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Clear-Sky Albedo Measured at Seven Rangland Sites in Southwest Idaho

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CLEAR-SKY ALBEDO MEASURED AT SEVEN RANGELAND SITES IN SOUTHWEST IDAHO

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ABSTRACT: As a component of the energy budget, albedo is used in the calculation of evapotranspiration in many natural resource and hydrologic models. There are few measurements of albedo over sagebrush-dominated rangelands, so albedo was measured at seven sites on the Reynolds Creek Experimental Watershed in southwest Idaho during 1989–1993. For all sites, the average albedo measured during midday under clear skies was 0.14 during the growing season. Albedo varied from a low of 0.11 during June at the Mountain big sagebrush site to a high of 0.17 at the low-elevation Wyoming big sagebrush site. Albedo varied little between about 2 h after sunrise and 2 h before sunset.

INTRODUCTION

Albedo is defined in this study as the ratio of solar radiation reflected from the soil and plant complex to the amount of solar radiation incident upon it. Albedo is often used in evapotranspiration algorithms of hydrologic and natural resource simulation models such as SHAW (Flerchinger and Pierson 1991), EPIC (Sharpley and Williams 1990), and SPUR (Wight and Skiles 1987). However, the use of these algorithms is limited because of the paucity of values for sagebrush communities. Aase and Idso (1975), Dirmhirn and Belt (1971), Kuhn and Suomi (1958), and Sellers (1965) show typical grass and rangeland albedos between 0.10 and 0.25, indicating the wide range of albedo that can be expected. In 1969, Dirmhirn and Belt (1971) measured albedos of about 0.13 at two sagebrush range sites in the Reynolds Creek Experimental Watershed. They also presented albedos for specific plants and soils at these sites.

The purpose of this study was to determine albedos for several rangeland sites in the Reynolds Creek Experimental Watershed as they relate to the variability between sites, variations of albedo during the summer season, and daytime variations of albedo. The sites used in this study were different from those used by Dirmhirn and Belt (1971), so this new information will add to their results.

STUDY SITES AND INSTRUMENTATION

The study sites were in the Reynolds Creek Experimental Watershed, located in the Owyhee Mountains of southwest Idaho (Robins et al. 1965). Five habitat types were represented at seven sites (Table 1). The habitat types were the Nancy site —Wyoming big sagebrush/bluebunch wheatgrass (*Artemisia tridentata wyomingensis/Agropyron spicatum*); Lower Sheep and Upper Sheep A sites—low sage brush/bluebunch wheatgrass (*Artemisia arbuscula/Agropyron spictum*); Upper Sheep B and C sites—mountain big sagebrush/mountain snowberry/Idaho fescue (*Artemisia tridentata vaseyana/Symphoricarpos oreophilus/Festuca idahoensis*); Reynolds Mountain site—mountain big sagebrush/Idaho fescue (*Artemisia tridentata vaseyana/Festuca idahoensis*); and Aspen site—quaking aspen (*Populus tremuloides*). Nancy, Lower Sheep, and Upper Sheep A are the three sites with the least effective precipitation because of their elevation and/or exposure, the least vegetative cover, and sagebrush with the shortest growth form (Table 1). The Upper Sheep B and C sites have the most sagebrush and grass cover because of their northern aspect and because the area has a deep snow cover most winters. The Reynolds Mountain site has a southern aspect and does not have the dense sagebrush and grass cover that might be expected at an elevation of 2,097 m with 774 mm of annual precipitation. The Aspen site is a stand of rather bent and broken aspen because the area is under a deep snow drift most winters. The tops of the aspen were about 5.35 m above ground.

Eppley precision spectral pyranometers (model number PSP1) sensitive to wavelengths from 0.285 to 2.8 μm, were used to measure both the incoming and reflected solar radiation. (Mention of a trademark name of a proprietary product does not constitute endorsement by the writer and does not imply its approval to the exclusion of other products that may also be suitable.) The inverted pyranometer used to measure reflected radiation was positioned at a height of 1 m above the vegetation. All measurements were taken with both pyranometers set level and not necessarily parallel to the land slope. The results in Table 2 are based on data that were taken at or near the time of maximum solar angle and with clear sky conditions. Instantaneous pyranometer readings were stored electronically every 12 min throughout each day on a data logger.

RESULTS AND DISCUSSION

Monthly Albedo Values

A summary of the albedo measurements is shown in Table 2. At the Nancy site, albedos ranged from 0.15 in April and May to 0.17 in July. These values were about 13% greater than those at the other sites, most likely due to the lighter color soil at the Nancy site. Albedos varied between 0.13 in May and 0.15 in August at the Lower Sheep site. These values were similar to those measured at the Upper Sheep C site (0.13 in May, 0.14 in June, July, and August, and 0.13 in September). None of the monthly albedos at the Upper Sheep C site varied by more than 8% between years; therefore, only 3 year average values are shown in Table 2. At Upper Sheep B, albedo was 0.11 for June and 0.12 for July, August, and September, indicating only small differences in albedo within the same vegetation type. Albedos measured at the Reynolds Mountain site were 0.13 in June, 0.14 in July, and 0.15 in August. These data suggest that an albedo of 0.14 may be a representative value to use for sagebrush/grass rangeland in the Intermountain Northwest.

At the Aspen site, 1990 albedos were 0.11 in June before the trees were fully leafed, 0.14 in July, 0.15 in August, and 0.14 in September. The values were 0.12 in July and August of 1993. Between-year differences were greater than those found for the sagebrush-grass sites and were most likely due to (1) not having the sensors in exactly the same location both

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TABLE 1. Site Information, Reynolds Creek Experimental Watershed, Idaho

Site	Slope (%)	Aspect	Habitat type[a,b]	Soils[b]
Nancy	<5	NE	Wyoming big sagebrush Bluebunch wheatgrass	Glasgow loam
Lower Sheep	10	NW	Low sagebrush Bluebunch wheatgrass	Searla cobbly loam
Upper Sheep A	12	W	Low sagebrush Bluebunch wheatgrass	Gabica cobbly gravelly loam
Upper Sheep B and C	14	NE	Mountain big sagebrush Mountain snowberry Idaho fescue	Harmehl and Demast stony loams
Reynolds Mountain	<5	S	Mountain big sagebrush Idaho fescue	Bullrey gravelly loam
Aspen	15	N	Quaking aspen	Harmehl and Demast stony loams

[a]Hironaka et al. 1983.
[b]Stephenson 1977.

TABLE 2. Summary of Albedo Measured at Seven Sites on Reynolds Creek Experimental Watershed, Idaho

Site	Year	April	May	June	July	August	September
Nancy	1989	0.15	0.15	0.16	0.17	—	—
Lower Sheep	1988–1989	—	0.13	0.14	0.14	0.15	—
Upper Sheep A	1990	—	0.12	0.13	0.14	—	—
Upper Sheep B	1990	—	—	0.11	0.12	0.12	0.12
Upper Sheep C	1991–1993	—	0.13	0.14	0.14	0.14	0.13
Reynolds Mountain	1989–1992	—	—	0.13	0.14	0.15	—
Aspen	1990	—	—	0.11	0.14	0.15	0.14
	1993	—	—	—	0.12	0.12	—
Average	1988–1993	—	0.13	0.13	0.14	0.14	—

years, and (2) the possibility each year that the snow drift may have changed the structure of the stand of trees. This study suggests that, over the growing season, an albedo of 0.13 or 0.14 may be used for aspen trees that are growing in a snow drift area and possibly for other aspen stands as well.

Albedos found in this study were about 40% less than those reported for mature crops that completely cover the ground. These differences may be due to the color of the local vegetation and soils and to multiple reflection within the open multilayered community growing at each site (Dirmhirn and Belt 1971; Nkemdirim 1972; Lee 1978).

Seasonal Variation in Albedo

The information in Table 2 suggests that albedo values increased from spring through summer at each of the sites except Upper Sheep sites B and C, where it increased between the first and second months of the season and then stayed the same until September, when albedo decreased at site C. Because of this general increase in albedo values during the growing season, more detailed data analysis was done for the Nancy site, the lowest elevation site, and the Reynolds Mountain site, that is, the highest elevation site. There was a good linear relationship between albedo and day of year at both sites (Fig. 1). The slopes of the two regression lines shown in Fig. 1 are significantly different at the 5% level. However, they are both very close to 0.0003 unit per day of year, which may be a reasonable value to use to represent these rangeland vegetation cover conditions when measured albedo values are not available for an entire growing season.

Davies and Buttimor (1969) found that the albedo of the crops they were studying, which included grass, increased during the growing season. They found that the albedo did not increase as much in September, which they suggested was due to the structure of the crop and the solar elevation in September. The decrease in albedo in September at the Upper Sheep C and Aspen sites was also likely due to a combination of the solar elevation and plant structure at that time of the year. Ripley and Redmann (1976) found that the albedo of a mowed short-grass prairie site in Nebraska decreased during the growing season, and Aase and Idso (1975) found essentially no change of albedo during the growing season at a native rangeland site near Sidney, Montana. These studies, along with the Reynolds Creek Experimental Watershed study, support the supposition that the structure and reflectance of the plant material and the amount of visible ground surface are major factors in determining albedo values for different rangeland types.

Diurnal Variation of Albedo

Daytime albedos are shown in Fig 2 for two mostly clear days when the soil surface was dry at both the Nancy and Reynolds Mountain sites. Because of the changing sun angle and greater instrumentation error at low sun angles (Nkemdirim 1972), albedo decreased rapidly during the first 2 h of the

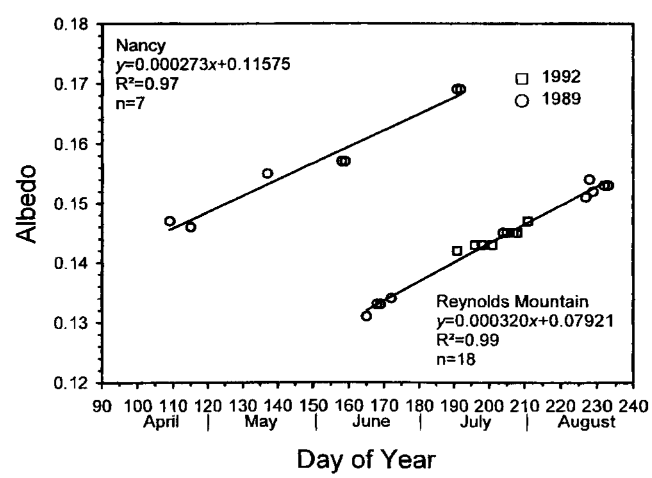

FIG. 1. Relationships between Albedo and Day of Year for Nancy and Reynolds Mountain Sites, Reynolds Creek Experimental Watershed, Idaho

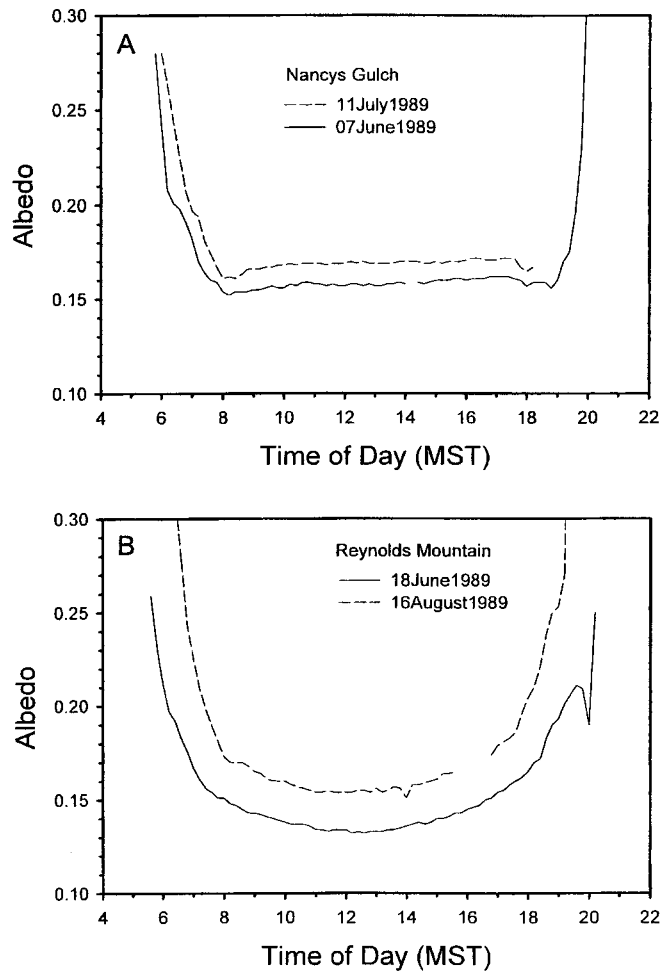

FIG. 2. Daytime Variations of Albedo at Nancy Site (A) and Reynolds Mountain Site (B), Reynolds Creek Experimental Watershed, Idaho

day at the Nancy site and then increased rapidly between late afternoon and sunset. The albedo decreased by a factor of almost two after sunrise at the Nancy site, which agrees with values suggested by Dickinson (1983) for a nonuniform surface where there is shadowing by the roughness elements such as the bunch grasses and sagebrush at this site. Albedo stayed nearly uniform (within 8% of the solar noon value) until about 1 h before sunset. The Nancy site was cloudy after 18:12 on July 11, 1989, which resulted in the albedo varying between readings, and thus this part of the day was not included in Fig. 2(a). On June 7, the albedo increased rapidly between 18:30 and sunset. This increase in albedo was similar to the decrease in the early morning and was about twice the albedo value at solar noon.

At the Reynolds Mountain site [Fig. 2(b)], albedo decreased rapidly in the early morning and increased rapidly between late afternoon and sunset, much as it did at the Nancy site. In contrast to the Nancy site, the albedo at Reynolds Mountain decreased gradually from about 08:00 local time until solar noon and then increased gradually until late afternoon. This change of albedo during the day more closely followed the pattern shown by Dickinson (1983), Nkemdirim (1972), and Aase and Idso (1975); however, the pattern shown by Aase and Idso (1975) for native rangeland did show a distinct uniform albedo value for about 4 h during midday. These results suggest that for summer months averaged albedo measurements from about 2 h after sunrise and 2 h before sunset can be used for daily albedo because only a small portion of daily total solar radiation occurs during the first and last 2 h of each day. In fact, a midday albedo reading is a relatively good estimate of the daily albedo.

CONCLUSIONS

In general, albedo increased 7 to 14% during the spring and summer and then decreased slightly in the fall. Albedo values did not differ greatly between range sites. The average albedo of 0.14 found in this study is very close to the values of 0.131 and 0.134 found by Dirmhirn and Belt (1971). The value of 0.14 is a little less than the 0.146 to 0.148 reported by Sellers (1965) for forest and grassland, and 0.158 to 0.165 for Great Basin shrubland. Albedo measured by Aase and Idso (1975) on mixed prairie in northeastern Montana was about 28% greater than those measured in this study. Albedo decreased rapidly during the first 2 h of each clear day and then stayed within 7 and 20% of the minimum measured value throughout most of each day until late afternoon, when the albedo values increased rapidly during the 2 h before sunset.

REFERENCES

Aase, J. K., and Isdo, S. B. (1975). ''Solar radiation interactions with mixed prairie rangeland in natural and denuded conditions.'' *Archives for Meteorology, Geophysics, and Bioclimatology, Series B*, 23, 255–264.

Davies, J. A., and Buttimor, P. H. (1969). ''Reflection coefficients, heating coefficients and net radiation at Simcoe, southern Ontario.'' *Agric Meteorology*, 6(5), 171–386.

Dickinson, R. E. (1983). ''Land surface processes and climate—Surface albedos and energy balance.'' *Adv. in Geophysics*, 25, 305–353.

Dirmhirn, I., and Belt, G. H. (1971). ''Variation of albedo of selected sagebrush range in the intermountain region.'' *Agric. Meteorology*, 9(1/2), 51–61.

Flerchinger, G. N., and Pierson, F. B. (1991). ''Modeling plant canopy effects on variability of soil temperature and water.'' *Agric. and Forest Meteorology*, 56(3/4), 227–246.

Hironaka, M., Fosberg, M. A., and Winward, A. H. (1983). ''Sagebrush-grass habitat types of southern Idaho.'' *Forest, Wildlife and Range Experiment Station, Bull. No. 35,* University of Idaho, Moscow.

Kuhn, P. M., and Suomi, V. E. (1958). ''Airborne observations of albedo with a beam reflector.'' *J. Meteorology*, 15, 172–174.

Lee, R. (1978). *Forest microclimatology*, Columbia University, New York.

Nkemdirim, L. C. (1972). ''Relation of radiation fluxes over prairie grass.'' *Archives for Meteorology, Geophysics, and Bioclimatology, Series B.*, 20, 23–40.

Ripley, E. A., and Redmann, R. E. (1976). ''Grassland.'' *Vegetation and the atmosphere*, J. L. Monteith, ed., Vol. 2, Academic, London, 349–398.

Robins, J. S., Kelly, L. L., and Hamon, W. R. (1965). ''Reynolds Creek in southwest Idaho: An outdoor hydrologic laboratory.'' *Water Resour. Res.*, 1(3), 407–413.

Sellers, W. D. (1965). *Physical climatology*, University of Chicago Press, Chicago.

Sharpley, A. N., and Williams, J. R., eds. (1990). ''EPIC—Erosion/productivity impact calculator: 1. Model documentation.'' *USDA Tech. Bull. No. 1768*, U.S. Department of Agriculture, Washington, D.C.

Stephenson, G. R. (1977). ''Soil-geology-vegetation inventories for Reynolds Creek Watershed.'' *Agric. Experiment Station, Misc. Ser. No. 42*, University of Idaho, Moscow, Idaho.

Wight J. R. and Skiles, J. W. (1987). ''SPUR: simulation of production and utilization of rangelands. Documentation and user guide.'' *ARS-63*, Agric. Res. Service, U.S. Department of Agriculture, Washington, D.C.