Albedo

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INTRODUCTION

The fraction of the incident radiation that is reflected from the surface is called the albedo. Albedo plays a major role in the energy balance of the earth's surface, as it defines the rate of the absorbed portion of the incident solar radiation. Soil albedo is a complex feature, which is determined by many soil dependent and independent (environmental) characteristics. The process that results in the reflected radiation is called reflectance, whereby the energy of radiation is reradiated by the chemical constituents (e.g., atoms or molecules) of the surface layer approximately half the thickness of wavelength.

The portion of solar radiation not reflected by the earth's surface is absorbed by the soil or the vegetation, which interacts with the incident radiation. The absorbed energy can increase the soil temperature or the rate of evapotranspiration from the surface of the soil-vegetation system. Some of the energy that is absorbed and transformed into heat is reradiated at a longer wavelength than the incoming radiation. That is why the peak terrestrial radiation occurs in the infrared spectrum while the peak incident radiation occurs in the blue–green portion of the visible spectrum.

The albedo value ranges from 0 to 1. The value of 0 refers to a blackbody, a theoretical media that absorbs 100% of the incident radiation. Albedo ranging from 0.1–0.2 refers to dark-colored, rough soil surfaces, while the values around 0.4–0.5 represent smooth, light-colored soil surfaces. The albedo of snow cover, especially the fresh, deep snow, can reach as high as 0.9. The value of 1 refers to an ideal reflector surface (an absolute white surface) in which all the energy falling on the surface is reflected. The mean albedo of the earth system is[F1] [T1] 0.36 ± 0.06[1] (Table 1).

FACTORS AFFECTING ALBEDO

Albedo varies diurnally and seasonally due to the changing sun angle.[2,3] In general, the lower the sun angle the higher the albedo. Besides the sun angle, many of the surface characteristics have large impact on the albedo. The most significant factors affecting the soil albedo are the type and condition of the vegetation covering the soil surface, soil moisture content, organic matter content, particle size, iron-oxides, mineral composition, soluble salts, and parent material.[4]

The type and the condition of the vegetation has a strong impact on the surface albedo. Forest vegetation with multilevel canopy has a low albedo because the incident radiation can penetrate deeply into the forest canopy where it bounces back and forth between the branches and leaves and get trapped by the canopy.[5] The albedo for grassland and cropland ranges between 0.1 and 0.25.[6–9]

Changes in soil moisture content change the absorbance and reflectance characteristics of the soil. Increase in soil moisture content increases the portion of the incident solar radiation absorbed by the soil system. This relationship is well known and used for soil color differentiation when the Munsell color chart is used. The colors of dry and moist soil samples are always different. The higher the soil moisture content, the darker the color and lower the albedo. However, this relationship is valid only for soil moisture contents up to the field capacity. Beyond field capacity, the increase in soil moisture content does not darken the color any more, but starts building up a water sheet on the aggregate surface, creating a shiny and better reflecting surface, which increases the reflectance and thus the albedo. This phenomenon is the major reason for differences in the albedo among soils of different textural classes. Clayey soils can maintain high moisture content in the presence of water supply, while the sandy textured soils drain and dry out much more rapidly. Due to the differences in the resulting soil moisture content between the texture classes, there are differences in the reflectance and absorbance characteristics and so in the albedo (Fig. 1).

Surface roughness defines the type of reflection. Shiny, smooth surfaces, like water body, plant leaves, or wet soil surfaces may be near-perfect, specular reflectors, which may reflect well and show relatively high albedo for lower sun angles. Rough surfaces represent lower albedo values, especially when sun angle is low and the shading effect lowers the reflection. There are measurable differences in the surface roughness among soil textural classes. Fine-textured, dry soils with small particle size produce high albedo due to relatively smooth surface. However, clayey soils are often wet, and soil moisture absorbs the incident

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Table 1 The approximated ranges of albedo of natural surfaces

Natural surface types	Approximated albedo
Blackbody	0
Forest	0.05–0.2
Grassland and cropland	0.1–0.25
Dark-colored soil surfaces	0.1–0.2
Dry sandy soil	0.25–0.45
Dry clay soil	0.15–0.35
Sand	0.2–0.4
Mean albedo of the earth	0.36
Granite	0.3–0.35
Glacial ice	0.3–0.4
Light-colored soil surfaces	0.4–0.5
Dry salt cover	0.5
Fresh, deep snow	0.9
Water	0.1–1
Absolute white surface	1

radiation and decreases albedo. Conversely, dry, coarse textured soils with relatively large particles (sand grains) reflect larger portions of the incident radiation than clayey soils.

Surface color is determined by the interaction of the surface material with the visible spectra of the incident solar radiation. Soil color is a differentiating factor in all the soil classification systems. It reflects many of the most important soil physical and chemical characteristics. One of the most significant coloring agents of the soils is the soil organic matter content. Soil organic matter content increases the absorbance of the soil. Thus the higher the organic matter content, the lower the albedo. Iron oxides increase the reflectance in the red portion of the spectrum while causing a decrease in the blue–green and infrared portion. Salt crust on the surface increases the albedo dramatically. That is why mapping of salt-affected area with remotely sensed images is a very powerful tool for soil surveyors.

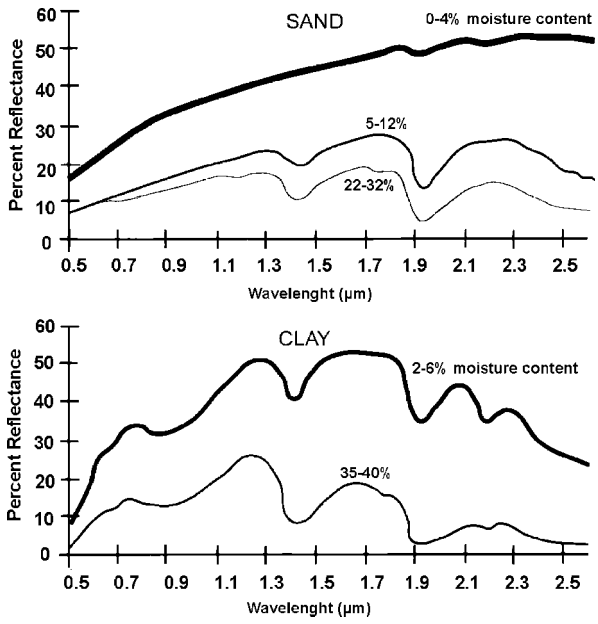

Fig. 1 The higher the moisture content the lower the reflectance throughout the visible and near-infrared region, especially along the water absorption bands at 1.4 μm and 1.7 μm. Notice the differences in the reflectance characteristics between the clayey and sandy soils. (From Ref. 10.)

MEASUREMENT OF ALBEDO

The theoretical concept of measuring albedo is simple. A radiation sensor (pyranometer) is pointed upwards to measure the incident radiation and then quickly flipped downwards to measure the reflected radiation. For deriving the albedo, the quantity of the reflected radiation has to be divided by the one for the incident radiation. In fact, the actual measurement of surface albedo under natural condition is rather complex. The problem is threefold. First, the incident radiation does not only come from the radiation source directly, but also from diffused light from other directions. Secondly, the reflector surfaces do not reflect equally in all directions and thirdly, the sensors gather light only from a small range of angles. Thus, our measurements of reflectance are only samples of the bidirectional reflectance distribution function (BRDF). Albedo is often defined as an overall average reflection coefficient of an object. More precisely the terms of spectral and total albedo are differentiated. The spectral albedo refers to the reflectance in a given wavelength, while the albedo is calculated as an integral of the spectral reflectivity times the radiation, over all wavelengths in the visible spectrum. A good estimation of the surface albedo can be done using clear-sky satellite measurements.[11]

CONCLUSIONS

Albedo measures the overall reflectance of the surface, providing lots of useful information about the soil system and better understanding of the soil energy balance. But different wavelengths of sunlight are normally not equally reflected, which gives rise to a variable color of surfaces and differences in reflectance of certain wavelengths due to differences in physical or chemical characteristics of the soil surface. Differences in soil albedo can be measured with radiometers.

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REFERENCES

1. Weast, R.C. *Handbook of Chemistry and Physics*; CRC Press: Boca Raton, FL, 1982.
2. Matthews, E. Vegetation, Land-Use and Seasonal Albedo Data Sets. In Global Change Data Base Africa Documentation, Appendix D; NOAA/NGDC, 1984.
3. Kotoda, K. Estimation of River Basin Evapotranspiration. Environmental Research Center Papers; University of Tsukuba, 1986; Vol. 8.
4. Baumgardner, M.F.; Sylva, L.F.; Biehl, L.L.; Stoner, E.R. Reflectance Properties of Soils. Adv. Agron. **1985**, *38*, 1–44.
5. Geiger, R. *The Climate near the Ground*; Harvard Univ. Press: Cambridge, MA, 1965.
6. Jones, H.G. *Plants and Microclimate: A Quantitative Approach to Environmental Plant Physiology*, 2nd Ed.; The Cambridge University Press: Cambridge, U.K., 1992.
7. Jensen, M.E.; Burman, R.D.; Allen, R.G. Evapotranspiration and Irrigation Water Requirements. *ASCE Man. Rep. Pract. 70*; American Society of Civil Engineers: New York, NY, 1990.
8. Oke, T.R. *Boundary Layer Climates*; Methuen: New York, NY, 1978.
9. Van Wijk, W.R.; Scholte Ubing, D.W. Radiation. In *Physics of Plant Environment*; Van Wijk, W.R., Ed.; North-Holland Publishing Co.: Amsterdam, The Netherlands, 1963; 62–101.
10. Hoffer, R. Biological and Physical Considerations. *Remote Sensing: The Quantitative Approach*; 1978; 241–251.
11. Li, Z.; Garand, L. Estimation of Surface Albedo from Space: A Parameterization for Global Application. J. Geophys. Res. **1994**, *99*, 8335–8350.