Climatic Assessment
Of the Arid Southwestern United States for Use in Predicting Evapotranspiration of Turfgrass

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Climate exerts a significant effect on the geographical distribution, growth and water use of plants. Climatic factors, such as precipitation, number of frost-free days, temperature (maximum, minimum, mean) and the distribution and amount of precipitation influence the geographical range of native vegetation.

Irrigated agricultural and non-agricultural plants, however, are not under the same limitations associated with precipitation events. Microclimates associated with agricultural and non-agricultural plants can also be modified to enhance plant survival and productivity (south facing slopes, wind machines, heaters, etc.).

M.Y. Nuttonson referred to areas of agricultural production with similar climates as ***agro-climatic analogues***. Growth, productivity, quality characteristics and evapotranspiration of plants growing in these agro-climatic analogues would thus be very similar, indicating that if a species is introduced to a similar agro-climatic analogue, there would be a good chance that it would respond in a similar fashion. Differences in plant response between analogues might still exist, however, due to the obvious effects of different cultural management, irrigation water quality and soil type.

The desert areas of Southern California, Arizona and Nevada, although not identical, were developed under similar climatic conditions and thus have many soil characteristics in common, according to the Soil Conservation Service. These include:

- poor profile development
- low soil organic matter content
- high soil strength
- and significant accumulation of salts and specific ions.

These desert regions are also dependent on the Colorado River and local groundwater sources to meet irrigation needs. The Colorado River carries a significant salt content which makes it necessary for irrigators to apply additional water to achieve leaching and maintain favorable salt balances in the soil profile (U.S. Salinity Laboratory Staff).

Greater information, based on scientific research, is needed in order to to make wise decisions concerning the allocation of water to provide adequate amounts that meet the requirements of both agricultural and nonagricultural crops.

The desert regions of Southern California, Arizona, and Nevada have significant acreage in turfgrass, including residential, commercial, and recreational uses. The combined turfgrass operations in these three areas represent in excess of a billion dollars annually (Cockerham and Gibeault). Bermudagrasses (*Cynodon dactylon*) grow well in these three areas because they are salt tolerant, drought tolerant, heat tolerant and become dormant during cold winter months. (Devitt, Gibeault, Kneebone, Pepper).

Populations continue to grow in the desert southwest, placing increasing pressure on available water resources. As such, water users are being scrutinized more closely, and in particular, turfgrass water users. Greater information, based on scientific research, is needed in order to make wise decisions concerning the allocation of water to provide adequate amounts that meet the water requirements of agricultural and nonagricultural crops.

If all three geographical areas were similar with regard to climate, soil, water quality and turfgrass response, the transfer of experimental findings from one area to another area could take place. Such transfer would save time and money by allowing water managers to make more accurate and timely decisions with regards to the water management of turfgrass. The objective of this research was to evaluate climatic conditions in Las Vegas, NV; Palm Desert CA; and Tucson, AZ over a two-year period and to assess the growing conditions for bermudagrass in all three areas to determine if these regions could be considered as agro-climatic analogues for bermudagrass (water use).

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Materials and Methods

Climatological data were gathered for the years 1988 and 1989 from official weather stations located in Palm Desert, CA (CIMIS); Tucson, AZ (AZMET); and Las Vegas, NV. Geodemographical information for each location is summarized in below. All three sites were equipped with automated weather stations (Campbell Scientific, Logan, UT) from which data was downloaded via a telephone modem to a computer. Meteorological variables monitored included relative humidity, temperature, wind run, solar radiation and rainfall.

The modified Penman Combination Equation was used to estimate potential evapotranspiration (ETo) at all three sites. ETo was based on hourly estimates at both the Palm Desert and Tucson sites, whereas ETo was based on daily estimates at the Las Vegas site. Crop coefficients (ET actual/ETo) used at each site were obtained from the literature for comparative purposes.

Information pertaining to the turfgrass industry, soil conditions, cultural management, and water quality at each location was obtained from local surveys conducted by the coauthors (Brown, Snyder, and Devitt). All dates (monthly and yearly) were analyzed using linear regression analysis, descriptive statistics and/or frequency distribution analysis (Dowdy and Wearden).

Results and Discussion

Location

The three study sites in this investigation are situated in a triangular geographic arrangement, sometimes referred to as the "Bermudagrass Triangle." Las Vegas is located approximately 341 km from Palm Desert and 663 km from Tucson. Tucson is located approximately 597 km from Palm Desert. All three sites have latitudinal coordinates between 32 and 36 degrees north.

ELEVATION, LATITUDE, LONGITUDE AND POPULATION

	Las Vegas, NV Clark County	Palm Desert, CA Coachella Valley	Tucson Pima County
Elevation(m)	659	56	710
Latitude	36-5	33-50	32-17
Longitude	115-10	115-30	110-57
Population (1994)	741,459	191,602	666,880

Elevation is slightly higher in Tucson than in Las Vegas and approximately 654 m higher than Palm Desert.

Edaphic Characteristics

The soils formed in all three areas are classified as either recently developed mineral soils with poor horizontal development (Entisols) or as mineral soils formed under an aridic moisture regime (Aridisols) Within these two soil orders can exist a great deal of variability with regard to both the physical and chemical status of the soil.

However, the majority of the soils at the locations are alluvial soils, alkaline in nature, classified as saline and often as saline-sodic soils before reclamation occurs. They have been reported to contain boron at levels detrimental to plant growth (U.S. Salinity Laboratory Staff).

Water

Total rainfall at all three location is inadequate to meet turfgrass water requirements. During 1988 and 1989, rainfall at Las Vegas averaged less than 6.5 cm per year, whereas Tucson averaged 22.6 cm per year. Rainfall occur-red primarily during winter and early spring at all three locations, but also during the summer months at Tucson and Las Vegas. Colorado River water supplied to all three locations possesses a salinity level of approximately 1.1 dS/m, whereas groundwater salinity levels range downward to 0.4 dS/m. The 1995 cost of water per 3,785 liters (1,000 gallons) for residential use was \$0.98 to \$1.16 in Las Vegas, \$1.40 to \$4.34 in Tucson, and \$0.78 in Palm Desert.

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Turfgrass Management

Bermudagrass is the predominant grass growing at all three location during the months of April through August/September. Golf turfgrass acreage has increased every decade since 1950.

Turfgrass systems in these areas are categorized as high maintenance or low maintenance, based on cultural management (Kopec and Mancino, 1990). Golf courses are classified as high maintenance turf, while most parts and schools are classified as low maintenance turf.

During the active growing season, high

MAJOR GRASSES, CROP COEFFICIENTS

	Clark County, NV	Coachella Valley, CA	Pima County, AZ
Major Grasses	Common Bermuda Ryegrass Tall Fescue Tifway Bentgrass	Common Bermuda Ryegrass Tifgreen Bentgrass *Poa trivialis*	Common Bermuda Ryegrass Tifway Bentgrass
Crop Coefficients	B/R HF = 0.71 B/R LF = 0.50 TF HF = 0.94	B = 0.60 R = 0.80	B HF = 0.75-0.8 B LF = 0.65 R HF = 0.75 - 0.90 R FL = 0.75 TF = 0.60

B/R - Bermuda/Ryegrass
TF - Tall Fescue
B - Bermudagrass
R - Ryegrass
HF - High Fertility
LF - Low Fertility

Devitt et al, 1992; Snyder 1986; Brown et al, 1988 maintenance turf would be cut daily or every other day and receive nitrogen at rates of 36.7 to 73.4 kg/ha/mo. Additional nutrients would also be applied as needed (micronutrients, phosphorus, potassium and sulfur). Low maintenance turf would be cut once or twice per week and receive little to no fertilizer input.

Most high maintenance turfgrass systems (bermudagrass) would be overseeded with ryegrass in early September or October, whereas low maintenance turfgrass systems would generally not be overseeded and would be allowed to enter full dormancy during winter months. Crop coefficients currently used for bermudagrass (high and low maintenance) at all three locations vary within a narrow range of each other (see table previous page). Crop coefficients for both Tucson and Las Vegas were based on research conducted at those locations. The crop coefficients used at Palm Desert were extrapolated from CIMIS data and were not based on research there.

Irrigation systems on high maintenance turfgrass are typically managed by a specialist who makes daily changes in irrigation amounts based on environmental demand (weather data, crop coefficients). The specialist is usually knowledgeable about sprinkler precipitation rates, uniformity distributions, soil infiltration rate and leaching requirements. Because high maintenance turfgrass typically receives better irrigation management than low maintenance turfgrass, efficiency in water use is higher, even though actual evapotranspiration is also higher due to increased growth and vigor (Devitt et al, 1992).

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Climate counts

Monthly average values for maximum temperature, minimum temperature, average relative humidity, wind run and solar radiation measured at Las Vegas, Tucson and Palm Desert were charted. Both temperature and solar radiation varied with time in a sinusoidal fashion. Maximum temperatures averaged slightly higher in Palm Desert than in Tucson or Las Vegas, with the greatest divergence occurring during winter months. Average monthly minimum temperatures showed little deviation between sites, with Tucson recording slightly lower minimum temperatures during winter months.

However, the number of days on which minimum temperatures dropped below freezing varied significantly by location. Tucson averaged 31.5 days, Las Vegas 18 days, and Palm Desert 12.5 days.

Relative humidity and wind run showed greater variability among sites than was shown for temperature or solar radiation. Lower average monthly relative humidities were recorded during summer and higher average monthly relative humidities were recorded during winter at all three locations, with greater variation recorded at Tucson. Average monthly wind run was less variable than any other parameter on a monthly basis at all locations. Palm Desert averaged consistently lower monthly wind runs than Las Vegas or Tucson. Slightly lower wind runs were observed during winter at all three locations.

Potential evapotranspiration (ETo) was plotted on a monthly basis for all three locations. Estimates of ETo were very similar for all three sites during the months of October through April, with greater divergence occurring during the summer. Greatest separation in summer ETo estimates occurred during 1989, with Tucson having higher ETo than Las Vegas, which in turn had higher ETo estimates than Palm Desert

Higher wind runs combined with lower relative humidities during summer at both Tucson and Las Vegas resulted in higher ETo estimates, even though average maximum temperatures were higher at the Palm Desert site. This would indicate that during summer months at the three locations, the aerodynamic term in the Penman combination equation contributed significantly to the ETo estimates. ETo estimates for Tucson and Palm Desert were plotted against ETo estimates for Las Vegas. Both linear regressions were significant at the P=0.001 level, with the Tucson regression found above the 1 to 1 line and the Palm Desert regression found below the 1 to 1 line when monthly ETo estimates were above a value of 10 cm.

When Las Vegas ETo estimates were compared with the other two sites, a seven percent error was observed in estimating ETo for the Palm Desert site and a 13 percent error was observed in estimating the ETo for the Tucson site, where percent error was calculated by dividing the standard error of estimate (based on regression analysis) by the mean monthly ETo estimate at the Las Vegas site.

A slightly larger error (18 percent) was observed when estimates of ETo at the Tucson site were based on ETo from the Palm Desert site. Finally, frequency distributions were calculated for monthly ETo estimates (1988) based on mean daily ETo estimates reflecting the 95, 90, 75, 50 and 25 percent frequency distributions. Greater variability existed in the daily ETo estimates during most months of the year at the Tucson site compared to either the Las Vegas site or the Palm Desert site.

Greater variability in the daily ETo estimates (1988) at the Tucson site and the Las Vegas site occurred during April (transition month) and August (summer storms, cloud cover), whereas at the Palm Desert site greatest variability occurred during March and August.

Conclusions

Only slight differences existed between the average monthly minimum and maximum temperatures and solar radiation at the three sites. However, differences in average monthly wind run and relative humidity at the three sites led to greater separation in the ETo estimates during summer months. These differences resulted in a 7 percent and 13 percent error in estimating monthly ETo at the Palm Desert and Tucson sites respectively, based on using the Las Vegas monthly ETo data.

However, when Palm Desert monthly ETo data were used to predict ETo at the Tucson site, a slightly larger error of 18 percent was observed. Greater variability existed in the daily ETo estimates during most months at the Tucson site, compared to the other two sites.

This ETo variability combined with higher rainfall and a larger number of days in which temperatures dropped below freezing, would indicate that potential differences in the response of bermu-dagrass would be greatest if comparisons were made with the Tucson site.

However, the 13 percent and 18 percent error in predicting ETo at the Tucson site based on data from either the Las Vegas site or the Palm Desert site is still low, indicating that the three locations could be considered as agroclimatic analogues for bermudagrass.

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The fact that all three sites also used irrigation water of similar quality (Colorado River, groundwater, greater used of groundwater on golf courses in the Coachella Valley), the turfgrass is grown on poorly developed desert soils, and the turfgrass is maintained under similar cultural management (high or low maintenance turf) suggests that the growth and water use of bermudagrass (under similar cultural management) at any one of the three locations could be transferred and used at the other two locations, if consideration was given to the error in estimate and the time of the year. Finally, it should also be noted that such data should be continually reevaluated as larger data sets reflecting longer time periods are obtained.

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