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Dynamic factor analysis of groundwater quality trends in an agricultural area adjacent to Everglades National Park

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Abstract

The extensive eastern boundary of Everglades National Park (ENP) in south Florida (USA) is subject to one of the most expensive and ambitious environmental restoration projects in history. Understanding and predicting the water quality interactions between the shallow aquifer and surface water is a key component in meeting current environmental regulations and fine-tuning ENP wetland restoration while still maintaining flood protection for the adjacent developed areas. Dynamic factor analysis (DFA), a recent technique for the study of multivariate non-stationary time-series, was applied to study fluctuations in groundwater quality in the area. More than two years of hydrological and water quality time series (rainfall; water table depth; and soil, ground and surface water concentrations of $N–NO_3^-$, $N–NH_4^+$, $P–PO_4^{3-}$, Total P, $F^-$and Cl^-) from a small agricultural watershed adjacent to the ENP were selected for the study. The unexplained variability required for determining the concentration of each chemical in the 16 wells was greatly reduced by including in the analysis some of the observed time series as explanatory variables (rainfall, water table depth, and soil and canal water chemical concentration). DFA results showed that groundwater concentration of three of the agrochemical species studied ($N–NO_3^-$, $P–PO_4^{3-}$and Total P) were affected by the same explanatory variables (water table depth, enriched topsoil, and

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occurrence of a leaching rainfall event, in order of decreasing relative importance). This indicates that leaching by rainfall is the main mechanism explaining concentration peaks in groundwater. In the case of N–NH_4^+, in addition to leaching, groundwater concentration is governed by lateral exchange with canals. $F^-$and Cl^- are mainly affected by periods of dilution by rainfall recharge, and by exchange with the canals. The unstructured nature of the common trends found suggests that these are related to the complex spatially and temporally varying land use patterns in the watershed. The results indicate that peak concentrations of agrochemicals in groundwater could be reduced by improving fertilization practices (by splitting and modifying timing of applications) and by operating the regional canal system to maintain the water table low, especially during the rainy periods.

Keywords: Hydrology; Groundwater; Surface water; Water quality; Non-point source pollution; Dynamic factor analysis; Multivariate time series; Monitoring; Field methods; Everglades

1. Introduction

In the first half of the 20th century a complex drainage canal system was built in south Florida to protect urban and agricultural areas against flooding. However, this regional water management also led to the draining of protected natural wetland areas in the adjacent Everglades National Park (ENP) creating a negative impact on the environment. In an attempt to restore the wetland ecosystem of the ENP, the Combined Structural and Operational Project (CSOP) and the Comprehensive Everglades Restoration Plan (CERP) are being implemented along the extensive eastern boundary with the developed area (agricultural and urban) (SFWMD, 2004). The goal of these plans is to enhance water deliveries into the ENP while maintaining flood protection for developed areas. In addition, water quality is at the core of the restoration effort. Surface waters entering the ENP must not exceed a maximum regulatory level of total phosphorous of 0.010 mg l^{-1} and other chemicals must be monitored as well (Florida Senate Bill 0626ER, 2003). Implementation of these projects is complex and requires detailed understanding of the hydrological processes involved. Predicting the water quality interactions between surface water flow in the canals and the shallow and extremely permeable Biscayne Aquifer (Fish and Stewart, 1991) is a special priority for ecosystem restoration of the Everglades and flood protection of urban and agricultural areas. Previous studies in the area (Genereux and Guardiario, 1998, 2001; Genereux and Slater, 1999) have shown the complexity of the groundwater system with extremely permeable materials and evidence of a very dynamic interaction between canals and the aquifer. Muñoz-Carpena et al. (2003), based on preliminary hydrological data (1-year) obtained in an agricultural area located at the boundary of the ENP, reported the almost instantaneous response of the groundwater to canal and rainfall inputs in the area as well as evidence of water quality interaction between canals, the shallow aquifer and land use. Detailed data sets containing temporal variation of hydrological and water quality variables have the potential to be used to understand the surface–groundwater–land use interactions in the area. However, interpretation of results from data analysis based on visual inspection and descriptive statistics is