Chapter Two

THE STUDY DESIGN AND STUDY AREA

Study Design, Variables Measured, and Methods Used

Malaria control strategies

From April 1972 to October 1973, villages in 3 concentric areas were treated with one of 3 control strategies, as follows:

1. Residual indoor spraying with the carbamate insecticide, propoxur, for three or four rounds, at intervals of 2 months, before and during each of 2 main transmission seasons (1972, 1973) was applied in the largest area (B-see Fig. 1). The operation aimed at total coverage of buildings. Propoxur [b] was selected as being probably the most effective insecticide available, and because it had not been tried on a large scale in Africa. On account of its fumigant effect it was expected to have an impact also on exophilic vectors. A small-scale preliminary insecticide tria1 was conducted to test the operational methods, to select the appropriate frequency of spraying, and to obtain preliminary entomological evaluation (103).

2. Propoxur, as above, plus mass drug administration (MDA) of sulfalene-pyrimethamine at low frequency (every 10 weeks) was applied in area A2 (see Fig. 1). The drug distribution aimed at total coverage of the ***de facto*** population of the villages, excepting infants between birth and their first detected parasitaemia. These infants were used as indicators of residual transmission; they were examined more frequently than the rest of the population. The sulfalene-pyrimethamine combination was selected as being probably more acceptable to the recipient population on a usually empty stomach (food was rarely available in houses at the time

a The study was designed mainly by Dr A. Rossi-Espagnet, Dr G. Gramiccia, Dr L. Molineaux, Dr K. Dietz and Mr S. Brogger, in consultation with many WHO staff members and consultants, listed in Annex 1.

b 2-(1-methylethoxy)phenyl methylcarbamare (also described as: 2-' isopropoxyphenyl N-methylcarbamate).

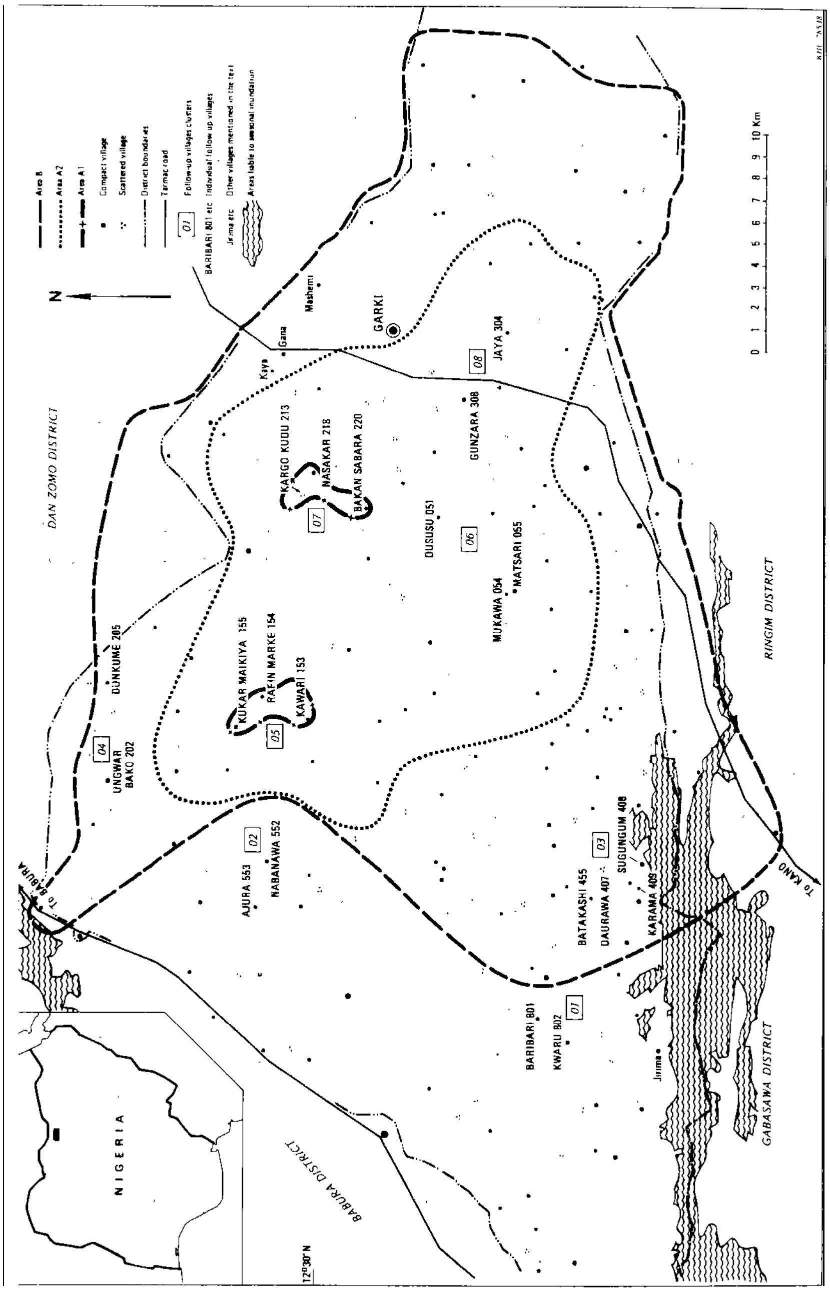

Fig. 1. The Garki project study area, showing the follow-up villages and the treatment areas

of MDA) than the standard chloroquine-pyrimethamine. A preliminary drug trial was conducted, to compare the two drug combinations in terms of clearance of ***P. falciparum*** trophozoites from the peripheral blood and of immediate side-effects; it was found that there was no significant difference in effectiveness, and that vomiting was less common after sulfalene-pyrimethamine, although the difference was not statistically significant (150). The selection of a long-acting sulfonamide (sulfalene) was made after careful consideration that took into account the limitation of the project in time, space and population affected. Two frequencies of MDA were found to be feasible on the scale envisaged, namely, either every 10 or every 5 weeks. Since computer simulations, using a preliminary version of the transmission model, indicated no great difference between the outcome from either period as long as the vectorial capacity remained well above its critical level (which was expected to be the case even after spraying with propoxur) the MDA was given at 10-week intervals.

3. Propoxur, as above, plus mass administration of sulfalene-pyrimethamine at high frequency, i.e., every 2 weeks in the wet seasons of 1972 and 1973, every 10 weeks in the intervening dry season, plus a limited amount of larviciding with temephos during the transition from the wet to the dry season in 1972 and 1973. This strategy was applied in area A1 (see Fig. 1). MDA aimed at total coverage, excepting negative infants. Temephos[a] was selected as being probably the most effective larvicide. The objective of this third, most intensive, control strategy was to reduce transmission and antigenic stimulation to the lowest feasible level, in particular for the purpose of the seroimmunological study (see p. 32). For operational reasons, this strategy could be applied only on a small scale.

While the above strategies were applied in areas B, A2 and A1, some untreated villages (area C) were studied for comparison. The project was planned as a time-limited research activity (see p. 19). After the 18-month intervention period, the following measures were taken to protect the study population against the consequences of possible malaria epidemics: in the villages treated with the third, most intensive strategy, those aged less than 10 years received 4 rounds of chloroquine, at intervals of 5 weeks, during the main transmission season of 1974; in addition in 1974 and 1975 in all villages previously treated by MDA, i.e., by the second and third strategies, chloroquine treatment was made available in each village to persons reporting with fever.

Further details regarding the control operations and the coverage actually achieved are given in Chapter 3.

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[a] Tetramethyl-thiodi-p-phenylene phosphorothioate (commercial name ABATE),

Table 1

Villages included in the follow-up clusters, showing numbers of compounds, population, types and periods of observation

Area	Antimalarial measures	Village cluster No.	Village	No. of compounds (initial survey): Compact Part	No. of compounds (initial survey): Scattered Part	Population registered (survey 5)	Types of observation[a]: Meteorology: Prec.	Meteorology: Temp'RH	Entomology: PSC	Entomology: NBC'ETC	Entomology: ORC	Human population: DP	Human population: Imm., Hb., Clin.	Period of observation
C	None	1	802 Kwaru	32	1	204	+	-	+	+	-	+	-	1970-73
			801 Baribari	27	1	179	-	-	+	-	-	+	-	
			806 Tafin Sale	0	47	330	-	-	-	-	-	+	-	
		2	553 Ajura	46	35	448	+	-	+[b]	+[b]	+	+	+	1970-76
			552 Nabanawa	89	5	700	-	-	-	-	-	+	+	
B	Propoxur in 1972-73	3	408 Sugungum	78	0	543	+	+	+	+	+	+	-	1970-73
			409 Karama	35	0	226	-	-	-	-	-	+	-	
			455 Batakashi	30	0	222	-	-	-	-	-	+	-	
			407 Daurawa[c]	13	17	182	-	-	-	-	-	+	-	
		4	202 Ungwar Bako	108	2	656	+	+	+	+	+	+	-	
			205 Dunkume[c]	85	0	481	-	-	-	-	-	+	-	
A2	(1) Propoxur + MDA (sulfalene-pyrimethamine) every 10 weeks in 1972-73.	6	55 Matsari	63	1	375	+	+	+	+	-	+	-	1970-73
			54 Mukawa	17	0	72	-	-	+	-	-	+	-	
			51 Dususu[c]	27	0	179	-	-	-	-	-	+	-	
	(2) Chloroquine to self-reporting fever cases in 1974-75.	8	304 Jaya	78	20	565	+	-	+[b]	+[b]	-	+	-	
			308 Gunzara[c]	21	18	251	-	-	-	-	-	+	-	

Area	Antimalarial measures	Village cluster No.	Village	No. of compounds (initial survey)		Population registered (survey 5)	Types of observation[a]							Period of observation
							Meteorology		Entomology			Human population		
				Compact Part	Scattered Part		Prec.	Temp. RH	PSC	NBC, ETC	ORC	DP	Imm., Hb., Clin.	
A I	(1) Propoxur + MDA (sulfalene-pyrimethamine)	5	154 Rafin Marke 155 Kukar	49	0	317	+	–	+	+	–	+	+	1970-76
	wet season, every / every 2 weeks in 10 in dry, in 1972-73.		153 Kawari[c] a	43 / 61	23 / 0	236 / 429	–	–	–	–	–	+	+	
	(2) Chloroquine below 10 years of age every 5 weeks, in wet season in 1974.	7	218 Nasakar	72[d]	0	367	+	+	+	+	–	+	+	
			213 Kargo Kudu	0	53	297	–	–	+	–	–	+	+	
	(3) Chloroquine to self-reporting fever cases in 1974-75.		220 Bakan Sabara[c]	28	0	164	–	–	–	–	–	+	+	

a Prec. = precipitation; Temp. = temperature; RH = relative humidity; PSC = pyrethrum spray collection; NBC = night bite collection; ETC = exit-trap collection; ORC = outdoor-resting collection; DP = demographic-parasitological surveys; Imm., Hb, Clin. = seroimmunological haemoglobin and clinical surveys.

b NBC and ETC limited to the compact part; PSC divided between the compact and scattered parts.

c Village added at survey 5.

d Including 33 new compounds built between surveys 3 and 4.

Project phases and calendar

There were four successive phases, as follows:

(a) Preparatory phase: September 1969 to September 1970: preliminary entomological and parasitological surveys; selection of study area and of the clusters of villages to be followed; drafting of study design, protocols, forms and operation manuals; testing of field and laboratory methods, including a preliminary parasitological trial comparing four methods of examining blood-films (149).

(b) Baseline phase: October 1970 to March 1972 (i.e., a dry season, a wet season, and a second dry season): collection of baseline data in the clusters of villages selected for follow-up; implementation of the preliminary insecticide and drug trials.

(c) Intervention phase: April 1972 to October 1973 (i.e., a wet season, a dry season, and a second wet season): application of the intervention strategies; continuation of the epidemiological study in both treated and untreated clusters of villages selected for follow-up. The duration of the intervention phase was not fixed *a priori,* but was left open between two and three consecutive main transmission seasons. In February 1972, an internal review of the results concluded that the additional information likely to be gained from a third year of intervention did not justify the expense and the expected additional loss of population immunity.

(d) Post-intervention phase: November 1973 to the termination of the project in February 1976: selective active and passive drug administration in the villages covered by MDA during the intervention phase; continuation of the epidemiological study in the villages treated with the most intensive strategy and in one cluster of untreated control villages; these were also the villages selected for seroimmunological follow-up.

Villages selected for follow-up and villages treated by the various strategies

In each of the 3 areas covered by the different control strategies (Fig. 1), 2 clusters of villages were selected for follow-up determinations. For each of these villages data are presented for the grouping of their domestic compounds (compact or scattered) and their number and population, the types of observations made, the period of observation, and the treatment applied (Table 1). The numbers of villages and their population, and the approximate area included, were highest in area B and lowest in area A1 (Table 2). The selection of villages for follow-up, their allocation to the various treatments, and the resulting subdivision of the study area were determined by a combination of principles and con-

Table 2

Numbers of villages, population and surface, in the areas treated by the 3 different control strategies

Area	Treatment	Number of villages	Population	Surface km²
B	Propoxur alone	104	32 828	550
A2	Propoxur + low-frequency MDA	54	14 129	350
A1	Propoxur + high-frequency MDA	6	1 810	12

straints. Given the available estimate of the age-structure, birth rate and expected attrition rate of the population and the expected changes in prevalence and incidence, it was considered desirable, from a statistical point of view, to follow an initial population of 2000 persons in each treatment group, or a total of 8000 persons for 3 treatments plus an untreated control group. This was also the maximum number that could be covered by parasitological survey 5 times a year. The collection of vectors from night bait was another limiting factor since it could be conducted at the required frequency (every 2 weeks in the wet season) in only 8 villages at the most and had to be limited to their compact part to allow satisfactory supervision; 8 is also the smallest number which allows independent study of 2 villages in each of the 4 treatment groups. Therefore, 8 clusters, of 2-4 villages each, including approximately 1000 persons per cluster, were selected for follow-up. They were selected throughout the district, in order to include as many as possible of the differences in intensity of transmission; they were also selected at least 5 km apart to permit, after stratification (see below), allocation of adjacent clusters to different treatments, taking into account the limited flight range of the majority of ***A.*** gambiae, ***A.*** arabiensis and ***A.*** *funestus.* The 3 largest villages-Garki, Gwarzo, Kargo, which were also the only villages with either a dispensary or a school- were excluded. The densities of these 3 vector species (i.e., ***A.*** *gambiae* sensu lato and ***A.*** *funestus)* were estimated during the preparatory and baseline phases as indicators of the intensity of transmission, to rank the selected follow-up village clusters. One of the 4 highest and 1 of the 4 lowest were allocated to each treatment. It was desirable to allocate contiguous areas to the same treatment, and also to reduce the effect of migrations by having similarly treated buffer zones around the evaluation villages. This led to the subdivision of the study area shown in Fig. 1 and documented in Table 2. It should be noted that the third, most intensive strategy was applied only to the 2 village clusters actually followed up. Given the available resources, the seroimmunological follow-up could caver about 3000 persons twice per year and was limited to the 2 village clusters receiving the most intensive treatment (No. 5 and 7) and to 1 untreated comparison village cluster (No. 2). These were also the villages in which the epidemiological study was continued in 1974-1975 (see p. 28).

At survey 5, 1 village was added to each of the follow-up clusters No. 3-8, in order to bring the size of the study population closer to the target of 1000 per cluster (see Table 1).

Variables measured, frequency of measurement, and methods used

The collection of data was multidisciplinary and longitudinal; i.e., it was designed in a way that would allow the study of the relationship between different variables in time or space, and make it possible to follow the history either of individual persons or of any group of persons. In each village selected for a given type of observation (Table l), the following variables were measured:

Meteorology

Precipitation was continuously recorded by a standard automatic pluviograph (Casella); temperature and relative humidity were continuously recorded by a standard automatic thermohygrograph (Casella), placed in a standard Stevenson screen. The thermograph was regularly calibrated with the help of a mercury thermometer also placed in the screen. Additional meteorological measurements made during the nightly bite collections (temperature, relative humidity, wind velocity) have not been used in the present publication.

Entomology

The methods used were those described in the *Manualon Practical Entomology in Malaria (176),* except as specified otherwise. The frequencies of collection were as follows:

Night-bite collection (NBC). In 1970-1973, taken every 2 weeks in the wet season, every 5 weeks in the dry season; in 19741975, in the wet season only, every 2 weeks in the 2 village-clusters previously treated (No. 5 and 7), twice in the season in the untreated control village cluster (No. 2); finally in 1975, in cluster No. 2, weekly for 14 weeks duringthe transition from dry to wet season. Each NBC was performed in 2 indoor and 2 outdoor fixed stations, with 2 human bait-collectors throughout the night in each station, i.e., for a total of 8 man-nights. Sixteen bait-collectors were employed in each NBC; at the start of each collection they were assigned by lottery to the first or second half of the night and to the various stations; at the end of each hour, each collector's catch was stored in a refrigerated bag, and the 4 pairs of collectors were rotated between stations in a systematic way.

Stations for NBC were selected in consultation with the village headman, taking into account the expected cooperation of the occupants; the 2 stations were selected in different parts of the village, but less than 10 minutes apart on foot, for reasons of supervision. Anophelines were identified, counted, dissected for Christophers' stages (176); those found in stages 1-IIM were examined for signs of prior oviposition by the method of Detinova (42); those found parous and those found in stages IIL-V were dissected for sporozoites. Either all anophelines were dissected or a representative sample with respect to hour and place (indoors, outdoors) of capture.

Pyrethrum spray collection (PSC). In 1970-1973, taken every 2 weeks, on the morning following NBC when applicable; in 1974-1975, in the wet season only, every 2 weeks in clusters No. 5 and 7, and every 4 weeks in cluster No. 2; finally in 1975, in cluster No. 2, weekly for 12 weeks during the transition from dry to wet season. Fixed PSC capture stations were selected as follows. The huts of 1 or 2 villages per village cluster (Table 1) were grouped in clusters of 2-4 huts, being whole compounds or sections of large compounds. The hut clusters were numbered in topographical sequence, and a systematic sample of 4 clusters, with a random starting-point, was drawn, so that the 4 selected clusters were dispersed within the village(s), e.g., out of 40 clusters, one would take every tenth cluster, starting with one chosen at random among the first 10. Anophelines were identified and counted, females were classified by stages of abdominal appearance, and, when feasible, dissected for sporozoites. Two further examinations were made at selected times, namely, the identification of bloodmeals by the precipitin test and the chromosomal identification of species of the *A. gambiae* complex.

E'xit-trap collection (ETC). Taken on the same night as the NBC in 3 (later 5) fixed huts. ETC stations were selected according to the same principles as the NBC stations. Traps were installed before sunset, emptied after sunrise, later also between 20h30 and 21hO0. The anophelines were identified and counted, the females being classified by stages of abdominal appearance.

Outdoor-resting collection (ORC). Taken in 1970-1973 only, on the same day as the PSC, in 3 villages only, in fixed artificial shelters (buried drums) within compounds and outside. The anophelines were identified and counted, the females being classified by stages of abdominal appearance. Bloodmeals were identified by the precipitin test.

The entomological observations listed above were made under the following conditions:

(a) the huts used for NBC, PSC, ETC were regularly inhabited; on the night of the NBC they were vacated by their normal inhabitants and occupied by the bait-collectors.

(b) no hut was used for more than one sampling method (NBC, PSC, ETC).

(c) very infrequently one hut had to be replaced by another resembling it as closely as possible.

(d) during the intervention period, the huts used as entomological catching stations were sprayed like any other hut, the spraymen ignoring which huts were used as catching stations.

Cytogenetic studies of the A. gambiae complex were also conducted in the study area during the same period. The methods and results are reported elsewhere (31, 145); selected results will be presented and discussed in Chapter 4.

Demographic-parasitological (DP) surveys

The surveys covered, in principle, the total ***de facto*** population of selected village clusters, every 10 weeks in 1970-1973; in 1974-1975 some intervals were longer (see Fig. 43) and only 3 village clusters were followed (see Table 1). Age was estimated at registration; births, deaths, arrivals and departures were recorded; ages were updated by computer; a person absent for 4 consecutive surveys was reclassified as having emigrated. At each survey, a thick blood film was collected and examined for 200 microscopic fields; in 1970-1973 a systematic sample of a fifth of the films was examined for 400 fields. The number of fields found positive for ***P. falciparum*** asexual forms, ***P.f.*** gametocytes, ***P. malariae*** and ***P. ovale,*** respectively, was recorded.

In addition to the demographic-parasitological surveys, local residents were employed as itinerant collectors of data on births, deaths and migration. Also, in addition to the regular DP surveys, the infants excluded from mass drug administration underwent a supplementary parasitological examination in each interval between successive DP surveys; they were thus examined every 5 weeks. In 1974-1975, in the villages previously receiving MDA at high frequency, infants were examined, if present, every 5 weeks in the dry season, every 2 weeks in the wet season, as long as they were negative.

Seroimmunological surveys and haemoglobin-typing

The seroimmunological surveys covered the population of the villages selected and were carried out twice a year in conjunction with the DP surveys, once in the dry season and once in the wet season (Fig. 43). Blood was collected from a fingerprick into 1 or 2 heparinized Caraway tubes and on to 1 or 2 filter papers. The following examinations werè performed in Kano on plasma from the heparinized tubes: quantitative immunoglobulin determinations by single radial diffusion for IgG and IgM (101); indirect fluorescent antibody tests (IFA) using an IgG conjugate and *P. falciparum* and *P. malariae*, later *P. brasilianum* antigens (157): Ouchterlony agar gel diffusion analysis for antibodies to *P. falciparum* antigens prepared from human placentae (110). The passive haemagglutination test was performed in the Center for Disease Control, Atlanta, GA, USA, with the eluates from the filter paper samples for antibodies to *P. falciparum* or *P. knowlesi,* the latter for the first serological survey only (102, 139).

The above tests were performed regularly at each seroimmunological survey. In addition, the ELISA test, with a *P. falciparum* antigen, and also with various viral antigens, was performed in London on a sample of the sera from Garki (158, 159). The ELISA tests were performed at a later date and will be reported separately.

The red blood cells from the persons included in the seroimmunological surveys were sent to the Department of Haematology, University of Zaria, to determine the haemoglobin phenotypes by paper electrophoresis (91).

Body temperature surveys

The population covered by the seroimmunological surveys (comparison village cluster No. 2, plus clusters No. 5 and 7 in A1) was surveyed 3 times by axillary thermometry, in the middle of the wet seasons of 1973, 1974 and 1975, i.e., during the second wet season of intervention and 1 and 2 years later. The temperature surveys coincided with the 15th, 19th and 22nd demographic-parasitological surveys (see Fig. 43).

An thropometric and spleen surveys

The above population was submitted to these surveys shortly after the wet seasons of 1973, 1974 and 1975. The following examinations were performed: height, weight, head, chest and arm circumferences, triceps skinfold (86) and spleen size. The head and chest circumferences were measured only in infants and children below the age of 5 years; above 10 years of age, only males were examined.

Recording, storage and retrieval of data

The data (observations and treatments) were recorded on precoded forms. The originals were sent to WHO, Geneva, and the data were transferred to tape with their precise coordinates of place, time, individual person, or mosquito, when applicable. The tapes were checked for errors and edited when appropriate. The tapes allow, in the analysis, for alternative groupings over time, space, or population, the study of the relationships between the different variables, and the extraction of the longitudinal histories of different types of units, e.g., individual persons, age-groups, villages.

The edited and documented tapes are on long-term storage in WHO, Geneva, where they can be made available for further use."

Services and staffing

Services

The services required for the direction, management and implementation of the project were distributed among WHO in Geneva, the WHO Regional Office for Africa in Brazzaville, the project headquarters in Kano, and the field station in Garki.

WHO, in Geneva, was responsible for the technical direction and coordination of the project, for the processing and analysis of the data, and for international procurements.

The WHO Regional Office for Africa provided local administrative coordination and assistance, in particular through the services of the WHO Representative in Lagos.

The project headquarters in Kano was responsible for the management and implementation of the field project, and had the following laboratories and services: parasitology, serology, entomology, data recording, stores including deep-freeze facilities for sera, transport, administration, and secretariat.

In Garki the field station situated in the chief town of the district afforded a hostel for the team members, stores for equipment and supplies for field operations, simple parasitological and entomological laboratories, and repair facilities for transport and field equipment.

Staffing

The list of the staff and their period of service in the project are given in Annex 1.

Some changes occurred in the staffing both at Geneva and in the field in relation to the phasing of the project and certain reorganizations.

Frequent visits were made by staff from WHO, Geneva, to the field area, and on a few occasions the project director or team leader was called

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[a] Requests should be addressed to Director, Malaria Action Programme, World Health Organization, Geneva, Switzerland.

to Geneva for meetings on planning or evaluation of the project. Field staff members were briefed in Geneva on recruitment, and some of them stopped over there for consultation or discussions during their leave.

Temporary consultants were recruited for special technical assignments, or for providing independent advice on the planning and evaluation of the project.

The field station in Garki, in addition to local watchers and keepers, was staffed during the week or sometimes longer by the staff from Kano or by temporary consultants.

Area, Climate, Population

The headquarters of the project was located in Kano, and the field station in the city of Garki, located at 100 km to the north-east of Kano.

The study area was almost coextensive with the District of Garki, Kano State, Nigeria (Fig. 1).

Orohydrography

The District lies below 500 m altitude, with very little relief, being part of the Lake Chad drainage area. There is usually no permanent surface water, and the only river is the Jakiri, which is an affluent of the Hadejia and forms part of the southern boundary of the District. Marshes are formed in the wet season, but they dry up more or less completely in the latter part of the dry season. Near the Jakiri, the water table is 2-5 m deep; northwards it sharply falls to 30-50 m in the dry season over much of Garki District. Deep wells (one per village or per small group of villages) are used throughout the year. In the wet season, there are uncountable temporary collections of surface water, of various sizes and durations. Water may persist long after the rains in the borrow pits from which clay is extracted for building.

Climate and vegetation

With respect to climate, the area belongs to the tropical continental region *(84)*[a], characterized by relatively wide annual and diurnal ranges of temperature, and a restricted rainfall (250-1000 mm per annum) with

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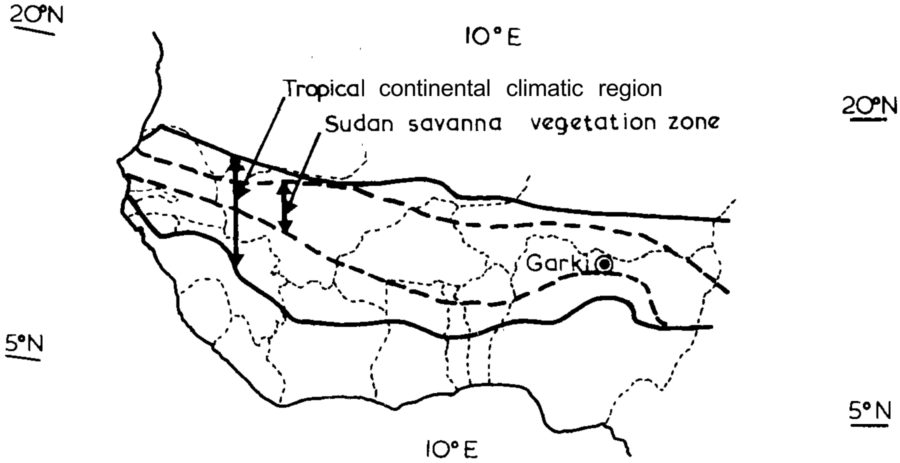
a Finer subdivisions of West African climates distinguish three horizontal belts within the tropical continental region; the project was located in the middle belt, called "Savanna climate" by Harrison Church and "Climat soudanien-nord" by Hubert (81). On the other hand, the project area is located near the northern limit of the "Tropical savanna" climate of Trewartha (55).

Fig. 2. Location of the Garki project area within the limits of, the tropical continental climatic region and of the Sudan savanna vegetation zone in West Africa (84)



clear single maximum (Fig. 2). The yearly maximum temperature immediately precedes the rainy season, and a secondary peak of high temperature occurs at its end. Three seasons may be recognized: dry cool (November-February), dry hot (March-May), and wet (June-October). The seasons are determined by the alternating preponderance of the dry tropical continental air mass coming from the north-east (the harmattan wind) and the moist tropical maritime air mass coming from the south-west.

With respect to vegetation, the study area belongs to the Sudan savanna zone (81, 84). This zone according to Harrison Church (81, pp. 76-77),

"is found in a belt some 120-240 miles [200-400 km] wide, from Senegal to Nigeria and beyond, north of the Guinea savanna. In the Sudan savanna, annual rainfall averages about 22-40 inches [550-1000 mm], there are seven almost rainless months, and relative humidity in early afternoons of the dry season may drop to 8%. It may be regarded as the most typical of all savannas and occurs roughly in the climatic belt of that name. It is one of the clearest climatic, vegetational and human zones, yet one of the most affected by man. It is often densely inhabited-e.g. in northern Nigeria, the Upper Volta and western Senegal-so that there is much secondary vegetation. There has also been some spreading of species from the south, and from the north-particularly of acacias. Consequently, the vegetation of this zone is difficult to define. Trees, which almost always occur singly, average 25-50 feet [8-12m] in height and have wide-spreading crowns.. . There are also smaller trees, 10-20 feet [3-6 m] high, such as the acacias. Lower again is the bush or shrub of 6-20 feet [2-6m] . . Most trees lose all their leaves in the dry season.. . In this zone, grass shoots up only just before the rains. It is also shorter (3-5 feet [1-2m]), less tussocky but more feathery than in the zones to the south. Consequently, it is very useful for grazing and is less deliberately burnt, so that fires are not so violent. It is a most interesting fact that moderate grazing, by keeping the grass short, can arrest fires and so allow greater tree growth and regeneration. The original climax (xerothermic) may perhaps still be seen on isolated or inaccessible rocky slopes, or along water courses".

With respect to agriculture, the project area lies in the "millet and groundnut zone" (81). In the area itself, millet and different varieties of Guinea corn (giant millet, sorghum) are the main crops. They grow to heights of approximately 2 m and 4 m respectively and closely encircle most of the villages during the growing season.

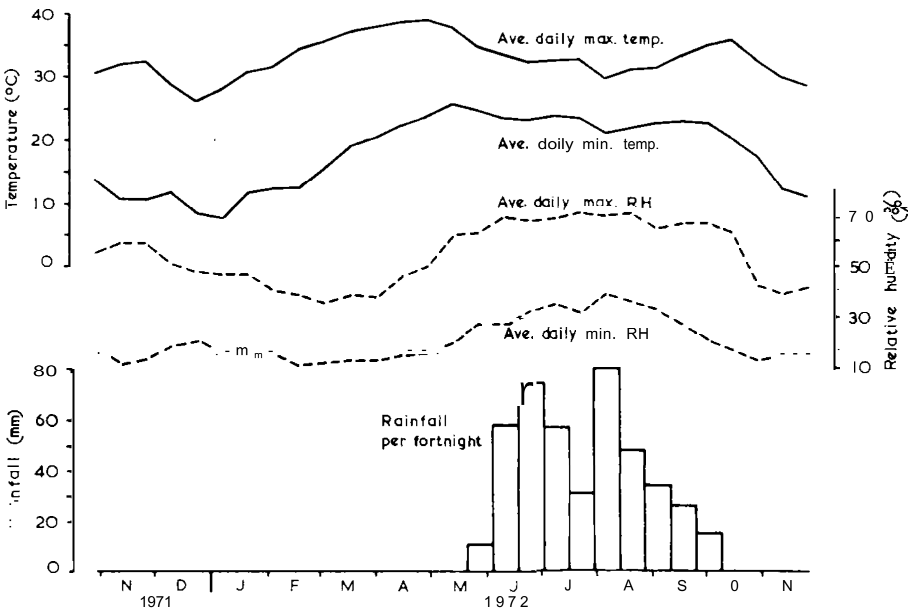
Meteorology

The meteorological observations made in the project have been the subject of an unpublished report (178).

Past meteorological data are available from some stations located near the study area including Kano (88), but not from the study area itself. They are typical of that climatic zone. In Kano, the average yearly rainfall over a 41-year period was 886 mm, with a standard deviation of 180 mm.

The meteorological data collected by the project in the Garki district (Fig. 3), showing the rainfall and the daily maximum and minimum tem-

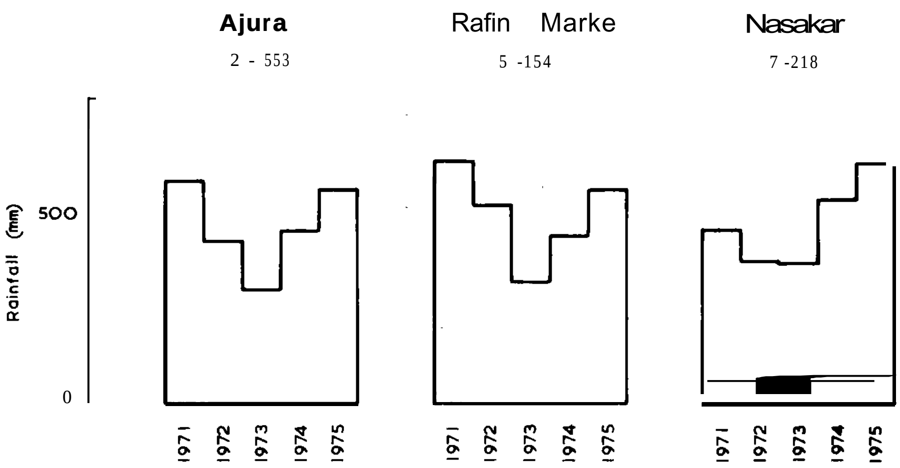
Fig. 3. Rainfall (14-day totals, average of 8 stations) and daily maximum and minimum temperature and relative humidity (14-day averages of 4 stations) in Garki district, November 1971-November 1972



perature and relative humidity in the study area over a complete calendar year (November 1971 to November 1972), allow the three seasons (dry cool, dry hot, wet) to be clearly identified.

The rainfall per annum varied, among 8 villages, from 467 mm to 691 mm in 1971, from 371 mm to 515 mm in 1972, and from 203 mm to 436 mm in 1973. There was a decrease from 1971 to 1972 and from 1972 to 1973 in every one of the 8 villages, but there was no significant correlation between the ranking by rainfall of the villages in the different years. In each of the 3 villages where observations were continued there was an increase in rainfall from 1973 to 1974 and from 1974 to 1975. Among the 3 villages, the rainfall per annum varied from 434 mm to 528 mm in 1974 and from 553 mm to 633 mm in 1975 (Fig. 4).

Fig. 4. Rainfall per year in 3 villages of the project area in 1971-1975



Rainfall in the area is discontinuous and irregular. For example, in the village of Ajura in 1975 (see Fig.9 below), the number of rainy days per month in the course of the wet season varied between 1 in April and 13 in August, while the time pattern was quite sporadic. The spatial pattern of rainy days was also quite irregular; during the years when 8 stations were in service in the study area only about half of the rainy days involved all of them.

The distribution of the rainfall over the rainy season varies markedly from year to year, as illustrated by the figures for 1971, 1974 and 1975 in 2 of the villages (see Fig. 19 below). The changes in the time pattern of the rainy season from year to year were very similar in the different villages.

Population

The population density in the Sudan savanna zone is relatively high, and notably higher than in the belts to the north and to the south (81). In the project area the population belongs almost exclusively to one of two ethnic groups, Hausa or Fulani. The Hausa form the majority: they are Negroes, live a sedentary life and are mostly farmers. Their huts are usually round, with clay walls and a thatch roof, rather closely grouped in fenced family compounds, which in turn are grouped in compact settlements. The Fulani were originally nomadic herdsmen who are believed to have corne from the north as invaders. Some, the "cattle" Fulani, are still nomadic. Small groups of them with large numbers of cattle move through the project area following the rains and the availability of grazing grounds. They live in temporary tents made of cowhides or grass. Other Fulanis have become sedentary; they are now bilingual and have intermarried to a certain extent with the Hausa. Most of the emirs and other aristocrats of northern Nigeria belong to this class. In the project area settled Fulani practise agriculture and also keep cattle, though in smaller numbers than the "cattle" Fulani. They live in huts similar to those of the Hausa, less closely grouped in family compounds, usually unfenced; and the compounds themselves are grouped in scattered settlements, often with 100 m or more between compounds. An administratively defined village unit has a chief responsible to the district governor and may be compact, scattered or mixed. In addition to the movements of nomadic Fulani, another significant type of migration that occurs in the project area is the temporary emigration of labourers during the dry season; in the Hausa language, this seasonal migration is called "cinrani", meaning "eating away" (the dry season). Both Hausa and Fulani practise polygyny. Both ethnic groups are Moslem. The demographie data collected by the project have been indicated to a small extent above but are to be found mainly in Chapter 8.