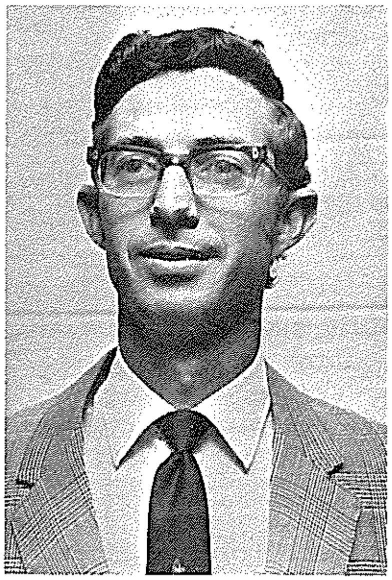
MONTHLY CONSUMPTIVE IRRIGATION REQUIREMENTS AS A GUIDE TO EFFICIENT MANAGEMENT

Bobby J. Creel[1/]



Biographical Sketch

Born - September 30, 1943; married, three children.

B. S. - New Mexico State University, 1968
M. S. - New Mexico State University, in progress.

Experience - Undergraduate Research Aide, New Mexico State University, 1965-1968. Water Resources Research Aide, New Mexico State University, 1968.

Research Areas - Water Resources Research.

Honors - Alpha Zeta.

Publications

Irrigation Water Requirements for Crop Production - Roswell Artesian Basin, An Economic Analysis and Basic Data; Water Resources Research Institute, WRRI Report 4 Part II, New Mexico State University, 1969.

Irrigation Water Requirements for Crop Production - Roswell Artesian Basin, Project Analysis and Summary; Water Resources Research Institute, WRRI Report 4 part IV, New Mexico State University, 1969.

Irrigation Water Requirements for Crop Production - Roswell Artesian Basin, Water Resources Research Institute, WRRI Report 5, New Mexico State University, 1969.

An Economic Land Classification of the Irrigated Cropland in the Pecos River Basin, New Mexico; Water Resources Research Institute, WRRI Report 7, New Mexico State University, 1970.

1/ New Mexico State University

Agriculture in New Mexico utilizes a major portion of the state's water resources. New Mexico presently diverts about 3,077,000 acre-feet of water annually for irrigation of about 1,000,000 acres of land (14). In 1965, slightly more than a million acres (1,046,600 acres) were irrigated from surface and groundwater sources. Irrigation of this acreage accounts for approximately 90 percent of the average annual depletion for beneficial uses of the state's surface and groundwater supplies (12).

The arid nature of New Mexico requires irrigation for successful crop production. The large use of water by irrigation, relative to other uses, is of prime importance in a state with limited water supplies.

Water problems are high on the list of public concern at present. Water supply and pollution problems have spread throughout the country and have become critical in many areas. Many of the problems are of a scope and nature requiring state and federal planning as well as large public investments in water development programs.

With a major portion of the water supply of New Mexico being used for the irrigation of agricultural crops, most of the problems dealing with water directly or indirectly concern the users of this water. Farmers are concerned not only with the utilization of a resource that is becoming increasingly scarce, but one in which the uses to which it is put and the results of this use are being scrutinized as never before.

Much interest has been directed to plans which would supply additional water to New Mexico and the Southwest. Importation plans appear to offer the only means of maintaining present levels of irrigation in some areas. Other plans would permit continued irrigation development in some areas. The uncertain future of irrigation should cause us to consider carefully these alternative plans.

Irrigation technology will almost certainly preclude the present practices such as furrow irrigation. It has been predicted that probably most crops will be solid planted and watered by subsurface irrigation systems or sprinklers in the not-so-distant future.

These are but two of the many ideas which have been presented and projected for the future concerning irrigated agriculture. The third, and primary topic of this paper, involves the idea of knowledge of irrigation requirements.

The primary purpose of this paper is to point out the need for knowledge of basic irrigation requirements which would allow for a more efficient utilization of the existing water supplies. It is recognized that improvements in irrigation technology will undoubtedly make substantial contributions to increased water-use efficiencies and in many respects pave-the-way for some of the water importation plans, desalination plans, and other such plans. However, before additional supplies are provided, those supplies presently available should be put to their fullest beneficial use. In this respect, the supplies of water currently available for irrigation should be used only to the extent that they satisfy the crops' minimum requirements.

This would be an ideal situation, but in the same respect an impossible task. Non-beneficial depletions in agriculture range from losses from canals to evapotranspiration by weeds on the farm ditches, which would not be eliminated without considerable expense and investments in time and energy.

In the opinion of the author, there is a potential for increasing the efficiency of water use in agriculture through the improvement of management knowledge relating to irrigation water requirements of the various crops. Before proceeding with this idea a review of the work and studies done in this area are in order.

Even though irrigation has been practiced in various parts of the world for centuries, only until about 70 years ago were intensive studies conducted to determine the basic water requirements of crops. This was primarily because actual measurements of consumptive use under each of the physical and climatic conditions of any large area were expensive in time and money.

Various methods have been used to measure the amount of water consumed by agricultural crops and native vegetation. The principal approaches have been tank experiments, studies of soil moisture, and observations of groundwater fluctuations -- and for larger areas, the inflow-outflow, effective heat, and integration methods (1). One of the more common methods of determining the use of water by individual crops was to grow them in tanks and measure the quantity of water necessary to maintain their growth satisfactorily. Another common method used employed soil-moisture depletion studies in which the change in the moisture content of the soil within the root zone of the crop was measured periodically.

Methods of estimating consumptive use of water by crops and other vegetation, for climatic factors, have been found to give reasonably accurate results. The Blaney-Criddle formula (U=KF) has been used extensively in many states. The procedure was developed by correlating measured consumptive-use data with monthly percentages of yearly daytime hours, precipitation and growing season. The coefficients developed allowed for the computation of consumptive use of each crop.

Actual measurements of consumptive use of water by plants have been conducted by a number of research agencies over the past 60-70 years. One of the first such studies was made in 1903 in California. Extensive studies of evaporation, evapotranspiration, temperature, humidity, and wind movement were conducted by Blaney in 1919 in Colorado. Several research studies have been conducted in New Mexico, one of the first being made in the Mesilla Valley in 1904 (13). Bloodgood (8) conducted experiments in 1924-25 on the irrigation requirements of alfalfa, barley, chile, sorghum, wheat, and other crops at the New Mexico Agricultural Experiment Station. The Rio Grande Joint Investigation in 1936 (4) and the Pecos River Joint Investigation in 1939-41 (5) conducted studies on consumptive use of water by irrigated crops and natural vegetation. More recently, Blaney and Hanson (7) reported in 1965 consumptive use and water requirements for crops in New Mexico using the Blaney-Criddle method, and Henderson and Sorensen (11) in 1968 published consumptive irrigation requirements for areas of New Mexico.

These studies were designed primarily to estimate the water requirements of irrigated crops as an aggregate for the individual states or areas under consideration. The knowledge of irrigation water requirements of crops were considered necessary in planning conservation projects, farm irrigation systems, water conservation, and full utilization of water in river basins. They were also considered as an important factor in the negotiation of compacts and treaties and in the litigation and adjudication of water rights (4,2).

The purpose of this paper is not to present the idea that these studies were limited in their usefulness. since in many large projects the construction costs chargeable against irrigation have been well above $500 per acre (1). With costs this high, large errors in estimating the acreage of land suitable for continued irrigation and the amount of water required for it must be avoided. If sufficient water is allowed for maximum production, the project lands will not produce properly and will not be able to pay the charges; but if the supply exceeds the needs, water costs may exceed the ability of the user to pay (1).

Most of these earlier studies on consumptive use of water were made only on a seasonal basis, with little consideration given for monthly, weekly, or daily use-rates. For most purposes, data on seasonal basis were sufficient. Certainly many storage reservoirs were safely and efficiently designed with a knowledge of only seasonal water requirements.

Most drainage systems were designed without detailed short-time use of water rates and determination of basin-wide water supplies, and water inventories hardly needed more than seasonal and annual consumptive use rates.

With growing use of sprinkler irrigation systems and need for better information on the most economical capacities of irrigation systems, there has been a growing need for monthly, weekly, and even daily consumptive use of water rates. Beginning about 1950, considerable effort had been directed by many agencies toward gathering such data. Several investigators have reported highly variable rates of use on a short-time basis, however. It was felt in most cases that considerably more research would be necessary before monthly or short-time consumptive use could be accurately predicted.

Studies dealing with the monthly or short-time consumptive water use recognized the greater variation in monthly coefficients than in the seasonal coefficients. This greater variation was thought to be due to the greater number of factors besides climate that might influence growth. Such factors as insect damage, cutting of alfalfa for hay, and actual solar radiation were thought to influence the consumptive use rates and probably accounted for the variation. Actual measurements indicated that water use varied widely throughout the season and such variation could not be explained by climatic data generally available.

Work in Texas (6) in the early 1950's suggested that the average consumptive use of water by grain sorghum started at about 0.06 inch per day during the emergence period, but increased rapidly to a peak of 0.30 inch per day, then continued to decrease to about 0.05 inch per day until harvest.

Blaney and Criddle (1) in the late 1950's reported results of studies in the United States and several foreign countries. In their report, the empirical formula for consumptive use, developed from the results of the various studies, was presented. They noted that the seasonal coefficient (K) for each crop appeared to be approximately constant for most areas where irrigation was practiced. However, the coefficients did not appear to be constant for consecutive short periods during the growing season. Adjustments could be made in areas where the data was available. For short periods and higher temperatures, the coefficients (k) appeared to be larger. They concluded that temperature was not the only factor affecting consumptive-use relations, and that each crop had its own particular growth and water-use pattern. Thus, for short periods, use coefficients varied, depending upon the temperature and stage of growth. Records of measured seasonal consumptive use of water by irrigated crops and calculated consumptive-use factors (F) and crop coefficients (K) were reported, as well as some suggested monthly crop coefficients (k) for selected locations.

More recent work in Arizona (10) presented consumptive-use curves for 30 different oil, hay, small grain, fruit, vegetable and green manure crops for various locations in the state. Without exception these curves suggested higher consumptive use over the periods of higher temperatures and periods of expected higher plant growth rates.

The consumptive-use curves included in this report were the averages of several years and did not show the short-time fluctuations in water use. The authors noted that they represented data from irrigation treatments which resulted in optimum crop production. Each figure contained estimates of seasonal use, semi-monthly use, and soil profile moisture depletion.

These curves also could be used for calculating irrigation schedules, thus allowing irrigations to coincide with needs of the plants. Inefficiencies of deep percolation resulting from over-irrigation and from crop damage or stress due to lack of sufficient water could thereby be reduced.

A direct transfer of this consumptive-use data to another area with widely different climatic conditions is not valid, but data from the study could be used for irrigation scheduling in areas having comparable growing seasons. Small differences in growing season length and planting dates could be taken care of by shifting the curves forward or backward on the time scale, as required.

Several methods of making such transfers have been proposed. One in wide use today is the method developed by Blaney and Criddle. If the consumptive use coefficient (K) was known for a specific crop at a certain location, it was this factor that was transposed to other areas, using the local area (F) factor, from which estimates of consumptive use were made (1).

Appendix Table 1 presents the seasonal and semi-monthly (k) factors as determined for crops grown in Arizona, to be used with the Blaney-Criddle formula in estimating consumptive use of water in other areas. When the 15-day (k) factors are used, the corresponding daytime sunshine hour percentages and the mean average temperature for the 15-day period at a particular location should be used.

For example, it might be desirable to estimate the consumptive use of cotton for the first half of July here at Las Cruces, using the developed (k) values. The (k) factor for cotton from appendix Table 1 is 1.10, and from the sunshine tables, the average daytime hour percentage for July at Las Cruces would be approximately 9.77. The first half daytime hour percentage would therefore be:

4.73, calculated as follows $\left(\frac{15}{31} \times 9.77 = 4.73\right)$.

The mean temperature for the first 15 days of July for Las Cruces (New Mexico State University Weather Station) in 1970 was 82° F (15). Thus the (f) factor for the first half of July would be:

3.88, calculated as follows $\left(\frac{82 \times 4.73}{100} = 3.88\right)$

and the estimated consumptive use for the first 15 days of July would be:

4.27, calculated as follows $(1.10 \times 3.88 = 4.27)$

Applying the consumptive-use coefficients (k) from the Arizona study allowed an estimate of the semi-monthly consumptive use of a crop that otherwise was not available. These estimates could be made for all semi-monthly periods of the seasons for the necessary crops and used to construct irrigation requirements or irrigation schedules, where the seasonal values could not.

Transposing of the Arizona (k) factors into New Mexico provides a means of supplying information developed from actual consumptive-use studies. The Arizona consumptive-use data was computed from gravimetric soil moisture measurements on soil samples taken at depths and locations that could be expected to evaluate the average soil moisture distribution and depletion by the plants under study. The application of the consumptive-use data from Arizona to New Mexico has certain limitations which affect the validity and accuracy of the estimates. It may not be accurate in assuming that the (k) factor for Arizona was valid for use in New Mexico since some factors which were not accounted for in the local (f) values, such as length of growing season, humidity, differences in soil fertility, topography, wind movement, quality of irrigation water, and the types and varieties of crops produced may be somewhat different for the two areas in question.

Consumptive irrigation requirements[1] are dependent not only on the consumptive needs of the plants, but also on that contributed from such natural sources as usable summer precipitation, available soil moisture and any contribution from groundwater. Normally in semi-arid regions where water tables do not contribute to the crops, the precipitation which occurs during the season need only be considered. Thus, the calculated consumptive use minus the effective precipitation for the same period would give the consumptive irrigation requirement.

In the many areas of irrigated agriculture in New Mexico, climatic factors vary considerably. This fact alone would rule out the transfer of the Arizona consumptive use coefficients into many areas of New Mexico. Thus, it would seem that in order to obtain valid and accurate estimates of monthly consumptive use and monthly consumptive irrigation requirements for crops in New Mexico. There is a need for research which would develop basic water requirements for the various crops.

With the large portion of the water resources of New Mexico being used in irrigated agriculture, and with the present concern for our water resource in the state; it would seem to indicate that the necessary research should be implemented which would provide monthly consumptive use and monthly consumptive irrigation requirements for crops produced in New Mexico.

REFERENCES

1. Blaney, H. F., and Criddle, W. D., Determining Consumptive Use and Irrigation Water Requirements: USDA Technical Bulletin No. 1275., 1962, 59 pp.

2. ______________, Determining Water Requirements for Settling Water Disputes, Natural Resources Journal, University of New Mexico, V. 4 No. 1, 1964, p. 29-41.

3. ______________, Determining Water Requirements in Irrigated Areas From Climatological and Irrigation Data, USDA, Soil Conservation Service Technical Publication No. 96, 1950, 48 pp.

4. Blaney, H. F., Ewing, P. A., Israelsen, O. W., et al., "Regional Planning, pt. VI," The Rio Grande Joint Investigation, Upper Rio Grande, Natural Resources Committee, 1938, p. 293-616.

5. Blaney, H. F., Ewing, P. A., Morin, K. V., and Criddle, W. D., "Consumptive Water Use and Requirements," The Pecos River Joint Investigation, Reports of the Participating Agencies, Natural Resources Planning Board, 1942, p. 170-230.

1/ The equation for monthly consumptive irrigation requirements is: cir=u=r, where u=kf, the (r) values are the monthly precipitation considered available for consumptive water requirements of crops, and does not include deep percolation below the root zone nor surface runoff, and (f) values are the monthly consumptive-use factor (1).

6. Blaney, H. F., Haise, H. R., and Jensen, M. E., Consumptive Use By Irrigated Crops in Western United States, USDA Agricultural Research Service, 53 pp. (Processed.)

7. Blaney, H. F., and Hanson, E. G., Consumptive Use and Water Requirements In New Mexico, New Mexico State Engineer Technical Report No. 32, 1965, 82 pp.

8. Bloodgood, D. W., Net Requirements of Crops For Irrigation Water In The Mesilla Valley, New Mexico, Agricultural Experiment Station, New Mexico State University, Bulletin No. 149, 1925, 48 pp.

9. Criddle, W. D., Harris K., and Willardson, L. S., Consumptive Use and Water Requirements for Utah, Utah State Engineer Technical Publication No. 8 (revised), 1962, 47 pp.

10. Erie, L. J., Orrin, F. F., and Harris, K., Consumptive Use of Water By Crops in Arizona, Agricultural Experiment Station, University of Arizona, Technical Bulletin No. 169, 1965, 43 pp.

11. Henderson, D. C., and Sorensen, E. F., Consumptive Irrigation Requirements of Selected Irrigated Areas In New Mexico, Agricultural Experiment Station, New Mexico State University, Bulletin No. 531, 1968, 55 pp.

12. Henderson, D. C., and Stucky, H. R., Agricultural Land And Water in New Mexico, New Mexico State Planning Office, 1966, 62 pp.

13. Tinsley, J. D., and Vernon, J. J., Soil Moisture Investigations For 1904, Agricultural Experiment Station, New Mexico State University, Bulletin No. 54, 1905, 27 pp.

14. Water Resources of New Mexico: Occurrence, Development and Use, Compiled by New Mexico State Engineer Office in cooperation with New Mexico Interstate Stream Commission and United States Geological Survey, State Planning Office, Santa Fe, New Mexico, 1967, 321 pp.

15. Weather Bureau, Climatological Data, New Mexico, (July 1970), United States Department of Commerce, Vol. 74, No. 7, p. 101-127.

Appendix Table 1. Computed Seasonal "K" and Semi-monthly "k" Values for Use in the Blaney-Criddle Formula CU=KF or u=kf

Crop	Seasonal "K" Values	January 1-15	January 16-31	February 1-14	February 15-28	March 1-15	March 16-31	April 1-15	April 16-30	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-31	August 1-15	August 16-31	September 1-15	September 16-30	October 1-15	October 16-31	November 1-15	November 16-30	December 1-15	December 16-31
Cash and Oil Crops																									
Castor Beans	0.84								.07	.21	.35	.58	.98	.95	.93	.86	1.08	1.44	1.56	1.23	.82	.48			
Cotton	0.79							.06	.11	.20	.34	.50	.79	1.10	1.30	1.43	1.36	1.23	1.00	.79	.47	.27			
Flax	0.78	.84	.86	.82	.85	.81	1.07	1.24	1.26	.79	.59	.38	.27									.68	.81	.87	.90
Safflower	1.21	.08	.20	.23	.44	.59	1.01	1.63	2.21	1.98	1.00	1.70	1.43	.34											
Soy Beans	0.68												.24	.38	.45	.71	.93	1.13	1.07	.86	.68				
Bermuda Lawn and Hay Crops																									
Alfalfa	1.20				.92	1.20	1.22	1.18	1.34	1.31	1.42	1.39	1.33	1.30	1.16	1.14	1.06	1.39	1.27	1.10	.87	.80	.80		
Bermuda Lawn	0.97								.66	.70	.88	1.00	1.12	1.19	1.15	1.16	1.05	.96	.82	.71					
Blue Panicum Grass	0.98							.83	1.03	1.03	1.11	1.07	1.03	1.11	1.11	1.10	1.01	.95	.89	.89	.75	.32			
Small Grain and Forage Crops																									
Barley	1.09	.25	.39	.79	.99	1.17	1.38	2.08	1.74	.99															.12
Sorghum Grain (Single crop)	0.87													.14	.74	1.29	1.67	1.34	.86	.51	.18				
Sorghum Grain (Double crop)	0.90							.03	.28	.71	1.37	1.61	1.60	.90	.71	.59	.96	1.66	1.18	.90	.67	.56	.44	.16	
Sorghum Forage (Double crop)	0.94							.02	.32	.80	1.42	1.49	1.42	1.05	.74	.59	1.15	1.79	1.39	1.10	.73	.56	.44	.10	
Wheat	0.99	.18	.25	.32	.40	.55	1.28	1.70	1.94	1.22	.51														
Fruits																									
Grapefruit	0.66	.45	.55	.48	.47	.47	.50	.49	.52	.55	.62	.67	.70	.76	.71	.80	.75	.79	.76	.83	.69	.72	.58	.63	.61
Grapes	0.70						.35	.33	.56	.78	1.06	.73	.77	.79											
Oranges	0.53	.34	.44	.43	.52	.39	.43	.42	.49	.47	.47	.55	.56	.58	.57	.66	.59	.63	.65	.69	.55	.59	.58	.46	.34
Vegetables																									
Broccoli	0.77	.95	1.09	1.08														.12	.27	.62	.85	1.29	1.09	1.08	.91
Cabbage (early)	0.72	.89	.80															.07	.23	.56	1.02	1.33	1.15	1.05	.94
Cabbage (late)	0.82	1.07	.95	.86	.89	.65												.12	.41	.81	1.02	1.29	1.21	1.14	1.04
Cantaloupe	0.74							.06	.20	.27	.78	1.32	1.34	.81											
Carrots	0.63	.89	.75	.66	.69	.40													.05	.25	.53	1.19	1.06	.94	.86
Cauliflower	0.78	1.07	.85															.11	.30	.51	.82	1.29	1.36	1.41	1.14
Lettuce	0.50																		.07	.27	.43	.59	.75	.98	.90
Onions (dry)	0.80	.30	.38	.46	.67	.95	1.50	1.66	1.81	.85												.02	.05	.11	.20
Onions (green)	0.88	.99	.85																.26	.38	1.06	1.38	1.28	1.17	1.03
Potatoes	1.01				.03	.09	.34	.93	1.65	1.78	1.53	.85													
Sweet Corn	0.98						.07	.26	.62	1.19	1.82	1.49													
Green Manure Crops																									
Guar	0.78													.38	.81	1.00	.93								
Papago Peas	1.01		.21	.47	.62	.91	1.29	1.54	1.42	1.08								.83	.81	.87	.64				
Sesbania	0.82														.11	.72	1.28	1.26							