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EFFECTS OF CLIMATIC CHANGES ON WATER ADVANCE FRONT OF A BORDER IRRIGATION SYSTEM ON A TROPICAL AQUIC PALEDULTS

AKINYEMI, J. O.
College of Agricultural Sciences, Ogun State University, Ago-Iwoye, Nigeria

Fok and Bishop (1965) equation to predict the water advance front in a border irrigation system has been applied to a field study on a tropical Aquic Paledults under different climatic changes. Eight different initial moisture contents corresponding to the rainfall distribution throughout the year was determined at Ogun Oshun River Basin Development Authority, Itoikin, South Western Nigeria. Results show that water advance front increased with increasing initial moisture content of the soil. The results of this studies also show that poor irrigation design and management in border irrigation system which are common occurrences in Nigeria and possibly in other developing countries is largely due to lack of information on the hydraulic characteristics of the processes involved. Other factors include poor land levelling, inappropriate stream sizes to design dimensions and a dearth of information on soil-water relation.

INTRODUCTION

The border irrigation method is a widely used method of surface irrigation in which water flows on a sloping rectangular field bounded by low soil dikes along both the edges of the field. Hydraulic analysis of all phases of irrigation from advance to recession is important for the successful operation of a border system. The full dynamic models for simulating border irrigation are based on the numeric solution of the complete Saint-Venant equations along with infiltration equation (Sing and Bhalandi, 1996).

The global demand for agricultural production, especially for food, has reached an unprecedented magnitude and promises to continue to escalate well into the next century. Much of the growth in agricultural production will continue to come from increasing yields. However, growth in demand, combined with unequal access to land and food, has extended the frontiers of agricultural production, inexorably outward, raising concerns about the environment wisdom and sustainability of major agricultural land expansion. Much of this concern follows from the belief that the 'prime' agricultural lands of the world have long been utilized, that little land, if any, remains, and that most expansion will involve "nonprime" lands that are agriculturally fragile, marginal or vulnerable (Turner and Benjamin, 1994).

Efficient use of irrigation water has become a global concern due to increased food production requirements with limited supply of available water. The management of surface irrigation system can be a very complex process. Optimal design and management of this system require detailed knowledge of field-wide infiltration and water advance characteristics. Surface irrigation system generally operate at low level efficiency most often because of poor design and management. The situation is even more critical in developing countries due to lack of adequate data for planning and designing the system.

Irrigated agriculture therefore faces a number of difficult problems in the future particularly the poor efficiency with which water resources have been used for irrigation. A relatively safe estimate is that 40 percent or more of the water diverted for irrigation is wasted at the farm level through either deep percolation or runoff (Walker, 1989).

The potential response of soil water properties therefore is a key indicator of the impact of agricultural management on the soil. The soil water characteristics information is so important to many potential users such as hydrologists and agro-climatologists who need the data input into crop yield simulation models used to establish irrigation schedules. The infiltration capacity of a soil serves as a guide to the rate of water application to avoid surface ponding and runoff. Failure in monitoring water advance process in the study area has resulted in non-uniform distribution of water as well as excessive water loss arising from deep percolation.

The problem of modelling border irrigation under varying climatic changes then becomes very important because of the different hydraulic characteristics that affect the efficiency of water application. This paper is therefore aimed at estimating water advance front under varying climatic conditions.

MATERIALS AND METHODS

To test the validity of equation of water advance front in this paper, experiments on border system were performed in Ogun Oshun River Basin Development Authority (OORBDA), Itoikin, South Western Nigeria. Itoikin is located on latitude 6°51'E and longitude 3°51'E. The vegetation is tropical rain forest, but massive cultivation has transformed it into a derived savannah. The soil is imperfectly drained during the rainy season when the water table is only 90cm from the surface. The surface is dark in colour and sandy loam in texture while subsoil is sandy clay loam to sandy clay, blocky to blocky sub-angular in structure with yellow brown mottles. The soil belongs to the Yampere series and classified as Aquic Paledults (USDA, 1975)

Infiltration of Water

Field investigations were conducted at different initial moisture contents of 8.9, 9.3, 11.7, 12.9, 16.8, 17.1, 20.9, and 22.6 percent. The values represent specific levels of soil moisture content on irrigated rice plots at Itoikin at different periods of the year Two sets of readings on infiltration were taken out at 45cm from the upstream end of the plot at each moisture level. Double ring infiltrometer (Michael 1978) was used for the infiltration tests. The infiltrometers 25cm high and having 60cm and 30cm as outer and inner diameters were installed to a depth of 10cm. A specially designed water supply with devices to maintain a constant head of water (11cm) in both cylinders was used. Arrangements were made for measuring depth up to the second decimal place.

Soil samples from 15cm and 30cm depths using a jarret auger at different locations on the plot were taken prior to each run. Each experiment was conducted for 130 minutes and the readings were noted at regular intervals. The average values from the locations were recorded and plotted as a function of elapsed time. The results were then analyzed according to Kostiakov (1932) equation to compute the infiltration constant B and exponent, N. The method of averages for least square curve fitting program was used to determine these constants.

Field Evaluation of Advance Wetting Front

The advance wetting front along each border was measured at 1, 2, 3, 4, 10, 15, 25, 30, 35, 40, 45 and 50 metres from the upstream and during each irrigation. Wooden pegs 50cm long were driven into the soil at the different measuring points. The stop watch was used to note the time it took the water to move from the upstream end to these points. The average values were recorded for each plot. Three different stream sizes of 1.5 l/s 2.0 l/s and 4.0 l/s were used.

The Predictive Equation of Fok and Bishop (1965) for Water Advance Front

Fok and Bishop (1965) predictive equation for estimating the water advance wetting front has been derived and applied to a field study under a tropical condition by Akinyemi et al. (1993). Detail of the analysis can be obtained from this paper. The summary of the equation is given as:

$$qT = BTL\,(1 - (Nb/b+1) + (N(N-1)b/2!(b+2)) + (Do/1+b)L \quad \ldots \qquad (1)$$

$$L = (qT/BT\sigma z + Do\sigma_S) \ldots \qquad (2)$$

Where: $\sigma z = [1 - (Nb/b+1) + (N(N-1)b/2!(b+2)) + \ldots.] \quad \ldots \qquad (3)$

and $\sigma s = 1/1+b$

Where q = inflow discharge (l/s)

T = application time (s)

L = advance length (m)

B = water advance exponent

Do = normal depth of flow at point of entry (m)

N = infiltration exponent of Kostiakov (1932)

B = empirical constant of Kostiakov (1932) infiltration equation

σz = surface storage

σs = subsurface storage

The values of the expression were estimated from infiltration functions and a computer program was written to compute the water advance wetting front using equation 2.

RESULTS AND DISCUSSIONS

Figure 1 shows the effect of climatic changes on the rate of water advance wetting front obtained from equation 2. The result shows an increase in advance wetting front as the initial moisture content increases. The marked increase in advance rate with increasing initial moisture content may be attributed to the fact that less energy is required at the wetting front to expand the mensiscus with moist soil. Consequently, there is less energy loss at higher initial moisture content since the flow occurs in larger channel. This results in a more rapid advance, even though the total available head may be less in drier soil. Another reason for this increase in rate of advance may be attributed to storage effect which is higher in moist soils than in drier ones.

The decaying effect of infiltration rate with time to soil air pressure build-up and air entrapment as water infiltrates through the soil may possibly contribute to the increase of water advance front with increase in initial moisture content. These results confirms the observations of Fagmeir and Strelkoff (1979) that infiltration functions are affected by initial moisture content which consequently affect water advance front. Figure 2 shows the effect of slope on advance wetting front computed from equation 2. As expected, the rate of advance of wetting front increases with increase in slope.

Slope generally represents the relative height or potential between two points. Increase in slope represents high potential gravitational force. It is therefore expected that higher slope should produce higher advance rate.

In order to verify the above equation used, computed values from the equation were compared with the observed values and shown in Figure 3. The figure shows a close comparison of the computed and measured values from the field. Similar trends were observed for when stream sizes of 1.5 l/s, 2.0 l/s and 4.0 l/s.

It can be observed therefore that the water advance front vary with climatic changes as a result of the changes that occur in the initial moisture contents. These changes affect the infiltration functions of the infiltration equations used in computing the advance length for surface irrigation designs. This variability shows that more data on the effect of climatic changes on the infiltration process of water into the soil is needed in order to improve the current low water application efficiency associated with surface irrigation.

CONCLUSIONS

Simple equation to predict water advance in border irrigation system has been tested under varying climatic conditions on a tropical Aquic Paledults in South Western Nigeria. Infiltration tests were carried out at eight different initial moisture levels. Results show that water advance front increased with increase in initial moisture content. The implication means that the dimensions of border strips would need to be varied at different periods in the year if an efficient system is to be designed. From this results a knowledge of the water advance wetting front in a border system can serve as guidance for selecting appropriate border sizes for different initial moisture contents.

This equation was tested on one major soil type, namely a tropical Aquic Paledults. There is a need to broaden this study on other soil types (e.g. on Alfisols, Ultisols, Oxisols, etc), and in other agro-ecological environments in the tropics.

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Fagmeier, D.D. and T. Strelkoff (1979). Mathematics models and border

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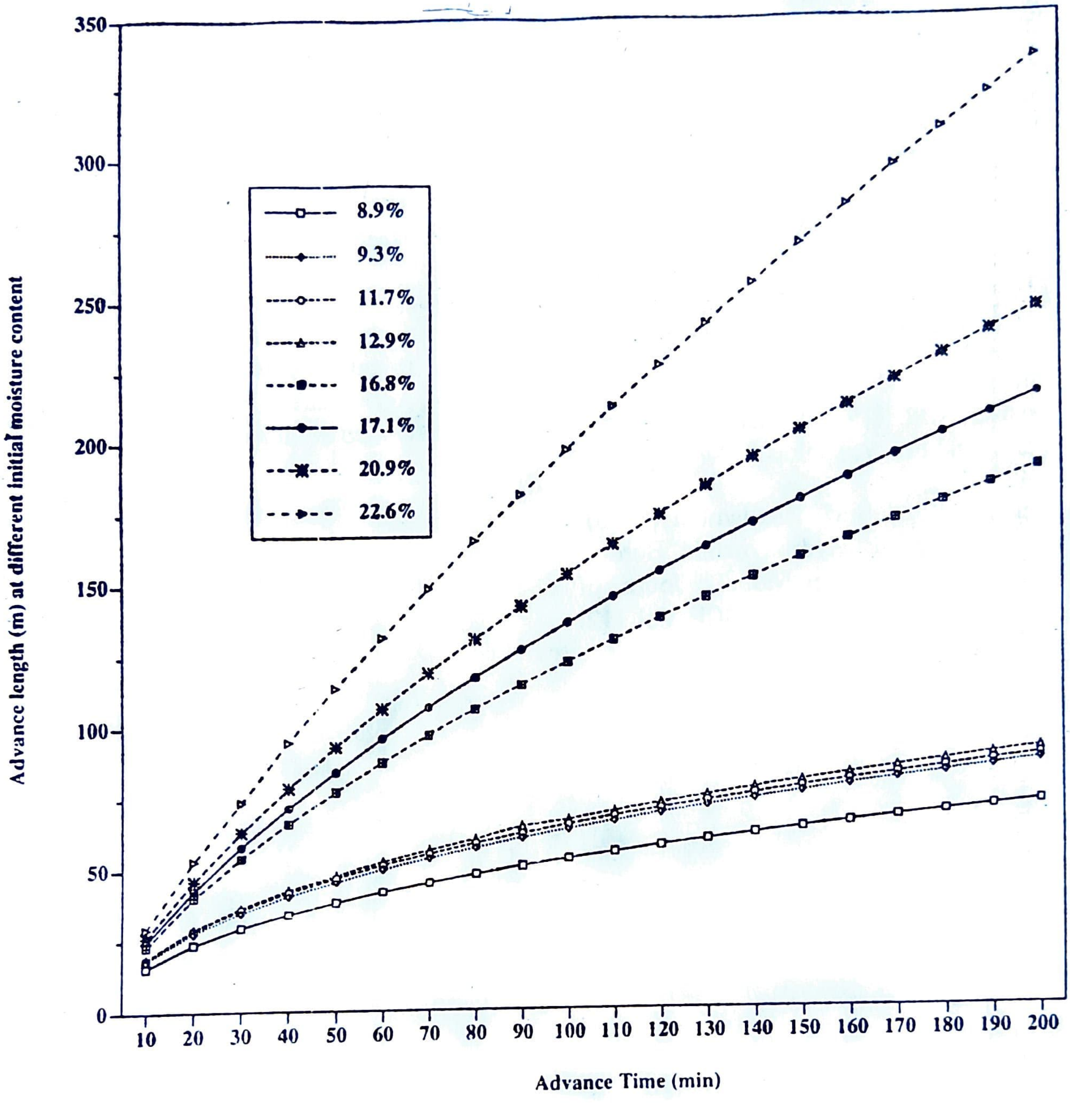

Figure 1: Effects of initial moisture content on the water advance front in border irrigation system using Fok and Bishop (1965) equation.

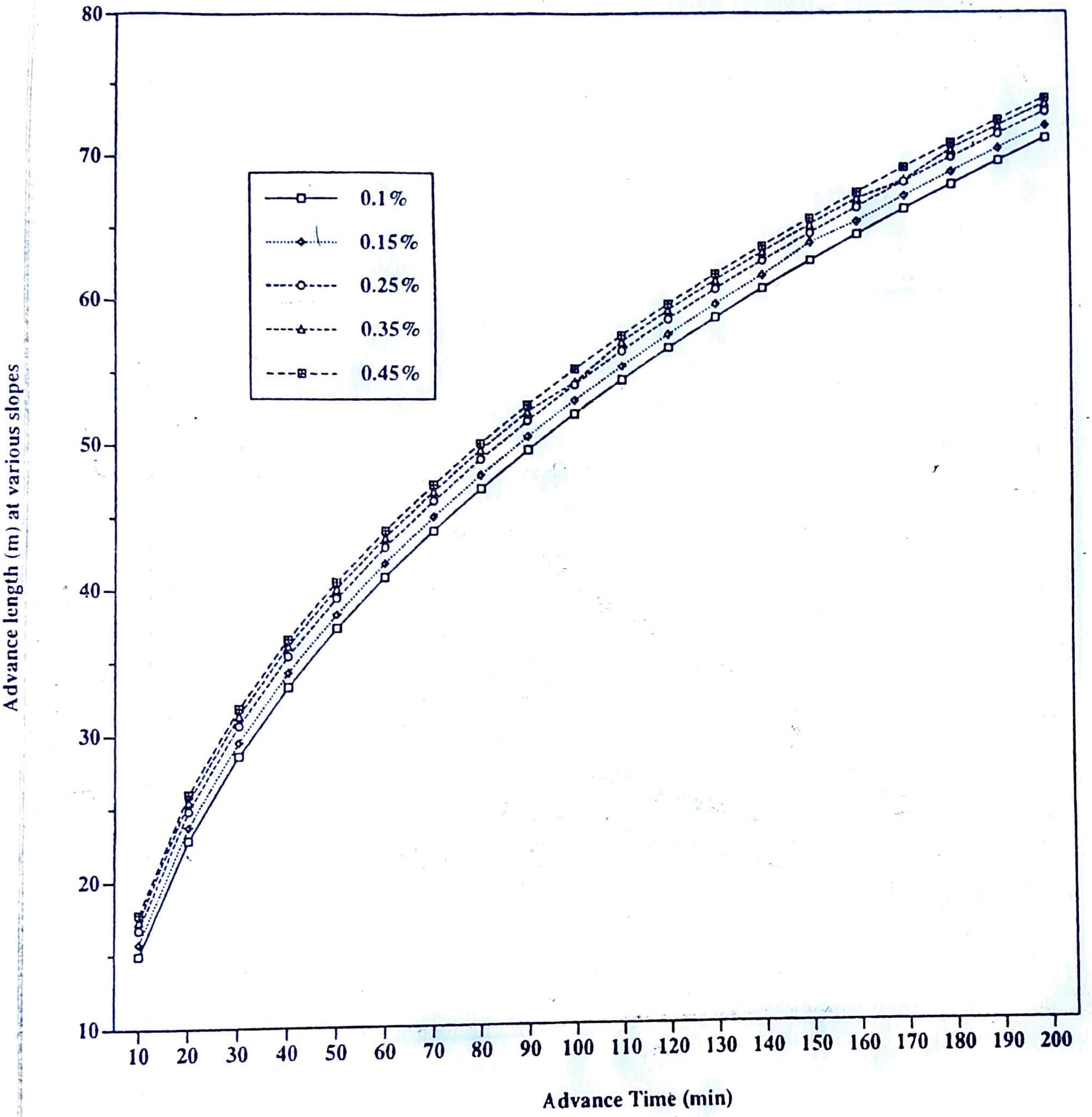

Figure 2: Effects of slope on the water advance wetting front using Fok and Bishop (1965) equation.

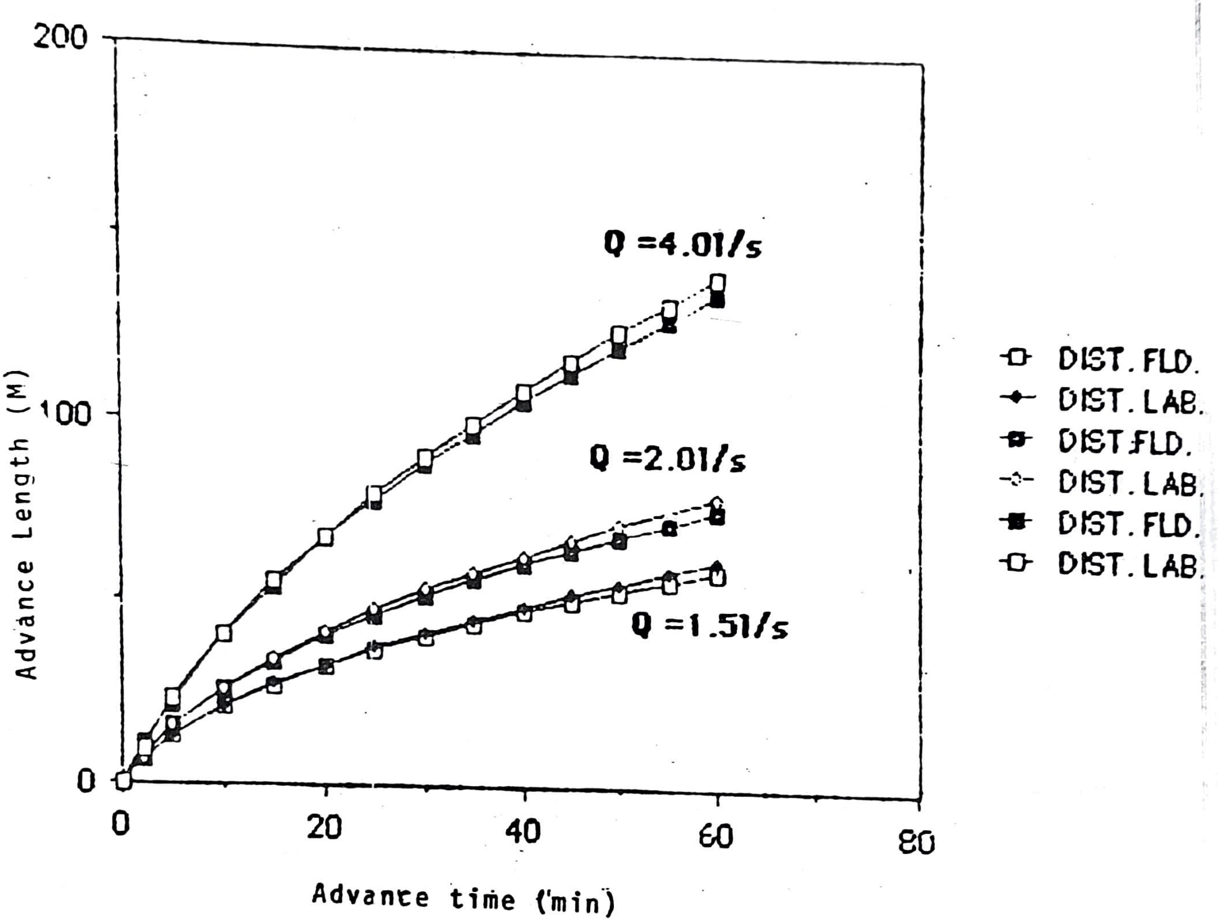

Fig. 3 Effects of discharge rates on advance rates using Fok and Bishop equation.