Modeling 100 Years of Water-use of a No-Till Double Crop Forage Production System

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ABSTRACT

Forage production in past years has been limited to one crop per year by producers. Due to limited water, winds and the need to maintain economically viable agricultural production, producers need to ... to maintain production. It may be possible with improved no-till equipment and management to harvest two forage crops in one year. The objective of this project was to look at 100 years of historical weather data and determine the theoretical potential to grow two forage crops in one year. To complete this objective, daily reference evapotranspiration (ET) and ET budgets for peas and sorghum forage crops were calculated using the Penman equation for each of 100 years. The Penman equation requires daily maximum and minimum temperatures, precipitation, average wind speed, solar radiation, dew point, and relative humidity. All of this data was available from 1991-2005. For 1905-1990 only daily maximum and minimum temperatures and precipitation were available. Remaining variables for those years were calculated using averages from 1991-2005. From 1905-1990, a pea crop was estimated to be stressed (55% (soil water equivalent) was less than 111.76 mm in the soil) only [illegible] of the time and at a permanent wilt point 8% (soil water equivalent was 0 mm of water in the soil) of the time. Sorghum was stressed 50% of the time and at a permanent wilt point 20% of the time. From 1991-2005 peas were stressed 20% of the time and at a permanent wilt point 0% of the time. The sorghum was stressed 33% of the time and at a permanent wilt point 7%. From 1905-2005 peas were stressed 41% of the time and at a permanent wilt point 8% of the time. Sorghum was stressed 61% of the time and at a permanent wilt point 18% of the time. The results show that with proper management, advanced equipment, and available soil water it may be possible to harvest two successful forage crops in one year for most years.

INTRODUCTION

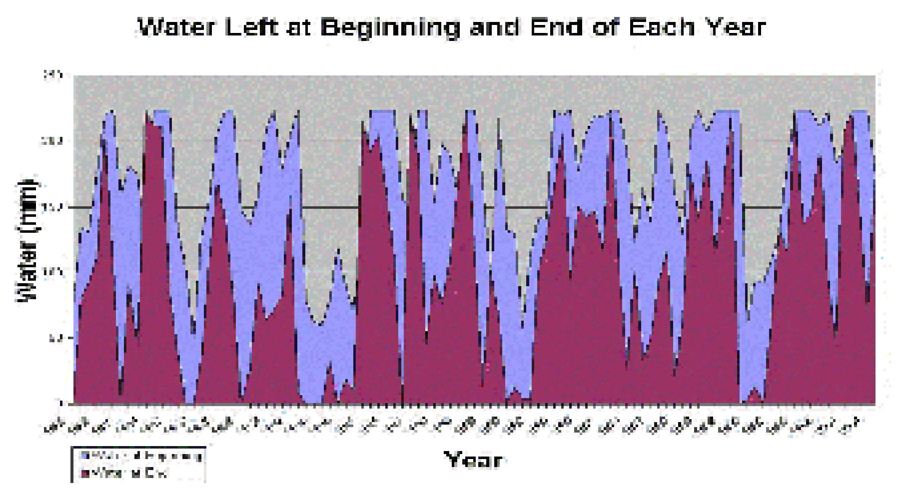
Traditionally agricultural producers in southwest North Dakota produce one forage crop per year. However with advanced equipment and proper management, it may be possible for producers to raise two forage crops per year. By examining and modeling 100 years of historical weather, one could estimate available soil water for and under actively growing crops. Irrigators have used a similar model for several years for scheduling irrigations.

OBJECTIVE

The objective of this project was to look at 100 years of historical weather data and create a model of a double cropping forage system. The model depicts estimated water use and soil water balance during a 100 year period at the beginning and end of the year. It also provides information on a yearly basis of crop stress and permanent wilt point. The Penman equation was used to determine reference ET.

ASSUMPTIONS

- No-till cropping system.
- No plant disease problems present.
- No insect or weed problems present.
- Planting on a silt loam soil in southwest North Dakota.
- Plant available water-holding capacity is 223.52 mm.
- All water in between from August 27 – April 15 is absorbed by the soil.
- If plant available water reaches 0 mm, or equal to reach permanent wilt (plant can no longer extract moisture from the soil).
- If plant available water reaches 111.76 mm, yield will be affected due to crop stress.
- Peas are planted on April 15 and harvested on June 30.
- Sorghum is planted on July 8 and harvested on August 26.
- Adapted crop varieties were used.

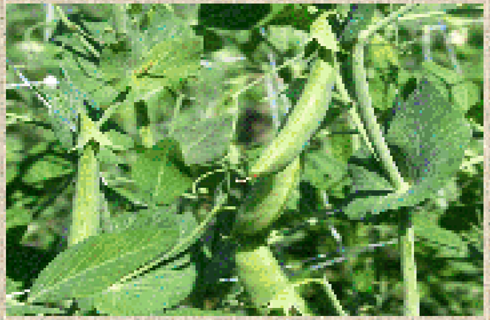


Year	Stressed Peas	Stressed Sorghum	Year	Stressed Peas	Stressed Sorghum	Year	Stressed Peas	Stressed Sorghum	Year	Stressed Peas	Stressed Sorghum
1905	🟥	🟥	1931	🟥	🟥	1957	🟥	🟥	1983		
1906		🟥	1932			1958		🟥	1984		
1907	🟥	🟥	1933	🟥	🟥	1959	🟥	🟥	1985		
1908		🟥	1934	🟥	🟥	1960	🟥	🟥	1986		
1909			1935	🟥	🟥	1961	🟥	🟥	1987		
1910		🟥	1936	🟥	🟥	1962	🟥	🟥	1988	🟥	🟥
1911	🟥	🟥	1937	🟥	🟥	1963		🟥	1989	🟥	🟥
1912	🟥	🟥	1938	🟥	🟥	1964			1990	🟥	🟥
1913	🟥	🟥	1939	🟥	🟥	1965			1991	🟥	🟥
1914			1940	🟥	🟥	1966			1992	🟥	🟥
1915			1941			1967		🟥	1993		
1916			1942			1968	🟥	🟥	1994		
1917		🟥	1943			1969			1995		
1918	🟥	🟥	1944			1970			1996		
1919	🟥	🟥	1945		🟥	1971			1997		
1920	🟥	🟥	1946	🟥	🟥	1972			1998		
1921	🟥	🟥	1947			1973		🟥	1999		🟥
1922		🟥	1948			1974	🟥	🟥	2000	🟥	🟥
1923			1949	🟥	🟥	1975		🟥	2001		
1924			1950		🟥	1976		🟥	2002		
1925		🟥	1951		🟥	1977	🟥	🟥	2003		
1926	🟥	🟥	1952	🟥	🟥	1978		🟥	2004		🟥
1927	🟥	🟥	1953			1979			2005		
1928		🟥	1954			1980	🟥	🟥			
1929		🟥	1955		🟥	1981	🟥	🟥			
1930		🟥	1956	🟥	🟥	1982					

Stressed 🟥
Not Stressed

Year	Permanent Wilt Peas	Permanent Wilt Sorghum	Year	Permanent Wilt Peas	Permanent Wilt Sorghum	Year	Permanent Wilt Peas	Permanent Wilt Sorghum	Year	Permanent Wilt Peas	Permanent Wilt Sorghum
1905	🟥	🟥	1931			1957			1983		
1906			1932			1958			1984		
1907			1933			1959		🟥	1985		
1908			1934		🟥	1960		🟥	1986		
1909			1935	🟥	🟥	1961	🟥	🟥	1987		
1910			1936	🟥	🟥	1962		🟥	1988		🟥
1911			1937			1963			1989	🟥	🟥
1912			1938		🟥	1964			1990		
1913			1939			1965			1991		🟥
1914			1940			1966			1992		
1915			1941			1967			1993		
1916			1942			1968			1994		
1917			1943			1969			1995		
1918		🟥	1944			1970			1996		
1919	🟥	🟥	1945			1971			1997		
1920	🟥	🟥	1946		🟥	1972			1998		
1921			1947			1973			1999		
1922			1948			1974			2000		
1923			1949			1975			2001		
1924			1950			1976			2002		
1925			1951			1977			2003		
1926		🟥	1952			1978			2004		
1927			1953			1979			2005		
1928			1954			1980					
1929			1955			1981					
1930			1956		🟥	1982					

Permanent Wilt 🟥
Not Permanent Wilt


Forage Peas


Harvesting Sorghum


Forage Sorghum

METHODS & PROCEDURES

100 years of historical weather data along with the Penman equation were used to complete this model. The weather data was put into Microsoft Excel and analyzed. The weather records used were provided by the Dickinson Research Extension Center and the North Dakota Agricultural Weather Network. The Penman equation was used to derive reference ET. In order to complete the Penman equation, daily maximum and minimum temperatures, precipitation, average wind speed, solar radiation, dew point, and relative humidity were used. All of this data was available from 1991-2005. For 1905-1990 only daily maximum and minimum temperatures and precipitation were recorded. Remaining variables for these years were computed using averages from 1991-2005.

Penman Equation:

$$ETo = c[W*Rn + (1-W)*f(u)*(ea-ed)]$$

ETo = reference crop evapotranspiration in mm/day.
W = temperature related weighting factor.
Rn = net radiation in equivalent evaporation in mm/day
f(u) = wind-related function.
(ea-ed) = difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air, both in mbar.
c = adjustment factor to compensate for the effect of day and night weather conditions.

RESULTS

From 1905-1990, a pea crop was estimated to be stressed (55% (soil water equivalent) was less than 111.76 mm in the soil) only [illegible] of the time and at a permanent wilt point 5% (soil water equivalent was 0 mm of water in the soil) of the time. Sorghum was stressed 56% of the time and at a permanent wilt point 21% of the time. From 1991-2005 peas were stressed 27% of the time and at a permanent wilt point 0% of the time. The sorghum was stressed 33% of the time and at a permanent wilt point 7%. From 1905-2005 peas were stressed 41% of the time and at a permanent wilt point 8% of the time. Sorghum was stressed 52% of the time and at a permanent wilt point 18% of the time.

CONCLUSION

With proper management, advanced no-till equipment, and adequate amounts of moisture, it is possible for producers to grow two forage crops in one year for most years. This project was mainly undertaken by reviewing 100 years of historical weather and developing a year by year model. The model focuses on available soil water under an actively growing crop.

LITERATURE CITED

- "Dryland Agriculture"
- "Modeling Plant and Soil Systems"
- "Crop Water Requirements FAO 24"
- "Yield Response to Water FAO 33"