normalized Difference Vegetation Index: an index of greenness

$$\text{NDVI} = (NIR-R)/(NIR+R)$$

NIR = spectral reflectance in the near-infrared band (0.725 - 1.1µm), where light scattering from the canopy dominates,

R = reflectance in the red, chlorophyll-absorbing portion of the spectrum (0.58 to 0.68µm).

Satellites measure reflectance in discreet bands or channels

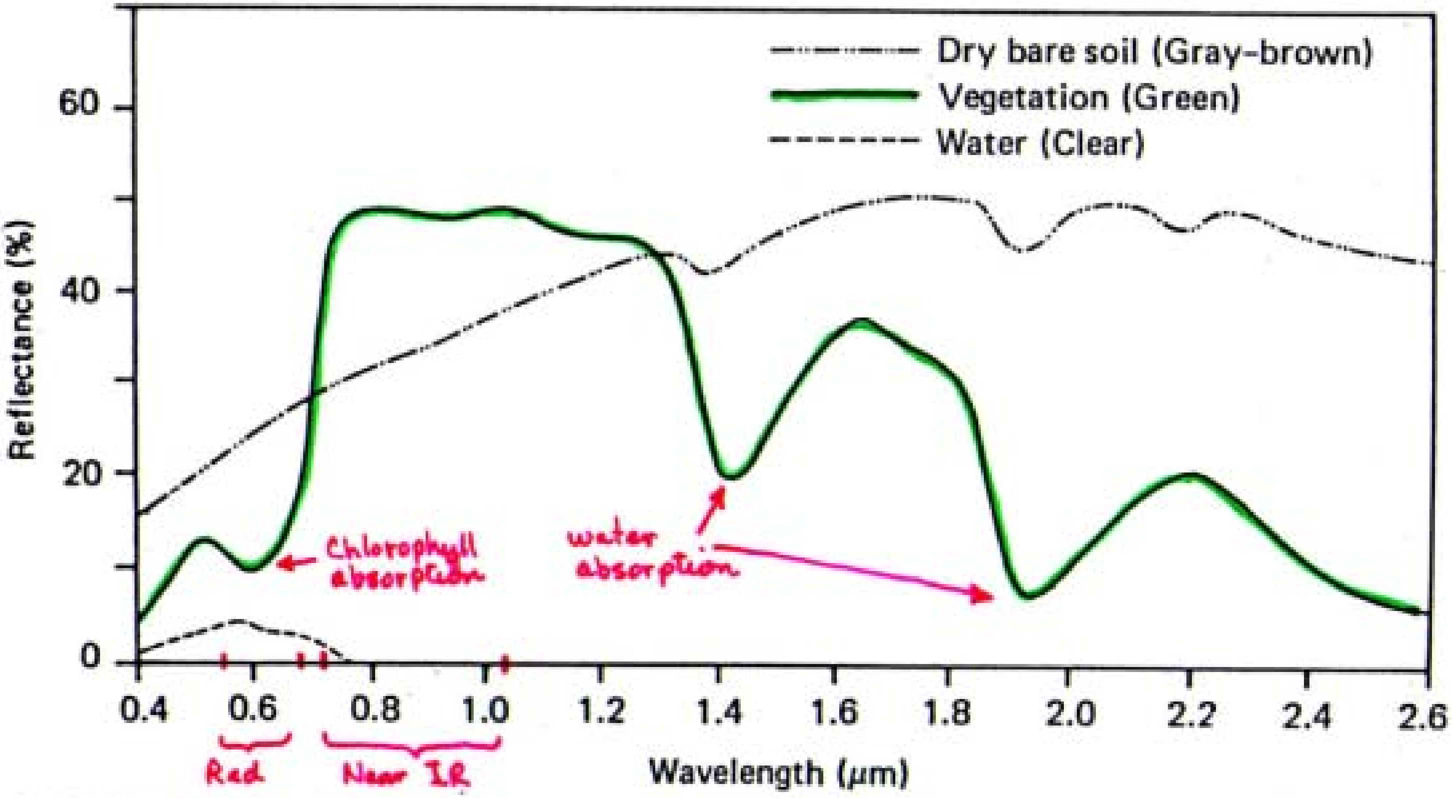


Thematic Mapper (TM) Sensor bands on Landsat 4 and 5 satellites

Band	Wavelength (µm)	Nominal spectral location	Principal applications
1	0.45–0.52	Blue	Designed for water body penetration, making it useful for coastal water mapping. Also useful for soil/ vegetation discrimination, forest type mapping, and cultural feature identification.
2	0.52–0.60	Green	Designed to measure green reflectance peak of vegetation (Figure 1.10) for vegetation discrimination and vigor assessment. Also useful for cultural feature identification.
3	0.63–0.69	Red	Designed to sense in a chlorophyll absorption region (Figure 1.10) aiding in plant species differentiation. Also useful for cultural feature identification.
4	0.76–0.90	Near-infrared	Useful for determining vegetation types, vigor, and biomass content, for delineating water bodies, and for soil moisture discrimination.
5	1.55–1.75	Mid-infrared	Indicative of vegetation moisture content and soil moisture. Also useful for differentiation of snow from clouds.
6[a]	10.4–12.5	Thermal infrared	Useful in vegetation stress analysis, soil moisture discrimination, and thermal mapping applications.
7[a]	2.08–2.35	Mid-infrared	Useful for discrimination of mineral and rock types. Also sensitive to vegetation moisture content.

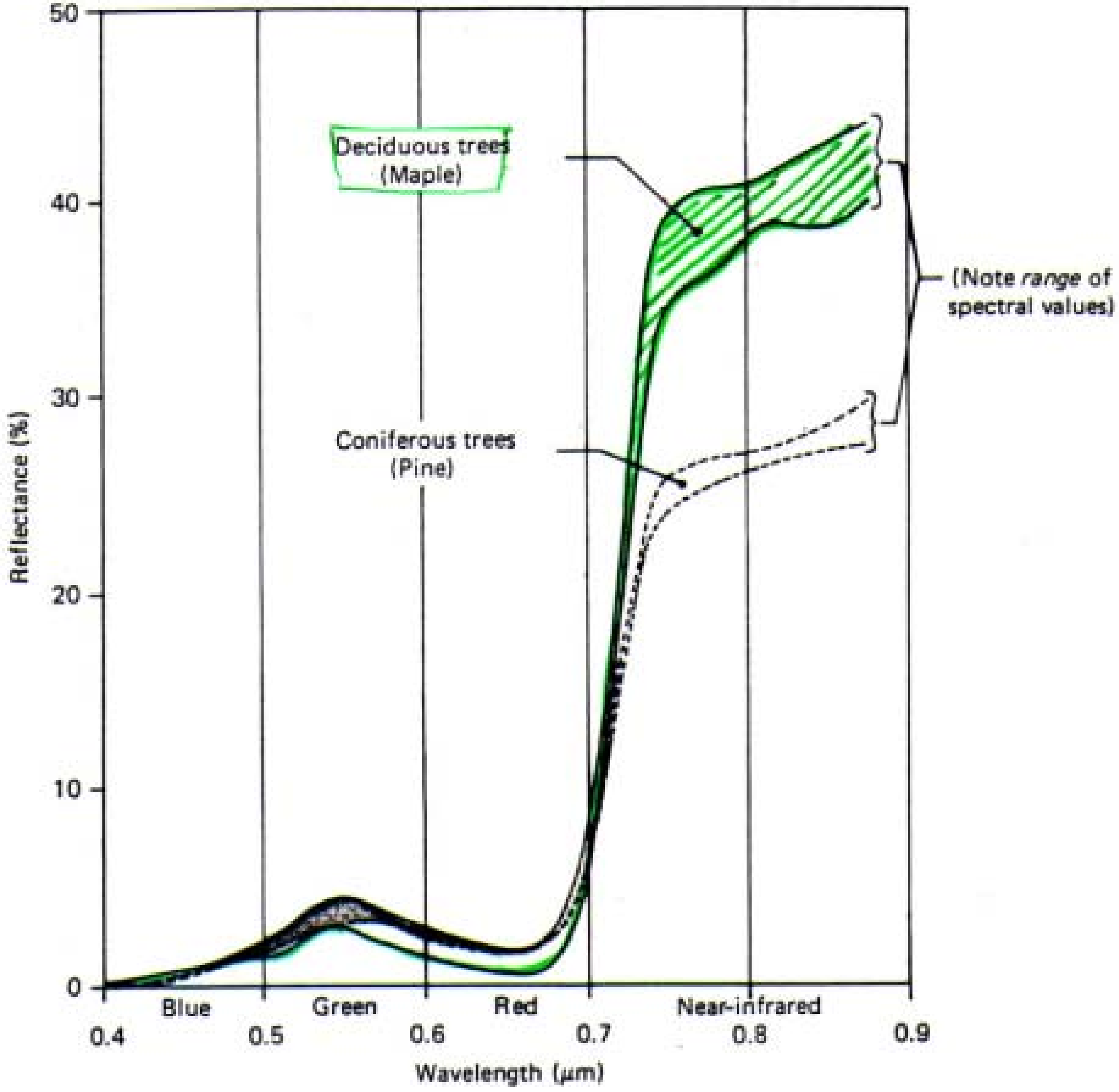
[a]Bands 6 and 7 are out of wavelength sequence because band 7 was added to the TM late in the original system design process.

Reflectance spectra for typical components of the Earth's surface



From Lillisand and Kiefer 1987

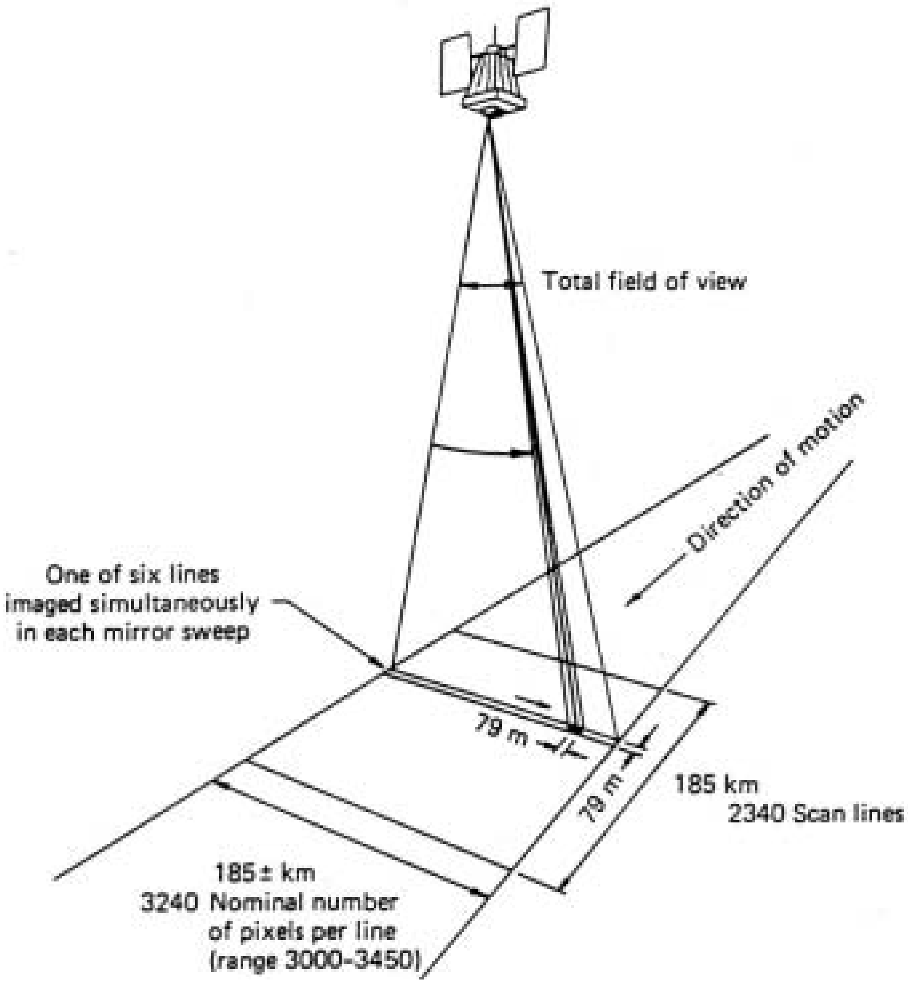
Different vegetation types have different reflectance spectra



Vegetation indices

- Vegetation indices are based on the principle that red, R, wavelengths (near 0.6µm) are absorbed by chloroplasts and mesophyll, while near infrared, NIR, wavelengths (0.7-0.9µm) are reflected.
- If the NIR reflectance is much larger than the red reflectance, then presumably there is a considerable amount of green vegetation present
- Satellites measure spectral reflectance in discrete bands for each picture element (pixel) in the image. For satellites monitoring the visible and NIR portions of the spectrum. Vegetation indices can thus be calculated for each pixel.
- In general, for many ecosystems, the vegetation indices are proportional to **IPAR (intercepted phytosynthetically active radiation)** and to LAI and biomass.

Landsat Multi-spectral sensor (MSS)

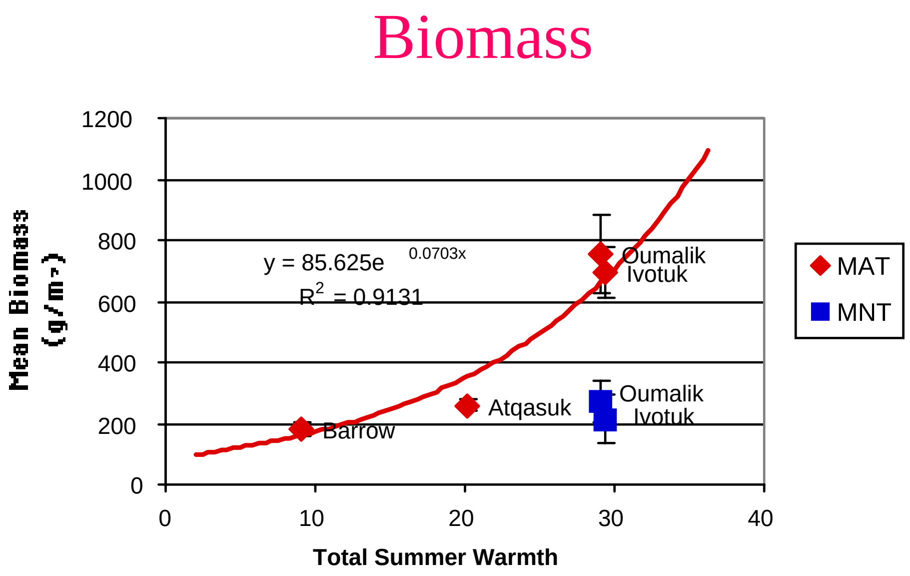


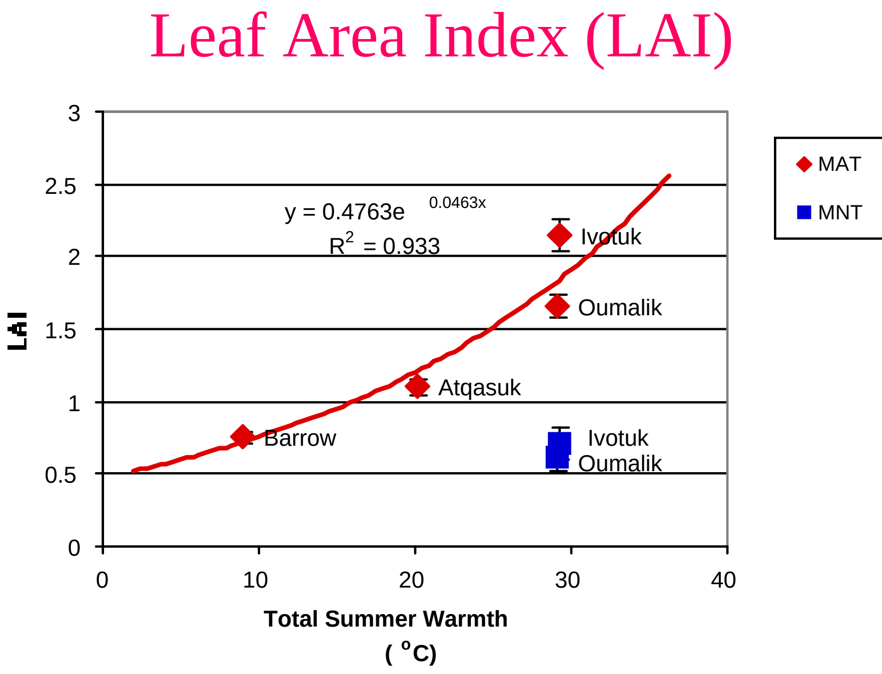
From Lillisand and Kiefer 1987

Hand-held radiometer for ground-level measurement of spectral reflectance

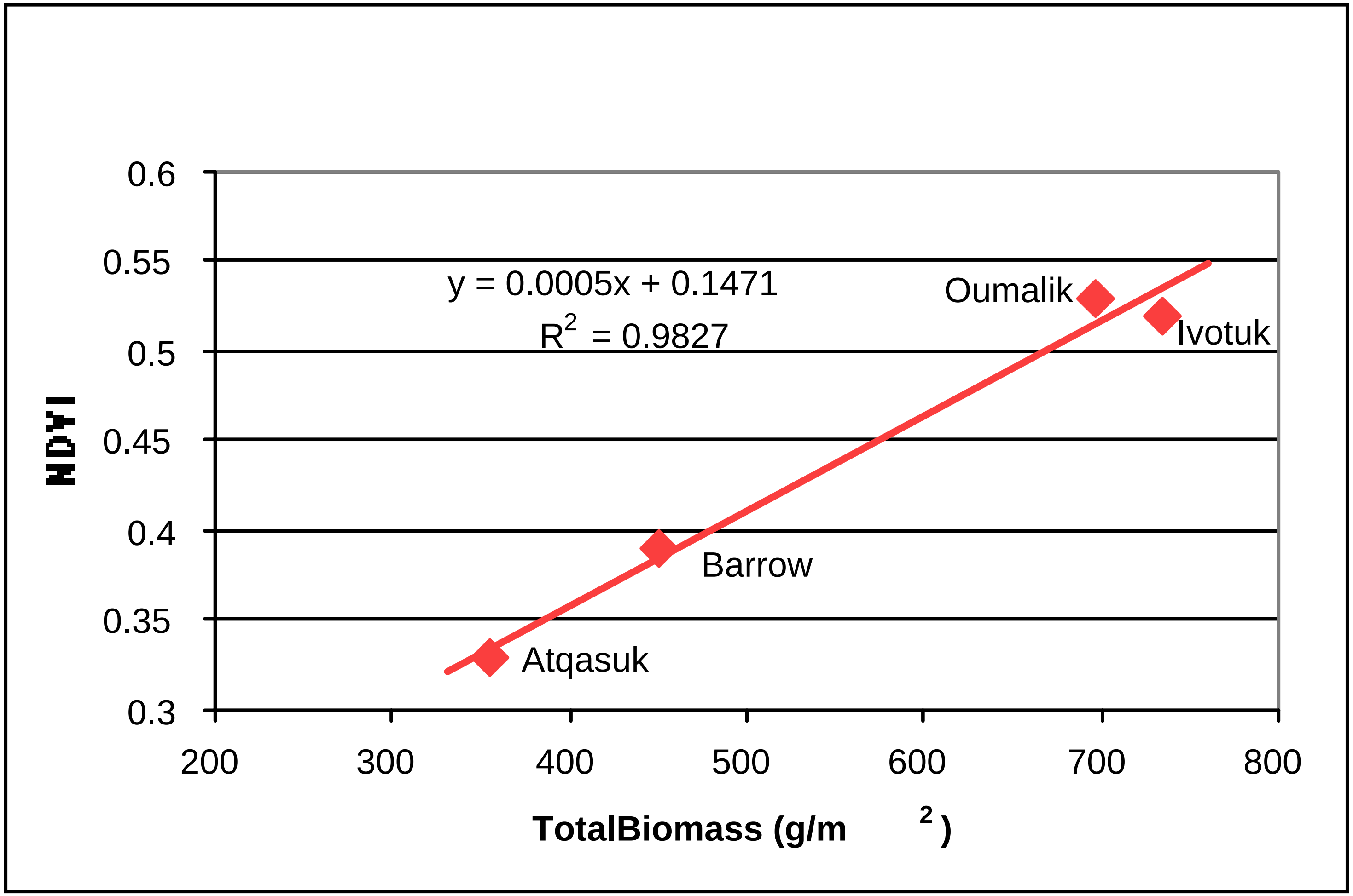
FIGURE 1.12 Spectron Engineering SE590 portable radiometer. *(a)* Microprocessor data logger, tape cassette, and detector head. *(b)* Unit shown in field operation. (Courtesy Spectron Engineering.)

Biomass and LAI vs. total summer warmth index

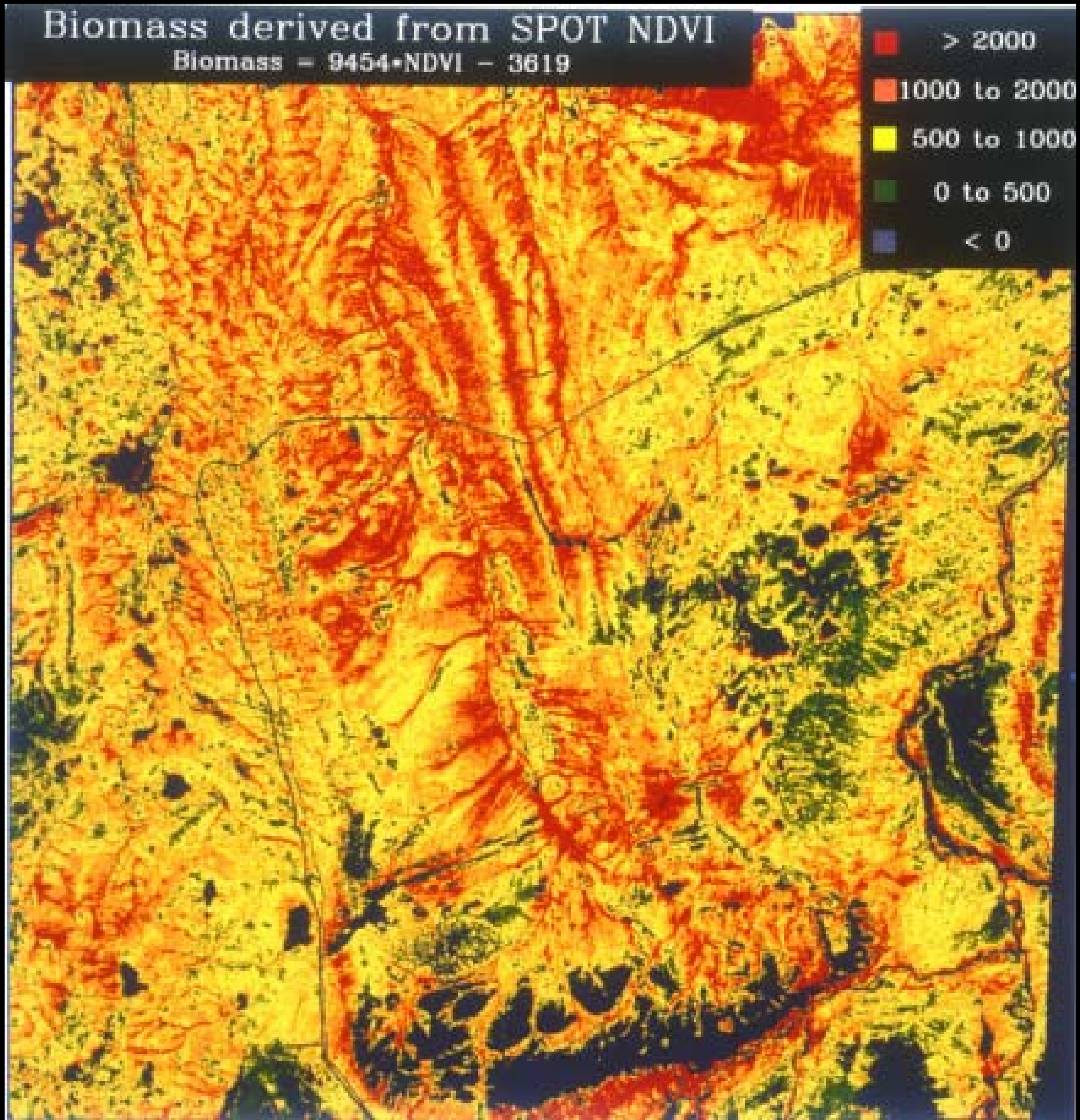




NDVI vs. total aboveground biomass

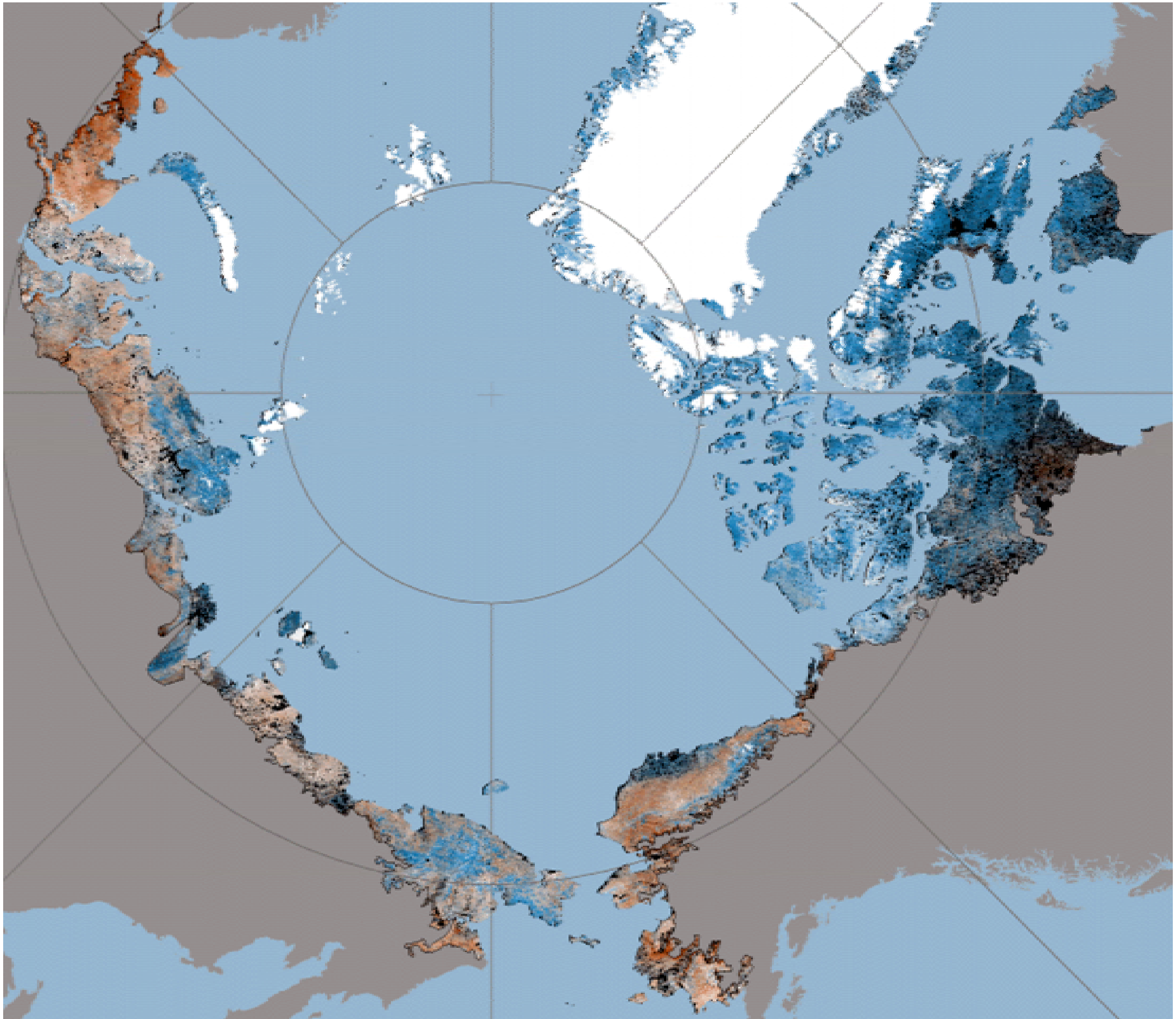


Biomass map of the Toolik Lake region derived from SPOT NDVI values

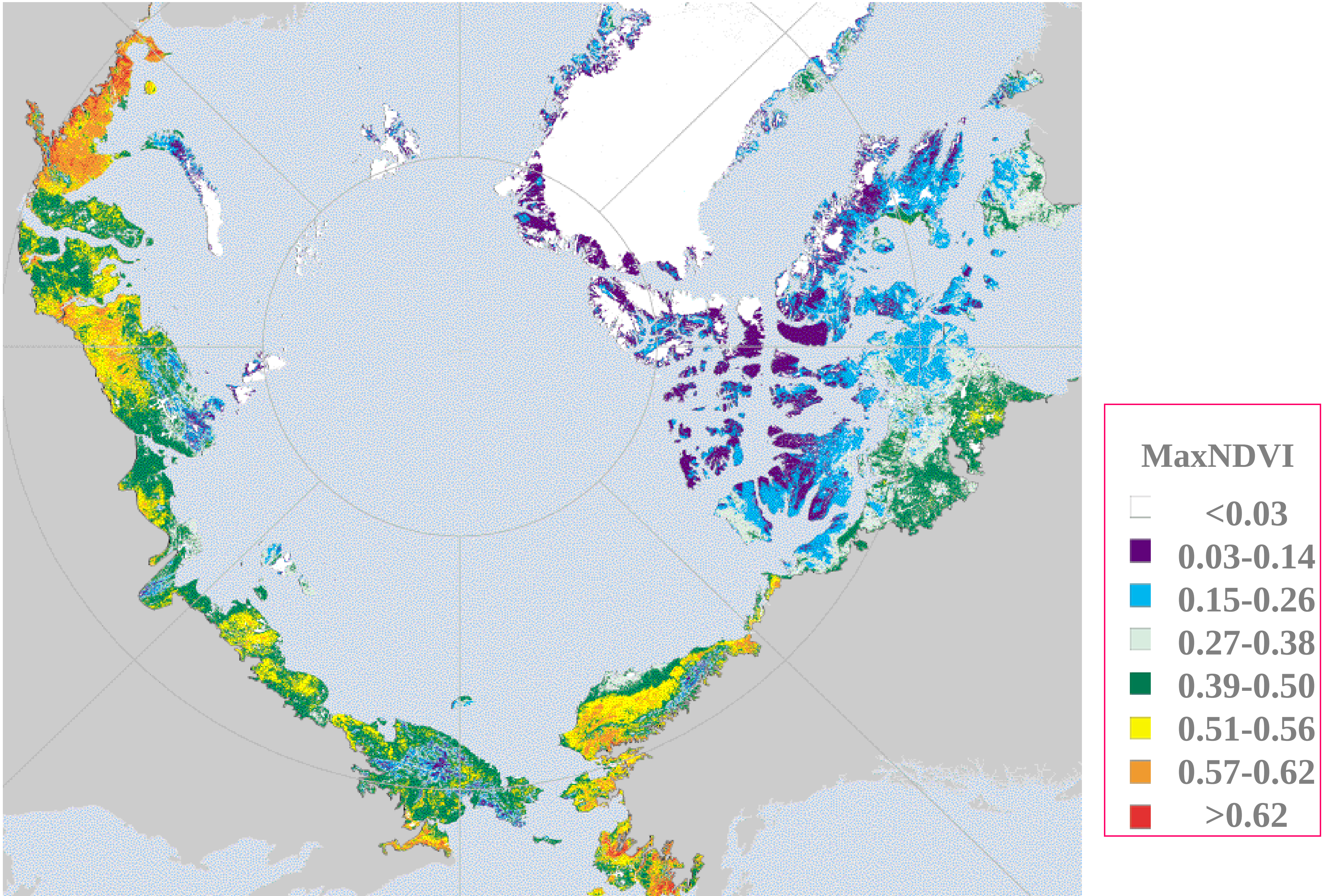


From Shippert et al. 1995

AVHRR false-CIR mosaic



MaxNDVI map of the circumpolar Arctic

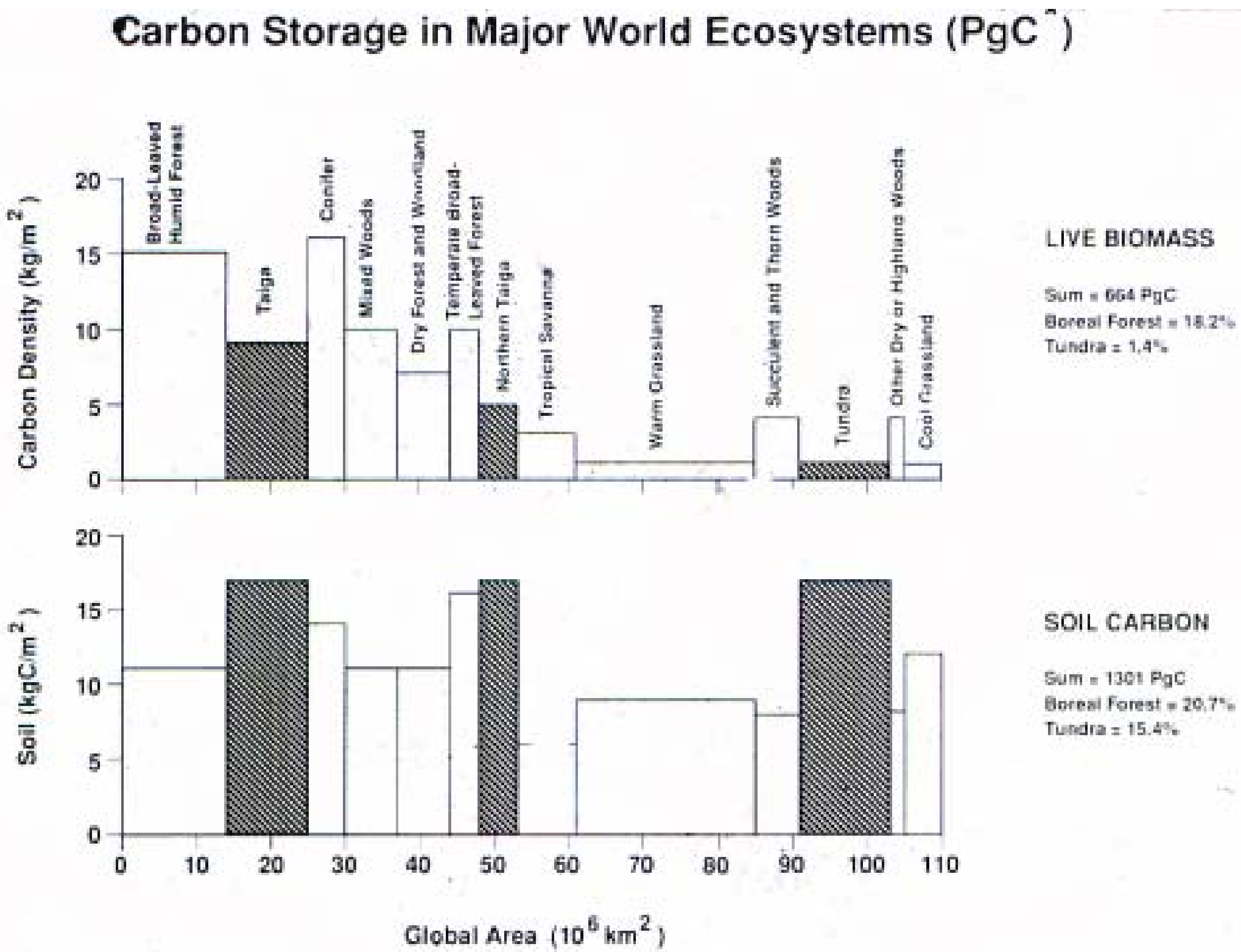


NPP and biomass in the major ecosystems

Table 12-4 Net primary productivity and related characteristics of terrestrial biomes. From R. H. Whittaker and G. E. Likens. 1975. "The biosphere and man." In *Primary Productivity of the Biosphere*, Lieth and Whittaker, eds. By permission of Springer-Verlag, New York.

		Net primary productivity (dry matter)			Biomass (dry matter)			Leaf surface area	
Ecosystem type	**Area (10^6 km^2)**	**Normal range (g m^{-2} yr^{-1})**	**Mean (g m^{-2} yr^{-1})**	**Total (10^9 t yr^{-1})**	**Normal range (kg m^{-2})**	**Mean (kg m^{-2})**	**Total (10^9 t)**	**Mean (m^2 m^{-2})**	**Total (10^6 km^2)**
Tropical rain forest	17.0	1000–3500	2200	37.4	6–80	45	765	8	136
Tropical seasonal forest	7.5	1000–2500	1600	12.0	6–60	35	260	5	38
Temperate forest:									
Evergreen	5.0	600–2500	1300	6.5	6–200	35	175	12	60
Deciduous	7.0	600–2500	1200	8.4	6–60	30	210	5	35
Boreal forest	12.0	400–2000	800	9.6	6–40	20	240	12	144
Woodland and shrubland	8.5	250–1200	700	6.0	2–20	6	50	4	34
Savanna	15.0	200–2000	900	13.5	0.2–15	4	60	4	60
Temperate grassland	9.0	200–1500	600	5.4	0.2–5	1.6	14	3.6	32
Tundra and alpine	8.0	10–400	140	1.1	0.1–3	0.6	5	2	16
Desert and semidesert scrub	18.0	10–250	90	1.6	0.1–4	0.7	13	1	18
Extreme desert:									
rock, sand, ice	24.0	0–10	3	0.07	0–0.2	0.02	0.5	0.05	1.2
Cultivated land	14.0	100–4000	650	9.1	0.4–12	1	14	4	56
Swamp and marsh	2.0	800–6000	3000	6.0	3–50	15	30	7	14
Lake and stream	2.0	100–1500	400	0.8	0–0.1	0.02	0.05	—	—
Total	149		782	117.5		12.2	1837	4.3	644

Total above- and belowground carbon in major ecosystems



* 1 PgC = 10^{15} gC = 0.47 ppm CO_2

From: D.A. Lashof 1989. *Climate Change* 14: 213-242
The dynamic greenhouse: feedback processes that may influence future concentrations of atmospheric trace gases and climate change.
Based on J. Olsen carbon budget.

Lab 4: Point Sampling methods

- Point Quadrat
- Buckner Sampler
- Densiometer
- Licor LAI-2000