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The Under-Appreciated Climate Factor in the Conservation Effects Assessment Project

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Decade-long climate variations and associated impacts on runoff, soil erosion and agrichemical movement may play a critical role in addressing the objectives of the Conservation Effects Assessment Project (CEAP). CEAP is a multi-agency effort to quantify the environmental benefits of conservation practices used by private landowners participating in selected U. S. Department of Agriculture conservation programs (Mausbach and Dedrick, 2004). The project has two components, the National Assessment which provides summary estimates of conservation practice benefits, and the Watershed Assessment Studies that conducts basic research on conservation practices in selected watersheds to provide a framework for evaluating and improving the performance of national assessment models. In the context of the second component of CEAP, impacts of decade-long precipitation variations on runoff-induced soil erosion and agrichemical movement are of particular interest because effectiveness of conservation practices varies with the particular precipitation years used in its assessment. In this viewpoint, decade long precipitation variations and their relation to runoff and related conservation effects are briefly described. The magnitude of the resulting impacts on runoff is illustrated for the 770 km^2 Fort Cobb Reservoir watershed in central Oklahoma, and the significance of these precipitation variations for the interpretation of the effectiveness of conservation practices.

Climate varies seasonally, from year to year, decade to decade and over longer periods of time (NRC, 1998). The key climatic variable for assessment of watershed runoff, soil erosion and water quality is precipitation. Precipitation is the driving force behind the generation of surface runoff which in turn erodes and transports soils, nutrients and agricultural chemicals into downstream water bodies that serve water supply, recreation and wildlife habitat. When precipitation changes, so does the runoff and associated erosion and transport of soils and agrichemicals. While seasonal and year-to-year variations in precipitation are readily recognized, variations in average annual precipitation lasting 5 to 50 years, termed decade-long variations, have the potential to surpass the impacts of short-term variations due to cumulative effects of sustained departure from average conditions (Mantua et al., 1997; Woodhouse and Overpeck, 1998). References to the existence of such climate variations reach far back in time. The Bible (Genesis 41:29-31) mentions 7 years of plenty followed by 7 years of famine. Historians have suggested that prolonged climate variations may have contributed to the collapse of well established civilizations in the past (Kolata, 1993; Wright, 1998). Examples of climate variations in the Unites States during the recent measured record include the Dust Bowl years of the 1930s (Worster, 1982); the record low water levels of the Great Lakes in the 1960s, followed by record high levels in the 1970s (Croley, 1995); the 1987-1992 drought in California (Dixon et al., 1996); the 1980 rise of the Great Salt Lake (Lall and Mann, 1995); the wet decades in the Central Plains of the United States at the end of the 20th century (Garbrecht and Rossel, 2002; Garbrecht et al., 2004); and, most recently, the persistent multi-year drought in the Colorado River Basin (Webb et al., 2004) and much of the western United States.

Soil erodibility and agrichemical input are primarily related to land use and agronomic practices, which are controlled by human activity. Yet, runoff-induced soil erosion and agrichemical transport are set in motion by precipitation-runoff processes. In the presence of decade-long precipitation variations, runoff, soil erosion and agrichemical movement also vary at these time scales. For example, the 1940-2004 annual precipitation of Fort Cobb watershed (Figure 1 top) shows decade-long precipitation variations relative to a long-term mean. A trend analysis identified three dry periods in the 1950s, 1960s, and late 1970s, and one extended wet period in the late 1980s and 1990s. The average annual precipitation for the dry and wet periods was about 640 mm/yr and 890 mm/yr, respectively, with a difference of 250 mm/yr or 33% of long term mean. These decade-long variations in precipitation led to corresponding variations in runoff (Figure 1 bottom): three low runoff periods in the 1950s, late 1960s, and late 1970s - early 1980s, and a single high runoff period in the late 1980s and 1990s. The average annual runoff for the dry and wet precipitation periods was about 1.3 cms and 3.1 cms, respectively, with a difference of 1.8 cms or 100% of long term mean. Thus, a 33% change in mean annual precipitation led to a 100% change in mean annual runoff, which in turn would undoubtedly impact runoff-induced soil erosion and sediment transport rates. Specifically, the exponential relationship between runoff and soil erosion and transport (Graf, 1971; Vanoni, 1975) suggests an even larger difference in soil erosion and transport between wet and dry periods than for runoff. Similar inferences are likely applicable for the movement of agrichemicals.

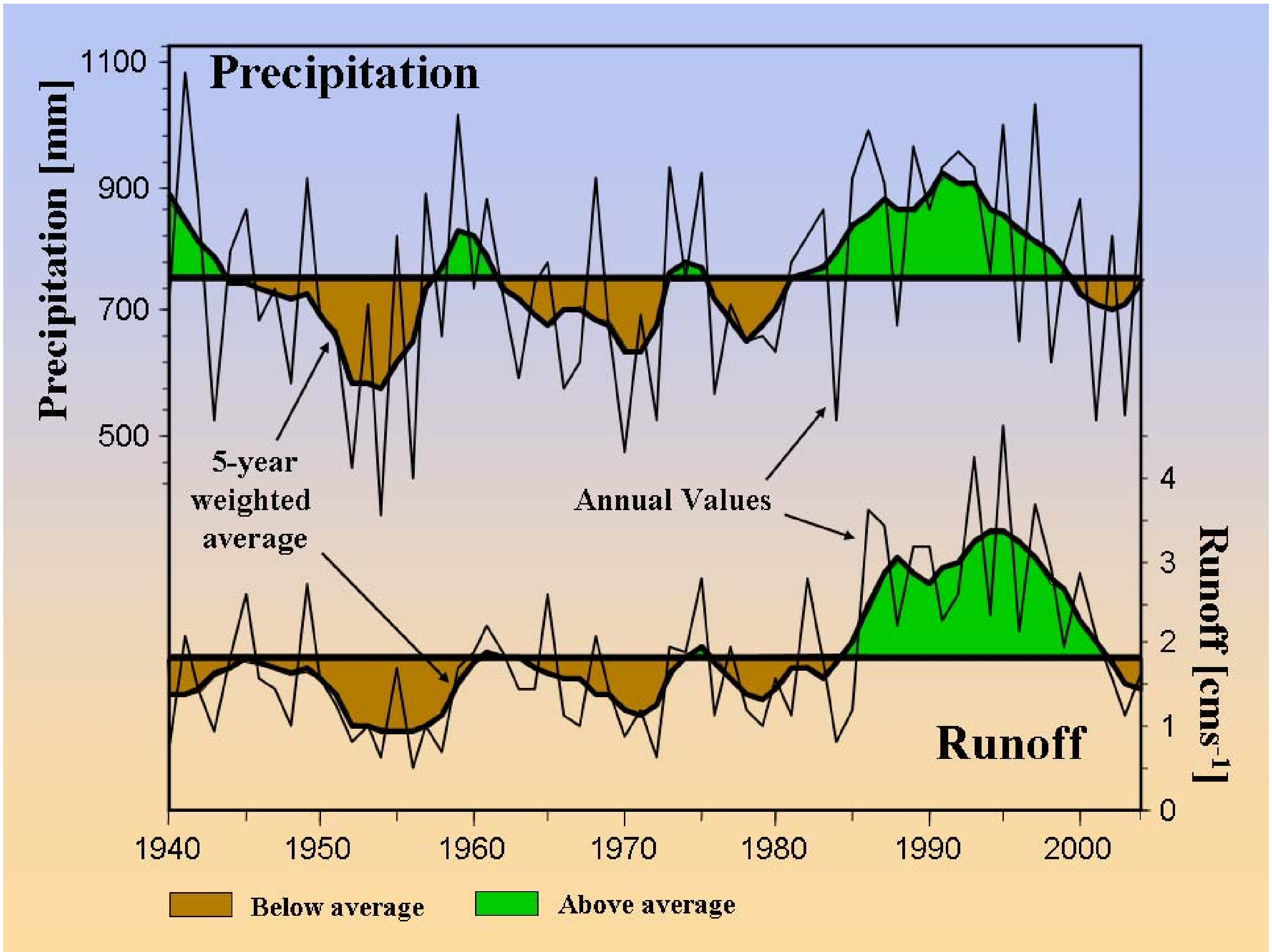

Figure 1: Year to year and persistent variations of annual precipitation (top) and annual stream flow in the Fort Cobb watershed (bottom).

Effectiveness of conservation practices is generally measured against base-line or initial conditions which themselves reflect climatic conditions. When climate and base-line conditions change, the numerical value of the calculated effectiveness also changes. Thus, for identical conservation practices, base-line conditions and conservation assessment that reflect a dry period will lead to a different effectiveness value than when evaluated for a wet period that has higher runoff, soil erosion and transport. This raises the fundamental question as to which climate and base-line conditions are most appropriate for assessing the effects of conservation practices on runoff-induced soil erosion and agrichemical movement. The immediate answer appears to be base-line conditions that are all encompassing and include wet, dry and average precipitation periods. But why evaluate conservation practices for dry periods when most runoff, soil erosion and transport take place during wet periods? Are there climate periods that are more suitable for conservation assessment than others? Alternatively, one could use the "current" climate instead of relying on conditions that reflect a time period in the past. However, "current" climate is dynamic and changes as the years go by leading to different effectiveness values for same conservation practices. A possibility would be to specify a standard or official "design climate". Either way, the issue of "appropriate" climate and base-line conditions for the assessment of effectiveness of conservation practices merits further consideration.

The CEAP assessment of conservation practices is mostly based on the evaluation of hydrologic and environmental models. In this regard, persistent precipitation variations (Figure 1 top) can also affect calibration and validation of simulation models used in the assessment of conservation practices. When the model calibration period coincides with a wet or dry precipitation variation, the calibration will inherently reflect climate, runoff, soil erosion and transport relationships that prevailed during the calibration period. Given the large differences in runoff due to decade long precipitation variations, it remains to be seen if a model calibrated under either wet or dry precipitation variations is valid for application under precipitation variations that are different than those used in the model calibration. Such a validation is necessary when the model is either applied with long term precipitation data that include decade long variations, or with precipitation data that are different in character from those used in the model calibration.

Despite these very compelling reasons to account for the climate factor, the reality of the situation is that available runoff, sediment and especially water quality records are often too short to fully account for the effect of decade-long precipitation variations on soil erosion and agrichemical movement. In practice, conservation models are calibrated and validated within the constraints of available runoff, sediment and water quality data, and the impact of climate variations is approximated by application of the calibrated model with climate records containing decade long variations.

However, the selection of an "appropriate" climate and base line condition for the assessment of the effectiveness of conservation practices remains an open issue and should be debated among policy makers, scientists, practitioners, conservation specialists, land owners and climatologists. Without an agreed upon standard, various numerical values of effectiveness could be obtained for the same conservation practices depending on the climate conditions that prevailed during the assessment period. This ambiguity at best limits the usefulness of the assessment, and at worst fails to meet the intended purpose of CEAP. Until an appropriate standard is defined, the calculated effectiveness of conservation practices should be reported with reference to the particular climate and base-line condition used in the calibration and subsequent assessment.

References Cited

Croley, T. E. II. 1995. Laurentian Great Lakes, Dynamics, Climate, and Response to Change. Chapter 9 in The Role of Water and the Hydrological Cycle in Global Change (H. R. Oliver and S. A. Oliver, Eds.), NATO Advanced Science Institute Series I: Global Environmental Change, 31, Springer Verlag, Berlin, p.253-296.

Dixon,L. S., N. Y. Moore, and E. M. Pint. 1996. Drought Management Policies and Economic Effects in Urban Areas of California, 1987-1992, MR-813-CUWA/CDWR/NSF, RAND; accessed at: http://www.rand.org/publications/MR/MR813.

Garbrecht, J. D., and F. E. Rossel. 2002. Decade-Scale Precipitation Increase in the Great Plains at the End of the 20th Century. Journal of Hydrologic Engineering, 7(1):64-75

Garbrecht, J. D., M. Van Liew, and G. O. Brown. 2004. Trends in Precipitation, Streamflow, and Evapotranspiration in the Great Plains of the United States. Journal of Hydrologic Engineering, 9(5):360-367.

Graf, W. H. 1971. Hydraulics of Sediment Transport. McGraw-Hill Series in Water Resources and Environmental Engineering, McGraw-Hill Book Company, New York.

Kolata, A. L. 1993. The Tiwanaku – Portrait of an Andean Civilization. Blackwell Publishing, Inc., Malden, Massachusetts.

Lall, U., M. Mann. 1995. The Great Salt Lake: A Barometer of Low-Frequency Climate Variability. Water Resources Research, 31(10):2503-2516.

Mantua, N. J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis. 1997. A Pacific Interdecadal Climate Oscillation with Impacts on Salmon Production. Bulletin of the American Meteorological Society, 78(6):1070-1079.

Mausbach, M. J., and A. R. Dedrick. 2004. The Length We Go; Measuring Environmental Benefits of Conservation Practices. Journal of Soil and Water Conservation 59(5):97-103.

National Research Council (NRC). 1998. Decade-to-Century-Scale Climate Variability and Change, A Science Strategy. National Academy Press, 2101 Constitution Avenue, Washington, D.C.

Vanoni, V. A. 1975. Sedimentation Engineering. ASCE Manuals and Reports on Engineering Practices, No. 54. American Society of Civil Engineers, New York, New York, 745 pp.

Webb, R. H., G. J. McCabe, R. Hereford, and C. Wilkowske. 2004. Climate Fluctuations, Drought, and Flow in the Colorado River. U.S. Department of the Interior, U.S. Geological Survey, USGS Fact Sheet 3062-04, accessed at:
http://water.usgs.gov/pubs/fs/2004/3062.

Woodhouse, C. A., and J. T. Overpeck. 1998. 2000 Years of Drought Variability in the Central United States. Bulletin of the American Meteorological Society, 79(12):2693-2714.

Worster, D. E. 1982. Dust Bowl: The Southern Plains in the 1930s. Oxford University Press, New York.

Wright, K. R. 1998. The Lessons of History – El Nino and the Fall of Empires. South American Explorer, Autumn 1998, No. 53, pp. 20-26.