Eurasian Soil Science, Vol. 35, No. 4, 2002, pp. 392–400. Translated from Pochvovedenie, No. 4, 2002, pp. 443–451.
Original Russian Text Copyright © 2002 by Bykhovets, Komarov.
English Translation Copyright © 2002 by MAIK "Nauka/Interperiodica" (Russia).

SOIL PHYSICS

A Simple Statistical Model of Soil Climate with a Monthly Step

S. S. Bykhovets and A. S. Komarov

Institute of Physicochemical and Biological Problems of Soil Science, Russian Academy of Sciences, Pushchino, Moscow oblast, 142290, Russia

Received January 5, 2001

Abstract—A model of soil hydrothermal regime has been developed for simulating the dynamics of soil organic matter. Air and soil temperature and precipitation are generated statistically on the basis of an analysis of empirical data records. Soil water content is calculated on the basis of the Budyko–Zubenok model.

INTRODUCTION

Mathematical models that describe soil and ecological processes, including the organic matter dynamics, require information on meteorological conditions and soil hydrothermal regime. Data of direct meteorological observations and/or data series generated by weather models on the basis of given statistical characteristics of the climate can be used. The need in statistical models of the climate can be caused by the (1) insufficient length of available data series, (2) the necessity of having a set of independent results of modeling with given statistical properties for the purposes of probabilistic forecasts, and (3) the necessity of simulating meteorological conditions upon changes in statistical characteristics of the climate (climate change).

Within the last 20 years, stochastic models of the climate have been intensively developed mainly for agrometeorological purposes [1, 18, 27, 28] and, to a lesser extent, for modeling the dynamics of forest ecosystems [29]. Virtually all known climate-simulating models have a daily resolution (ten days in [1]), which is necessary for the majority of modern agrometeorological models. In this case, one of the main problems is the simulation of a rather complicated time pattern of the series of daily precipitation.

Contrary to agrometeorological models, the processes considered in models of forest ecosystems have another temporary scale. In particular, the length of the time series is usually less than a characteristic time of simulated processes. In addition, a high degree of temporary discretization, as in agrometeorological tasks, is not required and average monthly values can be used in many cases.

We developed a Soil Climate Statistical Simulator (SCLISS) designated mainly for operation together with the model of dynamics of soil organic matter SOMM [20, 22, 23] and its modification ROMUL [24]. The two latter models are the components of the developed system of models for describing the dynamics of forest ecosystems. As input data, these models use air temperature and precipitation and temperature and moisture of forest litter and soil with a monthly step.

Thus, our model, along with the climate generator model as such, should include a simulator of the soil hydrothermal regime. Similar statistical simulators of soil climate have not been known. Usually, the soil hydrothermal regime is modeled using the equations of heat and moisture transfer in soil (however, these works, as applied to forest soils, are also rather scarce [14, 26, 31]). Such models, certainly, are more universal; however, they require knowledge of a great number of hardly determined parameters.

Therefore, we concentrated our attention on the development of a simple model with few parameters. Although the presented version does not yield the simulation of time series containing a trend, this task is not a particular problem.

MODEL DESCRIPTION

Simulator of Input Meteorological Data

This simulator is based on the following assumptions [1, 9, 11, 13]:

(1) The distribution of average monthly air temperatures is close to the normal distribution.

(2) The distribution of monthly precipitation is strongly different from the norm, and it can be satisfactorily described by lognormal or gamma functions.

(3) Autocorrelation in time series of air temperature, in contrast to time series of monthly precipitation, can be substantial.

(4) The cross-correlation of temperature and precipitation can be significant and have a positive sign in the winter period and a negative sign in the summer period.

Assuming that the distribution of monthly precipitation (r_m) is lognormal, we obtained

$$r_m = \exp(\mu_{r_m} + \nu_{r_m} n_1), \quad (1)$$