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Simulating agricultural drought periods based on daily rainfall and crop water consumption

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Abstract

Even though drought is difficult to define precisely, rainfall is the most widely used indicator of drought. This paper presents a methodology on modeling of the agricultural drought duration. For this purpose, study area was divided into four hydrologic homogeneous sections as W, CN, CS and E. To constitute the monthly time series of each section, the number of days in each month in which daily rainfall was less than the water consumption of the critical crop was assumed to be drought periods. Then, constituted monthly time series of drought durations of each hydrologic homogeneous section was simulated using ARIMA model. No linear trend was observed for the time series except that of the CS section. In general, the predicted data from the selected best models for the time series of each section represents the actual data of that section.

Keywords: Rainfall; Crop water consumption; ARIMA model; Agricultural drought period; Critical crop; Hydrologic homogeneous section

1. Introduction

Drought is one of the most serious problems arising for human societies and ecosystems from climate variability. Although its impact does not come through sudden events, such as flood and storms, drought is the world's costliest natural disaster, causing an average \$6–\$8 billion in global damages annually and collectively affecting more people than any

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Nomenclature

a_i	white noise time series value at time i
B	backward shift operator
C	constant term in ARIMA model
c	constant for Box–Cox transformation
d	order of the nonseasonal differencing operator
D	order of the seasonal differencing operator
ESS_L	the residual sum of square for the low set
ESS_H	the residual sum of square for the high set
k_p	degree of freedom
K_{xi}	rank of ith observation in the historical data
K_{yi}	rank in the historical data of ith observation in the ascended data
m	the number of autocorrelation lags being tested
n	the number of observations
n_L	the number of residuals in the low set
n_H	the number of residuals in the high set
$Q(r)$	Ljung–Box statistic at lag m
$r_k(a)$	ACF of a_i at lag k
R_{sp}	rank order correlation coefficient
s	seasonal length
x_i	discrete time series value at time i
w_i	stationary series formed by differencing the x_i
z_i	transformation of x_i series

Greek symbols

λ	exponent for Box–Cox transformation
μ	mean level of the w_i series (if $D+d>0$ often $\mu\approx 0$)
$\varnothing(B)$	nonseasonal AR operator of order p
$\theta(B)$	nonseasonal MA operator of order q
$\Phi(B)$	seasonal AR parameter of order P
$\Theta(B)$	seasonal MA parameter of order Q
$\sigma_a{}^2$	variance of residuals

other form of natural disaster (Wilhite, 2000). Human beings often increase the impact of drought because of high use of water, which cannot be supported when the natural supply decreases. Drought is difficult to define precisely, but operational definitions often help to define the onset, severity, and end of droughts. Le Houerou (1996) stated that droughts are experienced on almost all types of agricultural lands in the world, but arid lands are most susceptible.

Ranking the severity of droughts in cropping areas is difficult, due to the varying impact of rainfall at different times of year. Drought intensity and duration must always be related to a calendar of crop sensitivity to rainfall. Assessing drought severity requires a measure of effective rainfall in relation to soil moisture and plant condition, rather than just