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GEOMORPHOLOGICAL RESPONSE OF DOWNSTREAM CHANNELS TO DAM CONSTRUCTION IN THE SAVANNA ZONE OF NORTHERN NIGERIA: CASE STUDIES OF KANO AND CHALAWA CHANNELS

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ABSTRACT

An assessment of the downstream geomorphological responses of two channels to dam construction in the savanna zone of northern Nigeria reveals significant changes from predam to postdam conditions. The changes are reflected both in the postdam channels geometrical (i.e. width, depth, cross sectional area and abandoned width) and non-geometrical variables (i.e. silt + clay percentage and mud layer thickness). Reduction in the channels effective sizes, erosion in terms of incision of postdam depths into predam channels and development of lesser and finer deposits in the postdam channels, overbank and floodplain zones are characteristic channel changes identified to be due to dams construction. Development of abandoned tracts of land that gradually evolve into farmlands and areas of vegetation colonization are the observed consequences of the changes.

KEYWORDS: Downstream, Predam, Postdam, Channel Geometry.

INTRODUCTION

With a total number of more than 60 completed multipurpose dams and more than equal number of different forms of barrages, mainly for irrigation and water supply, Nigeria has the highest concentration of dams in the West African sub-region. Dams have gradually become popular in Nigeria as they have found relevance in the development of the people, mainly in respect of irrigation, water supply, livestock farming and hydroelectric power generation. Most of the dams however (about seventy percent of them), are located in the northern parts of the country. The concentration of dams in the north results from the need to supply adequate water to the major towns, and more importantly, the dependence of its agriculture on irrigation due to inadequate rainfall. Of the 70 000 Ha under formal irrigation in Nigeria, only about 4 400 Ha, i.e. about 6%, is in the south (Fatokun and Ogunlana, 1992).

The impacts of dam construction can be socio-economical and environmental (Ayoade, 1988; NEST, 1991; Martins and Olofin, 1992; Ackerman et al, 1973) and can both be positive and negative (Ruhe, 1975; Matlock, 1985; Adams, 1986). A mode of impact however, is the development of new landforms and landforms assemblages (geomorphology) in the upstream and particularly downstream channels and environments. Climates, naturally, by affecting geomorphological processes, have a controlling influence on the development of unique assemblages of landforms, even taking precedence over all other ones (Peltier, 1962; Tricart, 1972; Faniran and Jeje, 1983). The focus of this study therefore, is the assessment of the downstream channel geomorphological impacts of dams in the savanna of northern Nigeria using two channels, Kano and Chalawa (on which Tiga dam and Chalawa gorge are located respectively), as case studies.

The locations of the channels of study generally fall within the sudan savanna climatic region (Udo, 1978) which generally lies between latitudes 8^0N and 13^0N in northern Nigeria. The locations are towards the northern extremes of the sudan savanna and therefore are in close proximity to the sahel climate (Fig.1). The areas of study fall within the Kopen's Aw savanna and Gate (1972) tropical savanna climate (Ayoade, 1983), the Budyko (1956) steppe climate (Faniran and Ojo, 1980) and the Iloeje (1976) tropical continental north climatic region. The sudan savanna in Nigeria generally has an annual rainfall of between 500 mm and 1000 mm with single peak regime in August and between four and eight dry months. The mean monthly rainfall, relative humidity at noon and maximum temperature at Kano, which is about 45km south and southwest of Tiga dam and Chalawa gorge respectively, are presented in Table 1. The natural vegetation of the savanna in which the channels of study are located consists of grasses and scattered chumps of trees.

The Kano and Chalawa channels contain the flow of two of the headwaters of Hadeija river (Fig.1). Located on the Kano and Chalawa channels are the Tiga dam and Chalawa gorge respectively. The Tiga dam was commissioned in 1974 and has a total capacity of 1 968 x 10^6 m^3, reservoir surface area of 178 km^2 and a catchment area of 6 641 km^2.The Chalawa gorge was commissioned in 1992 after a period of partial operation. It has a total capacity of 969 x 106 m^3, reservoir surface area of 101.71 km^2 and a catchment area of 3 859 km^2. The hydrological influence of the dams especially in terms of upstream and downstream discharges have been reported in Martins and Olofin (1992) and Olofin and Martins (1993).

Table 1: Some climatic indices at Kano, close to the channels studied (after Udo, 1970)

Climatic Indices	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Relative Humidity at noon (%)	2	16	10	17	29	41	55	68	63	41	16	17
Average Rainfall (mm)	0	0	2.5	10.2	63.5	111.8	203.2	315.0	127.0	12.7	0	0
Average Daily Maximum Temperature (^OF)	85.6	89.9	95.7	100.8	99.3	94.5	87.2	85.1	88.0	93.5	92.5	87.1

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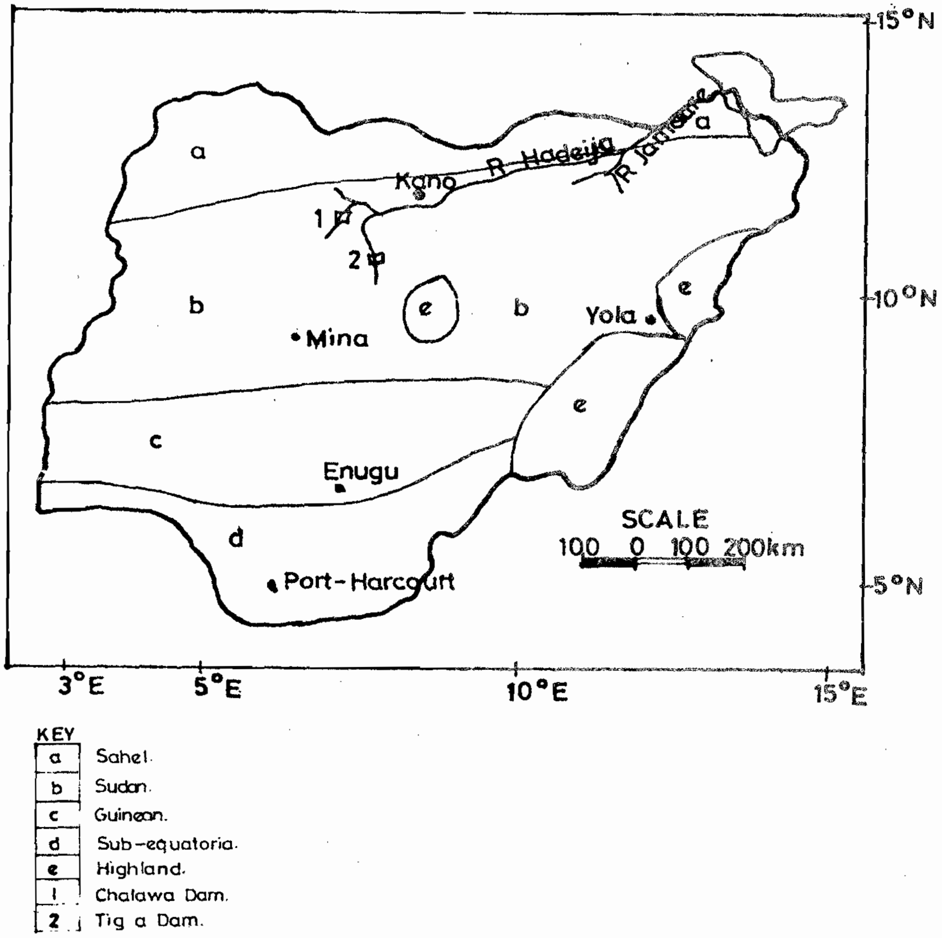


Fig. 1: Map showing the climatic regions of Nigeria (Udo, 1978) and channels of study.

MATERIALS AND METHODS

In carrying out this study, a predam and postdam approach is followed in order to isolate the effects of the operations of the two dams of interest on downstream geomorphology. The 60 km and 40km reaches of Kano and Chalawa channels respectively, between the respective dams located on the channels and the Kano-Chalawa confluence, constitute the areas under study.

Two broad variables were observed and analysed: the channels geometrical and non-geometrical variables. The channels geometrical variables include the width, depth and cross-sectional areas of the channels, while the non-geometrical variables include the abandoned width of the channels, percentages of silt and clay and the layers of mud thickness. The variables are presented in terms of mean, standard deviation and coefficient of variation in order to provide broad and representative picture of the characteristics of the variables in the channels of study. Insight into the nature and implications of the resulting geomorphological changes in northern Nigeria, particularly in the sudan savanna climatic region as a result of dam construction, are provided by the presentation of the cross sections of Kano and Chalawa predam and postdam channels due to full dam operations in Kano channels and partial dam operations in Chalawa channels. These are enhanced by the study of the earial photographs of Kano-Chalawa confluence predam in 1963 and postdam in 1978.

CHARACTERISTIC STORM CHANNELS

The locations of study are typified by storm channels with seasonal discharges designed to evacuate the flash floods of the wet seasons. Hence, their cross sectional areas are large (Fig. 2), ebb and related to the mean wet season flood flow (i.e. mean maximum wet season discharge) rather than the wet season overall mean discharge as should be expected in the more humid climatic zones in southern Nigeria. For example, the Kano and Chalawa channels had respective predam cross sectional areas of 482m^2 and 537m^2 with mean annual discharge of only 37 and 22 cumecs , whereas the wet season mean flood flows for the two rivers were 383 and 260 cumecs respectively. The relationship between the channels sizes and stream discharges dictate the geomorphological responses of the channels to dam construction.

IMPACTS ON CHANNEL GEOMETRY

The impacts of dam construction on channel geometry downstream are generally incision and reduction in the effective sizes of channels (Imevbore, 1975). Where the channels under study are located, the incision and reduction of the effective sizes are pronounced because the channel sizes are related to the regulated postdam wet season mean discharge which is usually less than the predam mean wet season flood flow on which predam channel sizes depend. The difference accounts for the reduction in the effective channel sizes. The regulated and persistent discharge over a postdam reduced channel size, accounts for the incision. Postdam discharge can be so significantly affected that a seasonal stream can become perennial (Martins and Olofin, 1992). The geometrical responses of Kano and Chalawa (effective) channels to regulation are presented in Table 2.

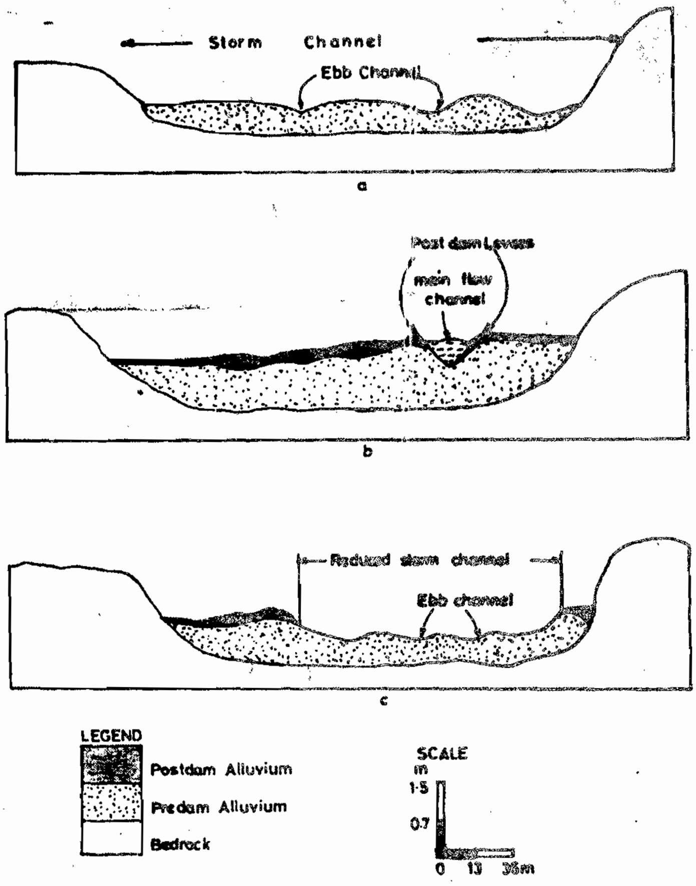


Fig. 2: Cross-sections sketches of characteristics storm channels in the dry season
(a) predam (b) postdam with full control e.g. Kano channel (c) postdam with partial control e.g. Chalawa channel

Table 2: Responses of Kano and Chalawa channels to dam construction

Channel Variables	Kano Channel						Chalawa Channel					
	Predam			Postdam			Predam			Postdam		
	Mean	S.d	C.V %	Mean	S.d	C.V%	Mean	S.d	C.V %	Mean	S.d	C.V %
Width (m)	249.0	80.2	32.2	33.7	8.4	24.8	251.0	52.9	21.0	183.0	20.8	11.4
*Depth (m)	2.01	0.32	15.9	+1.44	0.31	21.5	2.2	0.32	14.5	+1.15	0.08	7.0
Cross Sectional Area (m)	482.3	129.8	26.9	46.4	8.6	18.4	537.2	61.3	11.4	208.9	11.1	5.3
Abandoned Width (m)				216.3	74.2	36.0				68.4	34.7	50.8
Silt + Clay %												
Mud Layer (cm)	5.4	1.9	36.1	42.4	5.2	12.1	11.4	1.0	8.9	46.9	3.0	50.8
	3.4	0.45	13.2	19.2	13.8	71.7	1.5	0.54	36.0	7.3	1.5	20.6

* Postdam depth is incised into predam storm channel bed.
S.d: Standard deviation
C.V: Coefficient of variation

Channel incision takes the form of postdam depth cutting into the predam storm channel bed (Fig.2). Where the discharge is regulated to the extent that it varies little from the dry season flow, as in Kano channel (Fig.3), the channel stabilizes and remains fixed (Fig. 2 and 4). Where the wet season flow is unregulated and there is no dry season flow, as in Chalawa channel (Fig. 3), the secondary channel becomes more like the predam storm channel (Fig. 2 and 4).

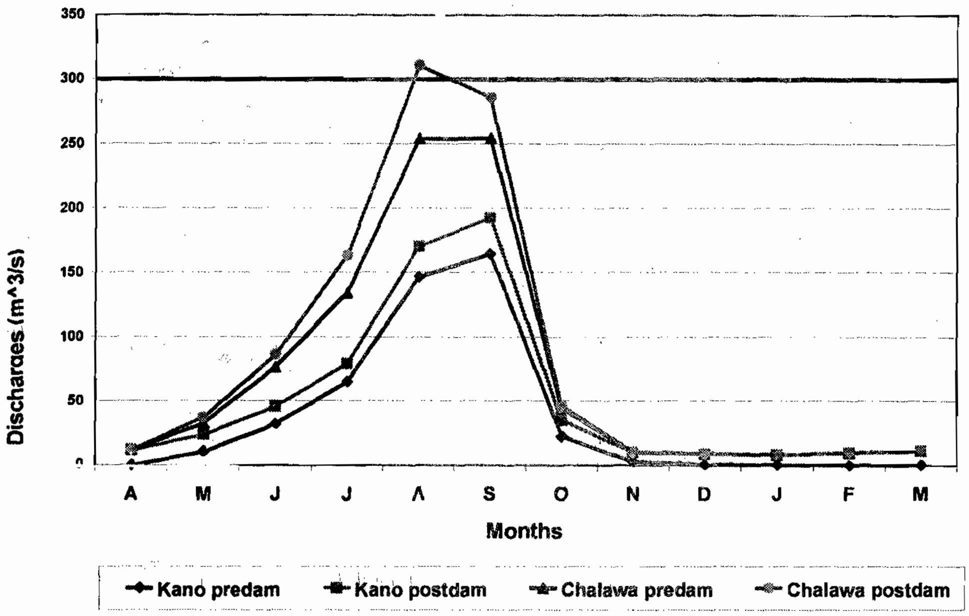
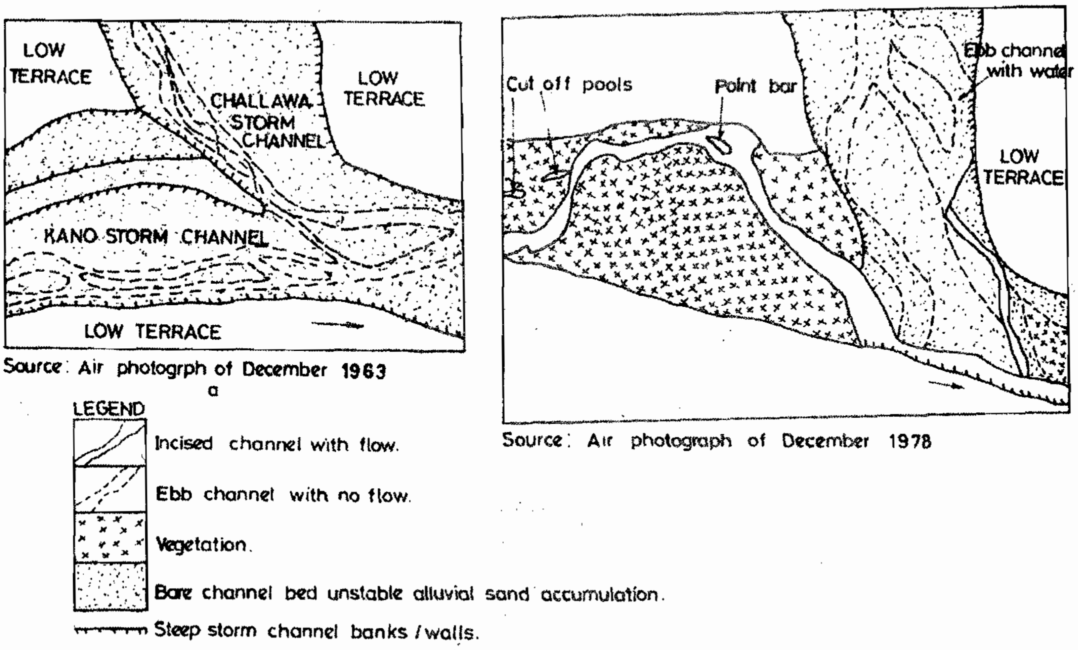


Fig. 3: Channels pre- and postdam mean monthly discharges (Predam, 1965-70; Postdam, 1974-80)



Source: Air photogrph of December 1963
a

Source: Air photograph of December 1978

Fig. 4: Channel characteristics at Kano-Chalawa confluence due to full and partial control; (a) predam (b) postdam

IMPACTS ON NON-GEOMETRICAL CHANNEL VARIABLES

The observed pre- and postdam non-geometrical variables differ greatly. The bed materials in the downstream reaches are usually eroded during the initial channel incision. Apparently, as a result of entrapment of river load in the reservoirs, the postdam bed and suspended sediment load are much reduced and finer, resulting in less and finer deposits in the channel, overbank and floodplain zones (Fig.2). Olofin (1984) has shown that in the River Kano case, the predam suspended load correlates strongly in particle size distribution with postdam mud deposits, while the postdam suspended load was about one sixth that of the predam concentration. Results of the observations made on the abandoned width, silt and clay percentages of sediments, and the mud layer thickness in the channel and overbank zones of Kano and Chalawa channels are part of Table 2.The postdam sediment has a mean silt+clay fraction of between forty and fifty percent as contrasted to that of the predam mean of between five and eleven percent (Table 2). The postdam mud layer thickness is also higher than in the predam's situation; a mean of 7.3 cm as against 1.5 cm in Kano channel and a mean of 19.2 cm as against 3.4 cm in Chalawa channel.

IMPLICATIONS OF GEOMORPHOLOGICAL CHANGES

The implications of the considered downstream geometrical and non-geometrical channel changes in the savanna on northern Nigeria can be significant. The significant reduction in the cross- sectional channel dimensions, with the corresponding increase in the abandoned width and stabilization of the postdam deeply incised channel within the predam channel, lead to the occurrence of tracts of abandoned lands within the predam storm channel which gradually evolve into farmlands and areas of vegetation colonization. In the 60 km reach of Kano channel, between Tiga dam and Kano-Chalawa confluence, more than 1 200 Ha of new farmland evolved on parts of the predam storm channel (Fig. 4).Another 500 Ha of the low terrace, usually flooded in the predam period has escaped annual floods. Similarly in the Chalawa channel, 270 Ha in 40km reach of the channel has been abandoned in addition to the previously flooded low terrace parcels of about 200 Ha. In Jakara river basin also in northern Nigeria, Nichol (1987) estimated a total of 65 ha of land no longer flooded downstream of Jakara dam while Adams (1985) has reported that 77 Ha of the previously flooded land around Birmin Tudu village in northern Nigeria was no longer flooded after the establishment of Bakolori dam.

The overall effect is that the predam wide, unstable alluvial storm channel which is bedload depositing, will change into a postdam narrow and stable channel with a true floodplain where an optimum and regulated perennial discharge is maintained, like in Kano channel (Fig 2). Otherwise, the postdam channel, though narrower, will be unstable, like in Chalawa channel (Fig. 2).

CONCLUSION

The construction of dams have significant downstream channel geomorphological impacts in the savanna of northern Nigeria. This is revealed by Kano and Chalawa channels downstream of Tiga and Chalawa gorge respectively. The different characteristics of the pre-and postdam channel conditions are in response to rainfall and the resultant channel discharges. What is decisive is the postdam wet season mean discharge which is usually less than the predam mean wet season flood flow on which the predam channel conditions depend.

Channel erosion in terms of incision of postdam depth into the predam storm channel, reduction in the effective channel sizes and stabilization in the case of full dam control, or mitigation of these effects in partial dam control, are characteristic. The postdam deposits are much reduced and finer in the channels, overbank and floodplain zones. The consequence of the predam changes is the occurrence of abandoned tracts of land which gradually evolve into areas of vegetation colonization.

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