REPORT ON NATIONAL CLOUD-SEEDING OPERATION 1974-75

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1. SUMMARY

The 1974-75 Cloud-Seeding Operation was carried out as an improved version of the previous year's programme, which was the first national cloud-seeding operation to be properly planned in advance. The rainy season turned out to be another good one, so that it was not necessary to use the full potential of flying hours and cartridge stocks. Nevertheless, there were serious rainfall deficiencies in some areas, notably northern Mashonaland during the growing season, which therefore derived benefit from a cloud-seeding facility which was a going concern.

2. CONTROL AND ORGANIZATION

The National Cloud-Seeding Operation (N.A.C.S.O.) was controlled by a committee of representatives from the Ministries of Agriculture, Water Development and Internal Affairs, with the Director of Metoeorological Services representing the Ministry of Transport and Power serving as Chairman. The function of the committee was to decide the broad tactics on when and where to seed where rain was needed, or not to seed where there was enough or too much rain.

Treasury allocated a sum of $154,000 for the operation, the same amount as for the previous season.

The seeding aircraft duly modified for cloud-seeding operation, and fully instrument-rated pilots were supplied by Rhodesia United Air Carriers (R.U.A.C.). The actual cloud seeding was done by meteorological staff of the Forecast Branch, drawn from meteorological offices at Salisbury and Bulawayo Airports. The Thornhill meteorological staff were kept in reserve.

As previously, two aircraft, a Baron and an Apache, were based in Salisbury and one, a Cessna 210, was based at Bulawayo Airport. This is the best disposition for covering the country's cloud-seeding requirements with three aircraft.

Mr. J. M. Ward of Salisbury Airport Meteorological Office (S.A.M.O.) was once again put in charge of the day-to-day conduct of the operation, on a full-time basis. Mr. S. J. Medcalf, also of S.A.M.O., was his deputy although he was not fully detached from forecasting duties. At the Bulawayo end, Mr. A. C. Davidge was once again in charge. Details of staff and aircraft are given in the appendices.

Early in the season it was agreed as a result of liaison with the Rhodesia National Farmers' Union (R.N.F.U.) and the Department of Conservation and Extension that the best way to advise seeding requirements was for farmers to tell their Conex Field Officers who reported each Friday or more often as required, to the Department of Conservation and Extension Irrigation Specialist, Mr. Gavin Wilson. Mr. Ward always worked in close liaison with Mr. Wilson, hence the areas in need of seeding were known every day.

Daily reports of positions and times of seeding were submitted to Meteorological H.Q. who distributed a weekly report each Wednesday to the addresses in Appendix I.

The Research Programme also continued during 1974-75. It operated quite separately. It experimented with the same technique used in the National Operation. It tried to assess how far short of the previously accepted standards a cloud could be, and still be successfully seeded. It seems that unless these criteria are substantially satisfied, the seeding does not work. Throughout the season the cloud-seeding research officer, Mr. D. L. McNaughton, maintained close liaison with Mr. Ward. The research and operational cloud-seeding officers accompanied each other's sorties to ensure that the experiments were geared to the current practical requirement, and that the technique used in the operation conformed with the latest findings from the experiments.

3. SEEDING TECHNIQUE

The seeding technique was a repetition of the method used in the 73-74 operation. Cartridges producing a silver iodide smoke were fired into selected suitable cumulus clouds from aircraft flying at cloud-top. To be suitable for seeding, the tops of cumulus clouds have to reach a temperature of about -10°C which in the rainy season is approximately 21,000 ft (6,400 m) above sea level. The clouds should be growing, with well-defined updraughts, have a firm structure without a "waist" and not show signs of flattening out at the top.

The skill and hence the profitability of the operation, depends upon recognizing the suitable cloud from a distance in sufficient time for the aircraft to arrive at the right stage of the growth cycle. If this is achieved, then the cartridge must be fired into the updraught to stimulate growth, because seeding into the down-draught can inhibit growth and may even disperse the cloud.

4. DAILY ROUTINE

Each day the Officer in Charge of the operation made full use of the forecasting facilities at S.A.M.O. The most vital information required for assessing suitability for cloud seeding is the data of temperature and humidity from the ground up to about 25,000 ft. This information is only available from the daily radiosonde ascents from Salisbury and Bulawayo.

The provisional assessment for each day was made by 0830B. Since the technique depends upon natural convection, the final decision was usually made on the strength of the 1100B meteorological reports.

At the end of the day a preliminary assessment was made for the operations for the following day.

5. THE 1974-75 RAINY SEASON AND SEEDING OPERATIONS

Narrative

The operation was planned to start on 1st November 1974 and to continue until 31st March. The Control Committee met on 28th October and decided to postpone seeding on a national scale until the 15th November, to assist farmers who had been delayed in harvesting their winter wheat by many showers during September and October.

During the latter half of November conditions were generally suitable for seeding and there were only four days on which sorties were not flown. However, on many occasions sorties were hampered by extensive middle-level cloud. During the second half of November 29% of the total sorties were flown and 42% of the total number of clouds were seeded.

December rainfall was widespread, and most of the country received above normal rain. The Kyle Dam spilled on the 3rd, and by the end of the month only 6 major dams out of 28 were not spilling.

However, early in December farms in the area from around Karoi across to Centenary and Mt. Darwin and down to around Glendale were short of rainfall, as was a part of Matabeleland, particularly to the north of Bulawayo. Seeding was therefore concentrated on these areas. Following widespread heavy rain between the 11th and 20th December, seeding was suspended until the 28th when seeding was resumed over the southwest of the country.

In early January the weather conditions were too dry for seeding in the southwest of the country, the only area where there was a known requirement for seeding. From 9th January to 31st January weather conditions were suitable for seeding but the only requirements were in Matabeleland, the Glendale area and later the Gadzema and Odzi areas. In these 23 days 38% of the total sorties were flown resulting in 35% of the total number of clouds being seeded.

In early February dry air moved across the country from the south, confining thunder activity to the north. There was no known requirement for seeding until the 9th. Between the 9th and the 12th sorties were flown over Gatooma/Gadzema areas, the Mtoko, Mayo, Virginia and Macheke I.C.A.'s and over Matabeleland to the northwest of the main watershed. There followed a period of widespread and often heavy rain until the 22nd and no more sorties were flown over Matabeleland.

One sortie was flown at the beginning of March over Hunters Road, where there was a very small area of rainfall deficiency. Thereafter, there was no further requirement for seeding and the operation was stood down on the 20th March, eleven days earlier than planned.

Number and Location of Seedings

For the convenience of reporting, the country was divided into nine areas as shown in Figure 1. In general the position of each cloud seeded was reported to the nearest five minutes of latitude and longitude, approximately to within 8 km.

The number of clouds seeded in each area was:

Northwest Mashonaland	140
Northeast Mashonaland	150
North Matabeleland	167
Midlands	104
South Mashonaland	134
Manicaland/Eastern Border	44
Victoria	Nil
South Matabeleland	300
Southeast Lowveld	9
	1,048

The more detailed locations are given in Figure 2, which shows the number of clouds seeded in quarter-degree squares.

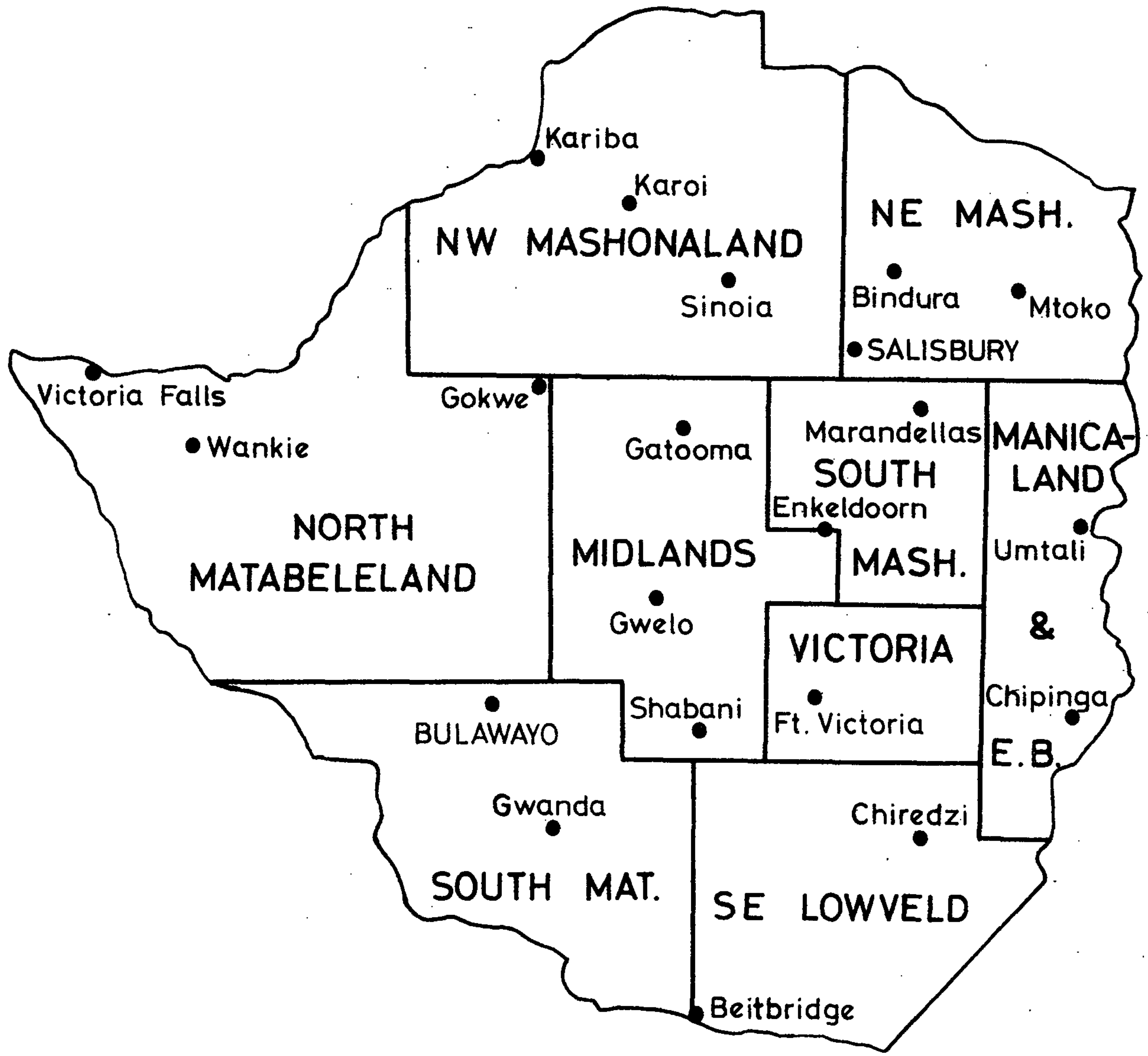
Results observed from the air

Number of cartridges fired	1,483	
Number of clouds seeded	1,048	
Number of clouds observed	793	
Number of clouds observed to rain		163
Number of clouds observed to grown but not possible to observe base		525
Number of observed failures		105
Number of clouds not observed	255	

Utilization of aircraft

Three aircraft were available on each day, with the exception of Christmas Day.

Number of days originally planned	151
Number of days in amended programme	124
Number of days selected for seeding	45
Percentage of programmed days utilized	36
Number of days suitable for all three aircraft	7
Number of days suitable for only two aircraft	13
Number of days suitable for only one aircraft	25
Total number of programmed aircraft days	369
Number of aircraft days weather unsuitable, too wet or too dry	297
Number of aircraft days selected and flown	72
Number of sorties on which seeding was carried out	72



CLOUD - SEEDING AREAS

Fig. 1

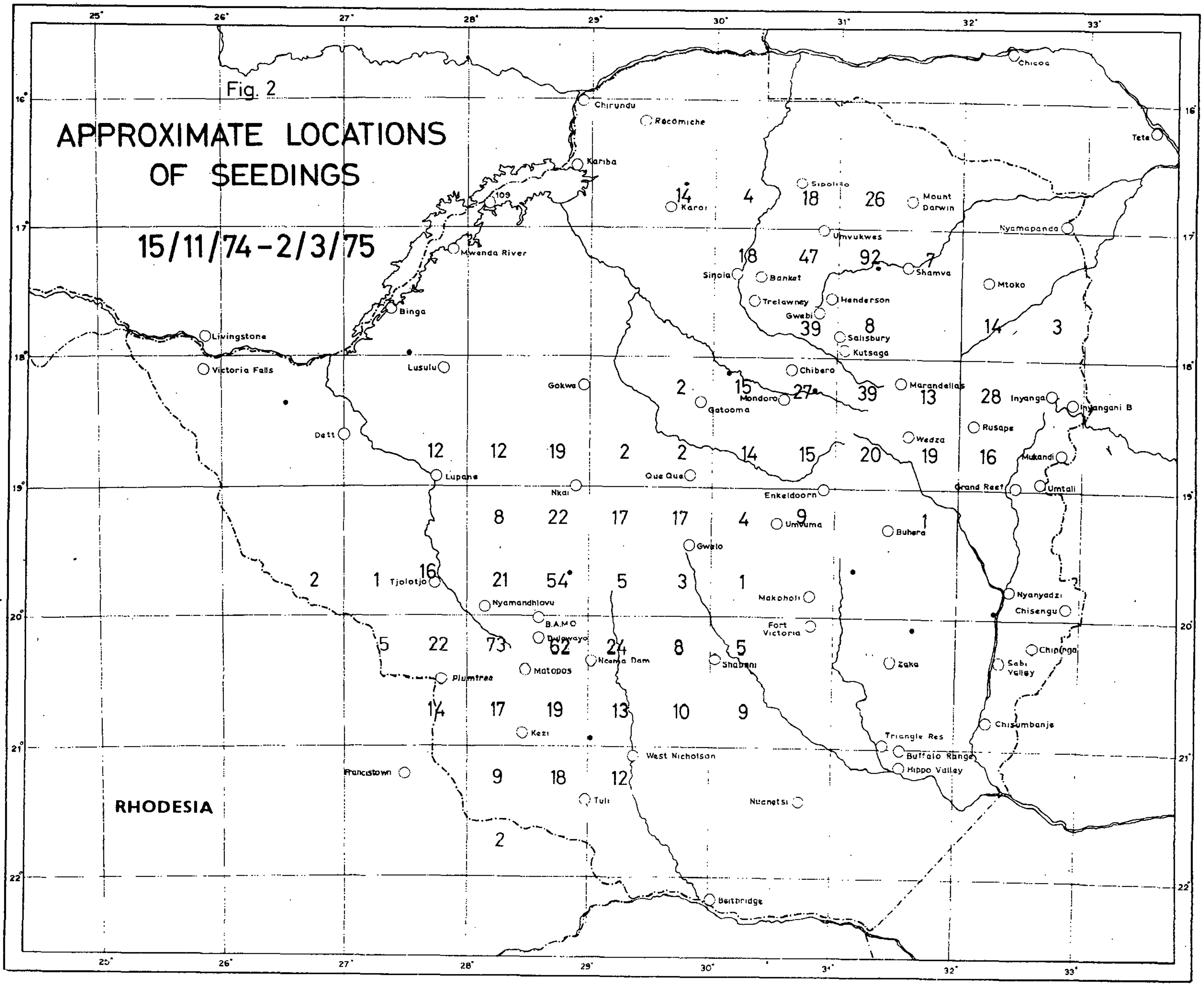


Fig. 2

APPROXIMATE LOCATIONS OF SEEDINGS

15/11/74-2/3/75

6. YIELD

Of 793 observed seedings, 105 did not succeed in increasing cloud growth or producing rainfall. The 105 unsuccessful seedings were largely because in the areas needing rain all possible clouds were tried, including marginal ones which did not fully satisfy the criteria. In such marginal cases, success could be 100,000 tonnes of water, yet with the aircraft in the vicinity failure is no more serious than losing $20 for trying.

If 688 of the 793 observed seedings were successful, this represents a success rate of 88%, the same as for the previous season. At 88% of the total 1,048 clouds seeded, 920 would have responded.

7. COSTS

The cost of the Operation, given in Appendix IV, was $64,057/

The cost of a successful seeding was,

$$\frac{\$64{,}057}{920} = \$69{,}63$$

The research programme has shown that on average a successful seeding produces approximately 120,000 tonnes of extra water.

At this rate the approximate costs were,

$58 per 100,000 tonnes or $100 \times 10^3 m^3$

58c per 1,000 tonnes or $1 \times 10^3 m^3$

72c per acre foot

The unit cost of seeding one cloud would have been appreciably lower had the season been poor and required more clouds to be seeded. The total cost would have been greater for more seeding.

8. APPRECIATION OF THE EXERCISE

The operation worked very smoothly, safely and economically.

Once again the operation was an outstanding example of close cooperation between Government and a commercial firm. The combination achieved the results at a small fraction of the cost of bringing in a commercial firm from overseas.

Even though the 1974-75 rainy season was in general another good one, there was a notable exception when an extensive farming area was very glad of assistance from cloud seeding.

In a generally good rainy season relatively few clouds are seeded. Because of irreducible overheads the cost of seeding each cloud is comparatively high. However, aircraft hours and cartridge stocks are conserved and the overall cost is reduced.

Experience confirms the advantage of approaching the problem of a National Cloud-Seeding Operation with a small nucleus of aircraft. The cost is low, and the ability to deal with localized or regional requirements is adequate. Should a season turn out to be generally deficient, it would be so much easier and quicker to expand the nucleus than to mount a full scale operation from scratch.

9. LESSONS LEARNED

Three lessons already learned should be placed on record because it has not yet been possible to implement them:

1. Higher-performance aircraft are required in order to avoid wasting seeding opportunities through the aircraft arriving at the cloud too late for seeding to do any good.

2. The aircraft need deicing equipment. If the aircraft is forced down from the -10°C level, 21,000 ft. to 12,000 ft., to get rid of ice, the delay in climbing back to operational height loses considerable seeding opportunity. This is particularly so because this difficulty is apt to arise on days of good seeding potential.

3. More radiosonde data of upper temperature and humidity are required; another two radiosondes per day during the season.

10. ACKNOWLEDGEMENTS

Once again it is my pleasure to acknowledge the efficiency and helpfulness of Mr. Colman Myers, Managing Director of R.U.A.C., and the competence, skill and patience of his pilots and engineering staff. This enabled a fully extended operation to be carried through without mishap.

All concerned are grateful to Mr. Gavin Wilson and other members of the Control Committee for the smooth liaison which was conducive to an efficient operation.

I am grateful to Mr. J. M. Ward and his team of meteorological officers who did the seeding and braved the discomforts and some anxious moments.

We also wish to thank Mr. D. L. McNaughton, the meteorologist conducting the research programme and the pilot of the research aircraft, Mr. J.G. Fraser, for their cooperation which ensured that the operation always had up-to-date advice on latest developments in seeding technique.

Finally, I am grateful to the meteorological staff stationed at Salisbury and Bulawayo Airports who worked additional overtime to release their colleagues from the bench to go on the cloud-seeding sorties to increase the rain where it was needed.

APPENDIX I

DISTRIBUTION LIST - WEEKLY N.A.C.S.O. REPORTS

Minister of Transport and Power
The Secretary for Transport and Power
The Secretary for Agriculture
The Secretary for Water Development
The Secretary for Internal Affairs
Members of the Cloud-Seeding Control Committee (Operation)

Mr. J. W. Hayward and alternate Mr. G. Wilson
Department of Conservation and Extension
Mr. P. A. Davies and alternate Mr. L. J. de Bruijn
Ministry of Internal Affairs
Eng. W. G. Wannell, Ministry of Water Development

The Director of Conservation and Extension
The Provincial Conservation Officers

Matabeleland
Manicaland
Mashonaland North
Mashonaland South
Midlands
Victoria

The President, R.N.F.U.
The Administrator, R.N.F.U.
The President, Matabeleland Branch R.N.F.U.
The Chairman, Natural Resources Board
The Provincial Water Engineers

Matabeleland
Mashonaland
Midlands
Manicaland
Victoria

The Provincial Commissioners

Matabeleland South
Matabeleland North
Mashonaland South
Mashonaland North
Victoria
Manicaland
Midlands

The Secretary to the Treasury
The Commander, Rhodesian Air Force
The Director of Civil Aviation
The Secretary for Information
Rhodesia Sugar Association
R.S.A. Experimental Station, Chiredzi
The Agricultural Development Authority
The Rhodesia Tobacco Association
The Rhodesia Coffee Growers' Association.

APPENDIX II

METEOROLOGICAL STAFF

Cloud-Seeding Officer	Station	Hours Flown							
		Seeding		Training		Research		Total	
		Hrs.	Min.	Hrs.	Min.	Hrs.	Min.	Hrs.	Min.
J. S. Ward	Salisbury	55	10			13	25*	68	35
S. J. Medcalf	Salisbury	3	45	2	20			6	05
M. L. E. Durrett	Bulawayo	54	15	8	10			62	25
A. C. Davidge	Bulawayo	12	45					12	45
M. R. Sinclair	Bulawayo	13	00					13	00
C. K. Worger	Salisbury	35	10			2	30**	37	40
D. B. Paterson	Salisbury			8	10			8	10
K. D. Chittenden	Salisbury			6	40	1	40**	8	20
R. M. Simpson	Salisbury			2	35			2	35
	TOTAL	174	05	27	55	17	35	219	35

* Six flights were carried out before the commencement of the operation in conjunction with research aircraft.

** Flights were carried out in the research aircraft in order to observe the experimental programme.

APPENDIX III

AIRCRAFT

The aircraft used and the hours flown were:

	HOURS FLOWN Hrs.	Min.	STATION
BARON....................VP-WAX	32	30	Salisbury
APACHE...................VP-WCE	61	35	Salisbury
CESSNA 210...............VP-YLT	83	55	Bulawayo
TOTAL	178	00	

APPENDIX IV

COST OF N.A.C.S.O. 1974-75

	$	$
AIRCRAFT OPERATIONAL COSTS		
Standing charges	37 500	
Hourly charges	9 583	
		47 083
CARTRIDGES		
1 483	8 000	8 000
SALARIES		
Salary and overtime	8 500	
Cloud-seeding allowances	474	8 974
TOTAL		$64 057

RAIN ENHANCEMENT ACTIVITIES IN EAST AFRICA: A REVIEW OF PAST EXPERIMENTS[1]

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1. INTRODUCTION

The recent Sudano-Sahelian drought has brought into marked prominence the need, long felt by the agricultural communities in many parts of Africa, for a rainfall enhancement scheme. In East Africa, for example, only a very small part has average rainfall in excess of 1,000 mm per annum, and in these parts, the rainfall variability is so great that it poses an every-present threat to the agricultural community. Droughts and floods can occur in succession and lead to considerable hardships to the community. In the past, the East African Meteorological Department has participated in a number of rain enhancement experiments which were later evaluated and reported on. (Brazell and Taylor, 1965; Davies, 1951, 52, 54). The requests for the rain enhancement experiments were usually at short notice and aimed specifically at rescuing a specific crop from failure or increasing the rainfall in a catchment area for other reasons. Because of the urgency and the need for "rain at all costs," the vast majority of the experiments were not designed, both statistically and physically, so that they could be amenable to evaluation later on. Further, it meant that in some cases, experiments had to be carried out under conditions that were not necessarily conducive to rain enhancement which inevitably makes it difficult to evaluate the results.

In this paper we examine the past rain enhancment activities on the basis of published data by the experimenters and attempt a critique of both the techniques and conclusions on the basis of what we know about cloud microstructure today. One is immediately limited by the absence of original data, but it seems possible that one can delineate essential features of the experiments and identify both weaknesses and prospects for the future. Again, it should be pointed out that owing to budgetary limitations most of the experiments were, per force, limited to initial exploratory work. The limitations thus imposed on the experimenters as regards experimental options and design can, therefore, hardly be overemphasized.

2. AREAS WHERE RAIN ENHANCEMENT EXPERIMENTS WERE CONDUCTED

Figure 1 shows the areas where rain enhancement experiments have been

[1]Part of a paper presented at the International Tropical Meteorology Meeting, Nairobi, Kenya, 1974.

conducted in East Africa in the past. Although Kericho is included in this figure, most of the work there concerned hail suppression, but on occasions seeding for rain was carried out when there was no chance of hail occurring. However, these will not be discussed as they are not fully documented and were quite haphazard. The first rain enhancement experiment was carried out in 1951 by the meteorological department in collaboration with the Overseas Food Corporation in the Kongwa groundnut scheme in Tanzania. Although these initial experiments were not very conclusive, they provided the basis for further experiments. In 1952 (January-April) another experiment was carried out on the same groundnut scheme but different seeding agents and techniques were used. We shall discuss the details of the seeding techniques later. In 1953, (October-December) the meteorological department, in collaboration with the Veterinary and Game departments and the National Parks of Kenya carried out a rain stimulation experiment in Amboseli, and in 1954, the department carried out a similar experiment in areas with two reservoirs at Dodoma, in Tanzania, where a serious water shortage existed. (Davies, et al, 1965). Other experiments were conducted in Mityana tea estate in Uganda in 1954 and Tabora, Tanzania, in 1957.

3. SEEDING AGENTS AND TECHNIQUES

In the first rain enhancement experiments in Kongwa in 1951, silver iodide was used as a seeding agent, but two seeding techniques were employed. First the conventional ground generator seeding technique was used. Second, small charges of gunpowder impregnated with silver iodide were fitted with a time fuse and carried up into clouds by hydrogen filled balloons, the length of the time fuse being adjusted so that the gunpowder exploded at the prearranged height (See Davies, et al, 1951 for details of the balloon-bomb technique which was developed in East Africa). These initial experiments were not very conclusive but they provided valuable experience for subsequent improved seeding techniques. On the basis of these experiments, a second series of experiments was carried out in 1952. This time the "balloon-bomb" technique was used exclusively, but silver iodide and sodium chloride (finely ground and dessicated sea salt) were the seeding agents. A strict three day cycle was adhered to. On the first day of each cycle silver iodide was used as a seeding agent, on the second day sea salt, and on the third day there was no seeding.

The balloon-bomb technique was employed in the seeding experiments in Amboseli and Dodoma in 1953 and 1954 respectively and in Mityana tea estates in 1954. In this case only sodium chloride was used since the experimenters appear to have reached the conclusion that sea salt was more effective as a seeding agent in East Africa than silver iodide. We shall have occasion to discuss this later. Unlike the other experiments discussed above, the experiments conducted in Tabora in 1957 utilized a different seeding technique. The seeding agent (sodium chloride) in this case was carried to cloud base by means of a modified two inch naval flare rocket. The rocket head carried a charge of nearly one and a half pounds of dessicated sea salt. It was fired electrically, and a fuse mechanism in the rocket head dispersed the seeding agent with explosive force after a specific time of flight. Unfortunately the number of seed and no-seed days were very few (seven and six respectively) hence it is difficult to draw any conclusions from the experiments (See Brazell and Taylor, 1965).

4. RESULTS AND DISCUSSIONS

The results of the experiments conducted in Kongwa are summarized in Figures 2 and 3. Figure 2 shows the difference between total rainfall on days of hygroscopic seeding and on days of no seeding, while Figure 3 shows excess total rainfall on days of silver iodide seeding over days of no seeding. These figures suggest, as they did to the experimenters, that seeding had an effect on the clouds. However, there are too many unknowns in this work for one to say with certainty that the increase in rainfall is attributable exclusively to seeding. The more intriguing conclusion from the point of view of cloud physics was the suggestion that in East Africa salt was a more effective seeding agent than silver iodide. An examination of the published data reveals no particular evidence to support this view. In order to test the conclusion, we have drawn isohyets of excess rainfall on days of hygroscopic seeding over days of silver iodide seeding and these are shown in Figure 4. It will be seen that except for the small portion on the extreme left of the figure, there are negative figures everywhere else, suggesting that, contrary to the conclusions of the experimenters, silver iodide appears to be a more effective seeding agent. These observations make one wonder if the experimenters had other visual evidence which is not recorded in the published work. The experimenters (Davis, et al, 1965) do point out that there were some days when seeding was to be carried out but could not because it was already raining. Although not actually seeded, they were included in the seeded category. There were 10 such days on days of silver iodide seeding and 3 on days of hygroscopic seeding. It is possible that this is reflected in Figure 4. However, it only goes to reemphasize the question: to what extent is the noted increase in rain attributable to seeding and not chance?

Presumably, the conclusion that salt seeding was more effective than silver iodide seeding was based on Langmuir's (1948) chain reaction hypothesis. It has not yet been experimentally or observationally established that a chain reaction has actually been initiated artificially in a cloud. Biswas and Dennis (1971) were, to the best of the author's knowledge, the first to claim having artificially initiated a chain-reaction by salt seeding. This was challenged by Blanchard (1972) and Haven (1972). Later, Biswas and Dennis (1972) carried out calculations to support their earlier statements but were a lot more guarded in their conclusions. Calculations such as those made by Biswas and Dennis would be helpful in the East African case and would go a long way in establishing the effectiveness of hygroscopic seeding in East Africa.

Figure 5 gives the results of the experiments carried out in Mityana, Uganda. Again, it is noteworthy that there is evidence of increased rainfall on seed days over no seed days. The experiments in Amboseli and Dodoma were observed visually to produce at best drizzle and in most cases virga. Again it would appear that the decision to use salt in seeding all clouds without regard to, or knowledge of, cloud microstructure explains the poor results in some places.

The major weakness of the experiments on rain enhancement seems to be in the lack of a close study of the cloud microstructure in specific areas and the apparent assumption that these were more or less the same in all the regions where the experiments were carried out. In particular it is dangerous to assume that clouds in Mityana where rain occurs quite often (as evidenced by the fact that tea is grown there) and those in Amboseli--a relatively dry area are the same. This assumption is inherent in the use of salt as a seeding agent in both places.

5. CONCLUSION

In any weather modification exercise, it is usually difficult to determine the extent to which any noted changes in normal patterns is attributable to chance. In the rain enhancement experiments in East Africa, this doubt is very prominent considering that in most cases the experimental design did not allow for a meaningful statistical evaluation later on. Nonetheless, these experiments have provided interesting seeding techniques and posed important questions that should form the basis for future research in this area. Specifically, a need exists for more carefully designed experiments (both statistical and physical) to test the effectiveness of salt seeding vis-a-vis silver iodide seeding in East Africa.

6. ACKNOWLEGEMENT

The author is grateful to Miss J. E. Tomsett for drawing the diagrams and the Director General, East African Meteorological Department for permission to publish this paper.

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FIGURE CAPTIONS

Figure 1. Areas where rain enhancement experiments have been undertaken in the past.

Figure 2. Isopleths showing difference between total rainfall on days of silver iodide seeding and on days of no seeding at Kongwa (after Davies et al 1952).

Figure 3. Isopleths showing difference between total rainfall on days of hygroscopic seeding and on days of no seeding at Kongwa (after Davies et al 1952).

Figure 4. Isopleths showing excess rainfall on days of hygroscopic seeding over days of silver iodide seeding at Kongwa.

Figure 5. Excess rainfall in inches on days of seeding over control days at Mityana (after Davies et al 1965).

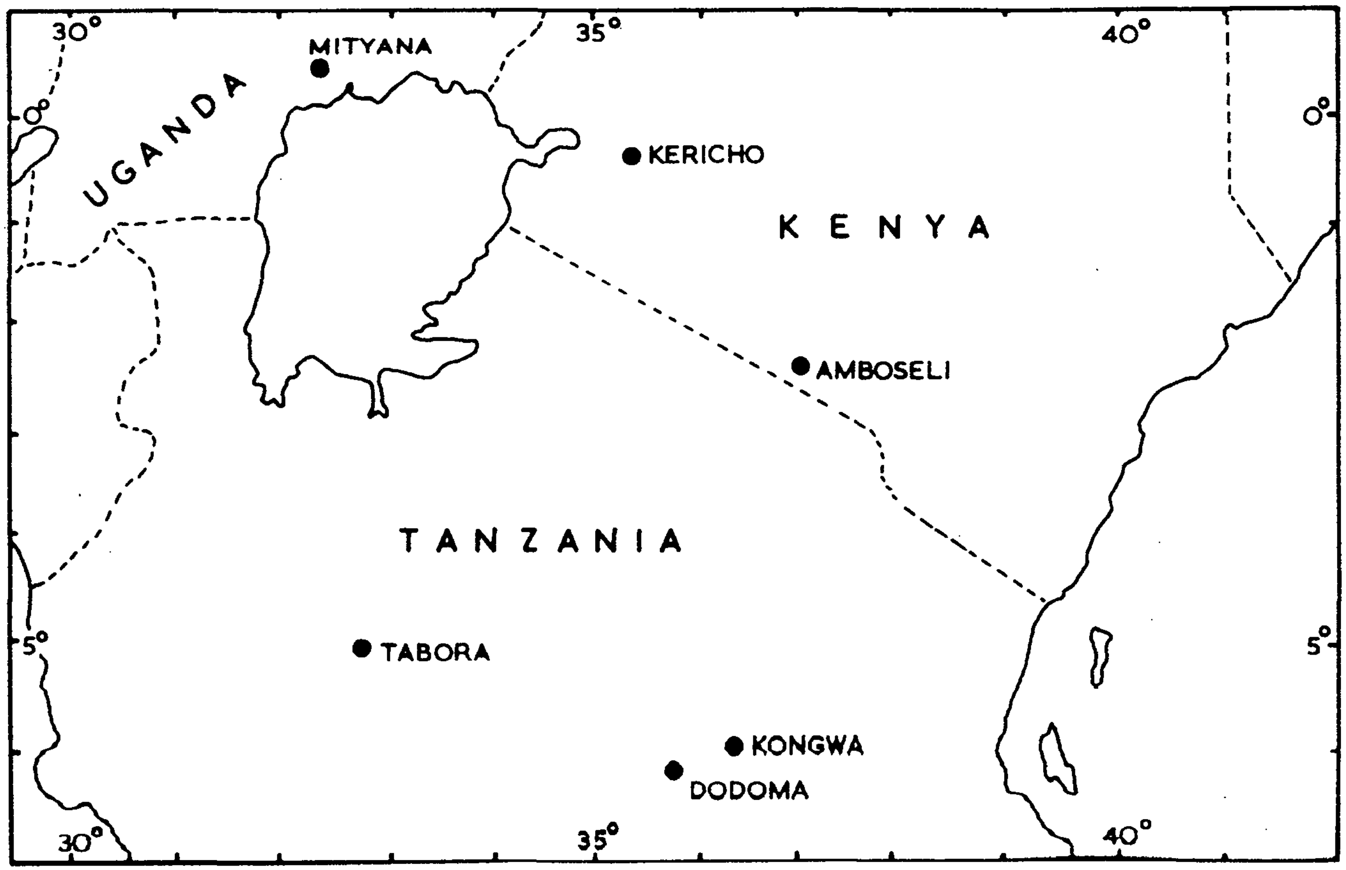
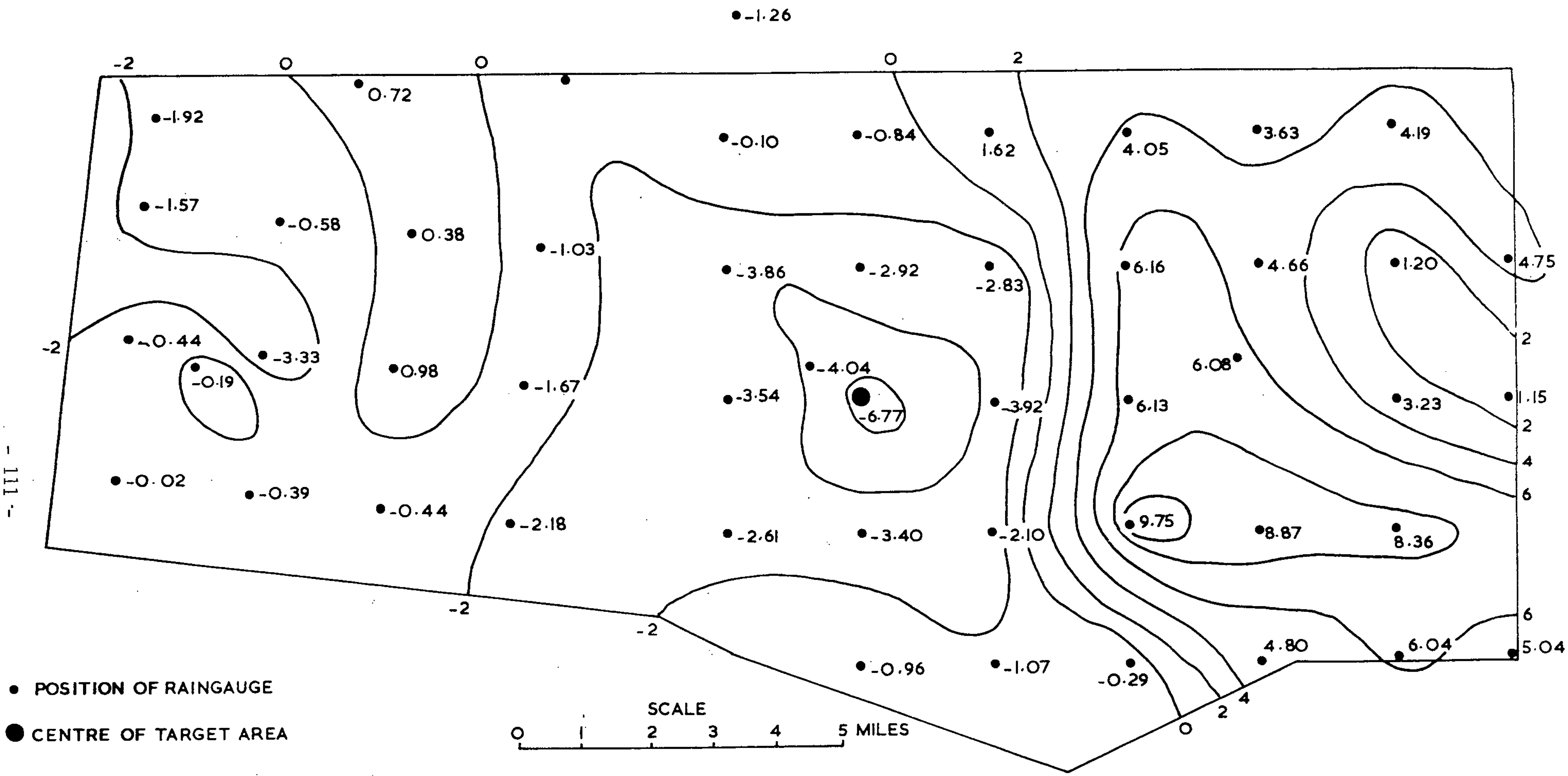

30°
35°
40°
0°
0°
5°
5°
30°
35°
40°
MITYANA
UGANDA
KERICHO
KENYA
AMBOSELI
TANZANIA
TABORA
KONGWA
DODOMA

FIGURE 1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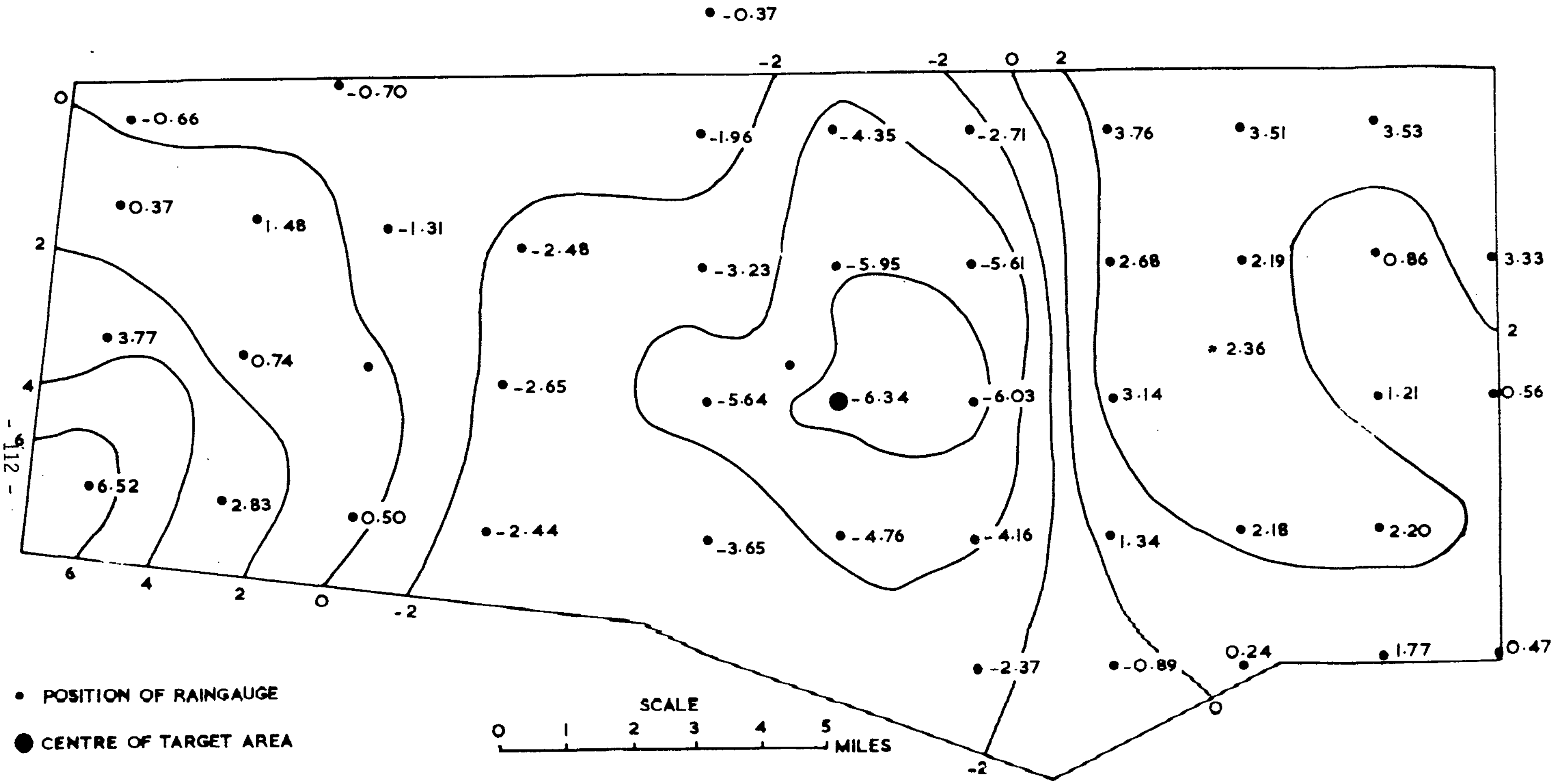
-2
0
0
0
2
0.72
-1.92
-0.10
-0.84
1.62
4.05
3.63
4.19
-1.57
-0.58
0.38
-1.03
-3.86
-2.92
-2.83
6.16
4.66
1.20
4.75
-2
-0.44
-3.33
0.98
-0.19
-1.67
-4.04
-3.54
-6.77
-3.92
6.08
6.13
3.23
1.15
2
2
4
6
-0.02
-0.39
-0.44
-2.18
-2.61
-3.40
-2.10
9.75
8.87
8.36
-2
-2
6
-0.96
-1.07
-0.29
4.80
6.04
5.04
0
2
4
POSITION OF RAINGAUGE
CENTRE OF TARGET AREA
SCALE
0 1 2 3 4 5 MILES

FIGURE 2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-2.48
-3.23
-5.95
-5.61
2.68
2.19
0.86
3.33
3.77
0.74
-2.65
-5.64
-6.34
-6.03
3.14
2.36
1.21
0.56
6.52
2.83
0.50
-2.44
-3.65
-4.76
-4.16
1.34
2.18
2.20
-2.37
-0.89
0.24
1.77
0.47
POSITION OF RAINGAUGE
CENTRE OF TARGET AREA
SCALE
0 1 2 3 4 5 MILES

FIGURE 3

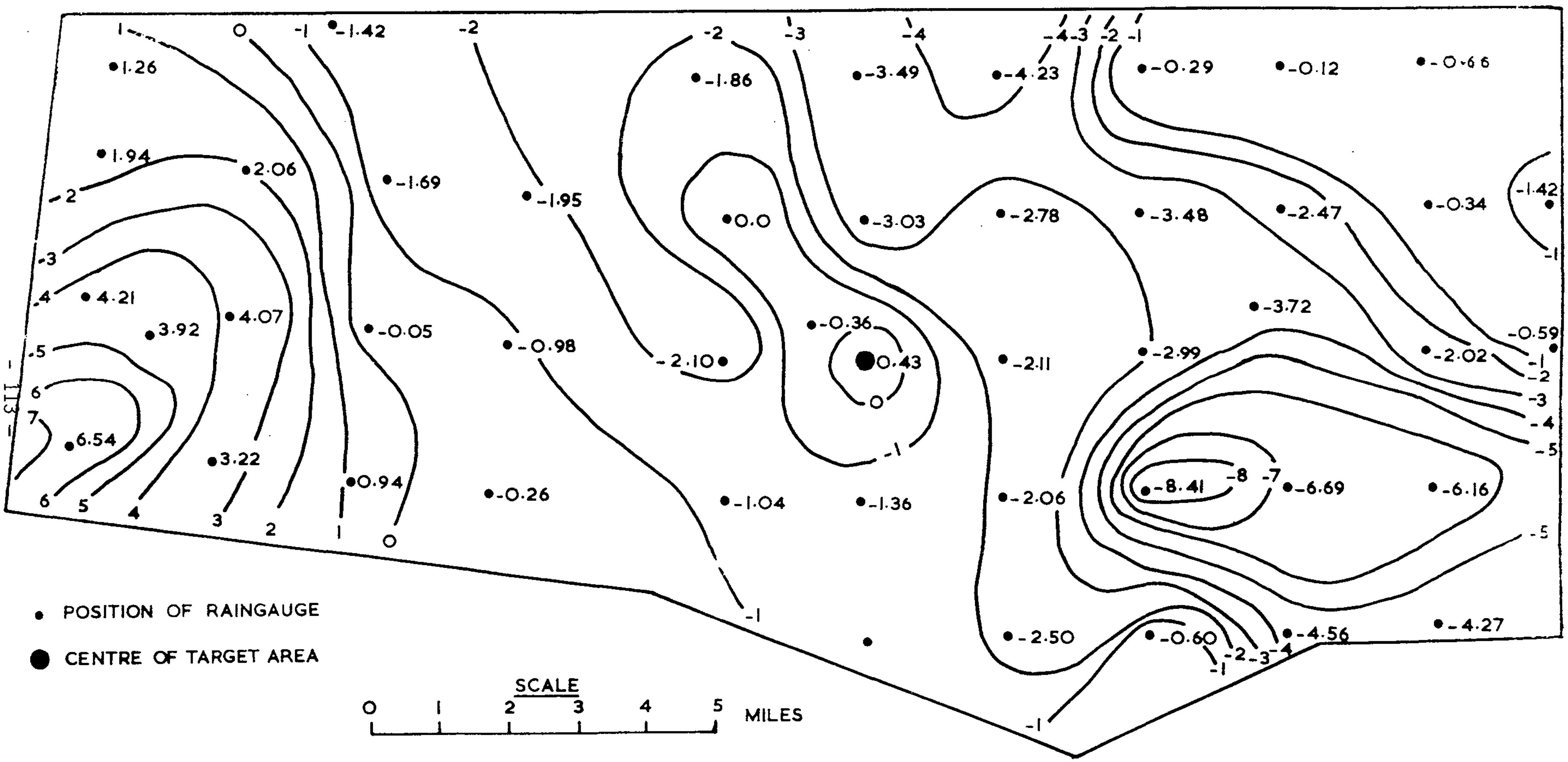
POSITION OF RAINGAUGE
CENTRE OF TARGET AREA
SCALE
0 1 2 3 4 5 MILES
1.26
-1.42
1.94
2.06
-1.69
-1.95
-1.86
-3.49
-4.23
-0.29
-0.12
-0.66
0.0
-3.03
-2.78
-3.48
-2.47
-0.34
-1.42
4.21
3.92
4.07
-0.05
-0.98
-2.10
-0.36
0.43
-2.11
-3.72
-2.99
-2.02
-0.59
6.54
3.22
0.94
-0.26
-1.04
-1.36
-2.06
-8.41
-6.69
-6.16
-2.50
-0.60
-4.56
-4.27

FIGURE 4

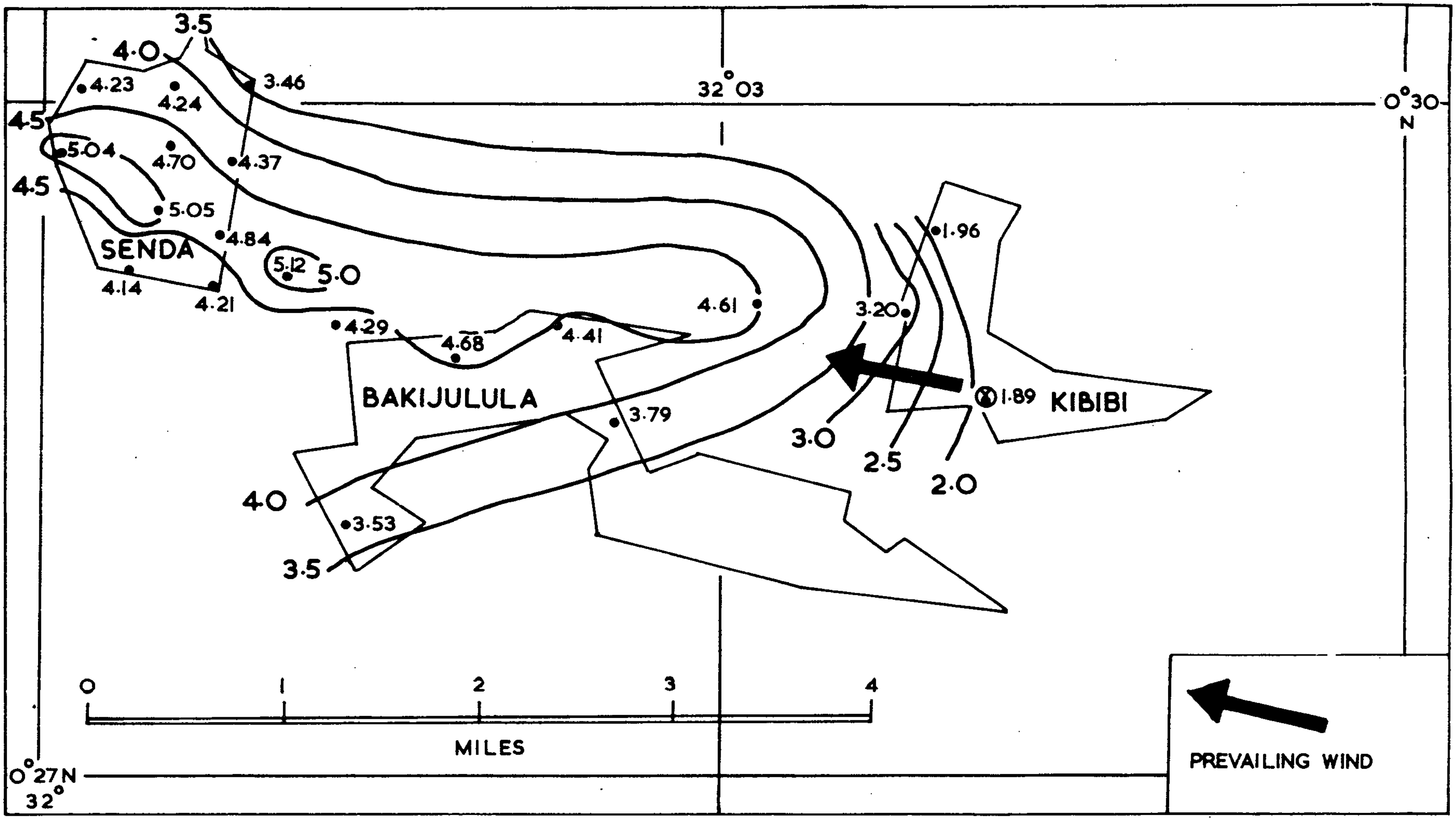
3.5
4.0
3.46
4.23
4.24
32° 03
0° 30
N
4.5
5.04
4.70
4.37
4.5
5.05
4.84
SENDA
5.12
5.0
4.14
4.21
4.29
4.68
4.41
4.61
3.20
1.96
BAKIJULULA
3.79
1.89
KIBIBI
3.0
2.5
2.0
4.0
3.53
3.5
0
1
2
3
4
MILES
0° 27 N
32°
PREVAILING WIND

FIGURE 5