PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Algerian Case Study and the Need for Permanent Desert Locust Monitoring [and Discussion]

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Algerian case study and the need for permanent Desert Locust monitoring

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Through the experience gained by Algeria and the Maghreb Commission for Desert Locust control during the past recession and the present plague (1987, 1989), especially in the use of operational meteorological products of the World Weather Watch of the World Meteorological Organization for improved forecasts of swarm movement, an integrated acridometeorological watch system is suggested for the whole Saharan breeding area to avoid any surprise in the future. This permanent monitoring system should be built and operated jointly by the meteorological and the plant protection services at the national level. The regional and international coordination by the Food and Agriculture Organization of this Desert Locust monitoring could make use of the now experienced and integrated system of the World Weather Watch. The system proposed is not only useful for Desert Locust survey and control, but for the realistic use of the Saharan environment for a better life for nomads and the newly settled peasants.

1. Introduction

In October 1987, the Food and Agriculture Organization (FAO) stated in its Desert Locust Situation Summary and Forecast: 'Swarms produced south of the Sahara invaded Algeria and Morocco on a broad front in the second half of October... Summer breeding has probably terminated in western Sudan, Chad and Niger, but continues in Mali where it may become more widespread, and is probably starting in Mauritania'. The next FAO bulletin of November 1987 stressed that 'The scale of summer breeding south of the Sahara has been far greater than anticipated. Mali was invaded by swarms in early October, and Mauritania in late October. Breeding continues in both countries and is widespread in Mauritania...' In spite of these two warnings, no general mobilization was declared in the Maghreb and for good reason: the financially important decisions that had to be taken needed more precise field information than was available at that moment. In fact, the war against the Desert Locust would be declared only in February 1988, after the first big swarms coming from Mauritania and the Western Sahara had crossed the border of Algeria and Morocco, in association with a series of exceptional weather situations during 21–28 February 1988. These weather situations brought exceptional rain in the southwest of Algeria and Morocco and well-organized warm and strong winds, which provided a transport system of 10 days duration in Western Sahara.

In September 1988, all the national and international specialized authorities (FAO, Overseas Development Natural Resources Institute (ODNRI), National Desert Locust Services) were unanimous in predicting a severe Desert Locust invasion for the north African countries, starting from October 1988. The reason was the heavy rainfall in the Sudan and Sahel, which enhanced an unprecedentedly successful breeding season in the whole of the summer breeding area from the Red Sea to the Atlantic. Year one of the worst plague in this century was announced. In fact, Dr R. C. Rainey (personal communication), in preparing this discussion meeting, was urging the Algerian Desert Locust control team to follow closely this special situation and wrote: 'Algeria's forthcoming Desert Locust invasion of 1988/1989 could well be the most damaging the country has ever had, by reason not only of the scale of the parent generation in the Sahel, but also from the extent of agricultural development in Algeria, since the last comparable invasion of 1954–1958'.

Following these unanimous and pessimistic forecasts, Algeria, the Maghreb countries and the FAO mobilized huge and costly resources, but apart from Morocco, the scourge did not materialize because the majority of swarms had boarded the Atlantic cyclones. These cyclones, taking their origin from the heart of the Sahara and Sahel area, transported the Desert Locust swarms to the Caribbean Islands in a spectacular and apparently unpredictable way. The mechanism was explained, however, once we had the time to use the World Weather Watch (WWW) products prepared and disseminated by world forecasting centres such as European Centre for Medium-range Weather Forecasting (ECMWF) (Reading) or U.K. Meteorological Office (Bracknell).

In September 1989, the FAO Emergency Centre for Locust Operations (ECLO) Desert Locust Summary disseminated the following information: 'The continuing heavy rains in several parts of West Africa... have created excellent conditions for continued summer breeding. This could constitute the beginning of another upsurge, so every effort should be made to detect and destroy any infestations which may result.'

One month later, the FAO/ECLO Summary stated that: 'The general Desert Locust situation remained unexpectedly calm during the past month. Despite adequate rainfall and good ecological conditions in many areas, there is no evidence suggesting an upsurge in Western Africa as previously forecast'. In fact, in Algeria the Desert Locust control system had been fully mobilized during the whole 1989 season and no definite decision had been taken as of November 1989. This created an unbearable situation of 'no war, no peace', the main reason being the lack of adequate and reliable Desert Locust information in the vast breeding area in the Sahara.

Any decision-maker involved in the Desert Locust operations was therefore asking and being asked the same questions: 'Should we demobilize the whole system or should we maintain the current capability; or should we perhaps reorganize the resources of preventive control operations and set up a permanent Desert Locust Watch?'

As a matter of fact, the Desert Locust is feared not only for its destructive capacity of the food crops but also for the permanent threat that the 60 countries concerned have to bear. During these past years, we have experienced a true psychosis of the Desert Locust invasion in many African countries of the Sahara and Sahel regions. To protect the threatened countries from invasions that may not occur, the expenditures incurred are as heavy as those involved during a real Desert Locust plague. Nevertheless, the progress made in the scientific knowledge of this migrant pest should have changed this situation.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Some specialized authorities assure the public and the governments that it is now possible to answer positively the questions on *where*, *when* and *how* the desert plague develops and even *what are the means* and *methods* required to control rationally any scourge.

In our opinion, the solution to the Desert Locust problem is not only technical, but also organizational. It depends mainly on the willingness of all countries concerned, the donors and the interested international agencies, to unify their efforts to build an integrated system for a permanent World Locust Watch (WLW of FAO) complementary to the World Weather Watch system of the World Meteorological Organization (WMO). An invasion of the Desert Locust in its gregarious phase presents many similarities with meteorological phenomena: it knows no frontiers, concerns large areas, has great mobility, develops in areas difficult to reach and monitor, can take man by surprise, and is unpredictable in the long term.

After this review of the status of the actual Desert Locust information system and control organization (and before suggesting a realistic contribution to the strengthening of the organizational scheme and information network for a better plague forecast), let us look at the expenses incurred by Algeria and the lessons drawn from the recent Desert Locust campaign, which is not yet over because of the lack of information on the Desert Locust in its large breeding and development areas.

2. Algerian case study: the 1987–1989 Desert Locust control campaign

Because of its importance and suddenness, the Desert Locust plague of 1987–1989, which occurred in West and northwest Africa, forced Algeria and Morocco into an unprecedented campaign covering more than 5 million ha† and requiring more than U.S. $100 million.

(*a*) *The invasion, as seen from Algeria*

In 1985, intensive breeding by the Desert Locust on the western edges of the Red Sea, though limited in space, started the formation of swarms that invaded Saudi Arabia in 1986 and left an important breeding potential in Sudan and Ethiopia. Insufficient control operations and favourable winds allowed the new swarms to reach the Sahel in July and August 1987. From September to October 1987 onwards the swarms settled in the northeast of Mauritania and in the Western Sahara where breeding was intense because of extremely favourable ecological conditions. This gave rise to winter-spring generations. These swarms invaded southwest Algeria during the first quarter of 1988 from February onwards. After that the monsoon rain, which fell in the Sahel from June to August 1988, led to the production of two locust generations that were expected to move to the north and the northwest from September 1988 in a massive invasion of the Maghreb countries. This scourge did not occur and many swarms ended in the Atlantic, with some reaching the Caribbean, forced by unusual westward winds. However, some swarms managed to reach western Algeria and southern Morocco.

This exceptional mass-cleaning phenomenon seems to have considerably reduced the locust potential in the west African and Sahel zone, enabling us to enjoy, since the end of 1988, a quiet period as regards acridian activity, despite the presence of a few populations in traditional breeding sites.

† 1 hectare = 10^4 m^2.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

(b) The organization of the locust control system: efforts and means

Algeria has responded to the 1987–1989 locust invasion on more than 2 million ha representing more than 30% of the treated area in the Maghreb (7 500 000 ha).

The dangerous evolution of the locust situation from October 1987 onwards had led the Algerian government to adopt exceptional procedures to face this plague so that minimum damage to agricultural production and the environment would result. The tasks of Desert Locust prevention and control are led by the National Plant Protection Institute (INPV), a specialized Public Service of the Ministry of Agriculture. During plague periods there is a strengthening of the preventive measures to ensure: (i) Government control; at the state's expense and conducted by the specialized public services in areas, such as in the Sahara and the Highlands, where swarms cannot be controlled by peasants. (ii) Collective control; to complement the public effort and locally conducted in the agricultural areas by peasants with coordination by professional associations.

The legal framework for this organization of locust control is provided by different laws, decrees and instructions:

(i) Decree No 67-177 dated August 8, 1967, appointing an interministerial committee responsible for the organization, coordination and evaluation of the Desert Locust control campaign.

(ii) Decree No 85-231 and 85-232 dated August 25 1985, related to the emergency organization and action at local level to prevent or face natural disasters, of which a Desert Locust plague is one.

(iii) Law No 87–17 dated August 1 1987, organizing the phytosanitary protection and prevention measures against pests and plant diseases, of which the Desert Locust is given top priority because of its potential damage to agriculture in both crops and pastures.

(iv) Instruction No 1 of July 13 1988, defining the tasks, organization and the creation of control groups during the invasion period.

(v) Instruction No 2 of October 16 1988, coordinating the collection and dissemination of Desert Locust monitoring and movement forecasts.

(vi) Instruction No 3 of March 1989, related to the protection of man and his environment.

Besides the legal form and organizational scheme at a high level, necessary to effectively control this plague over a vast territory, the following means have been progressively and rapidly deployed, beginning from February 1988: 50 light vehicles (4-wheel drive) for finding and monitoring the swarms; 60 heavy treatment vehicles fitted with exhaust nozzle sprayers; 200 heavy logistic transport vehicles; 1600 back sprayers (individual control in the oases); 60 airplanes (fixed wing and helicopters fitted with rotary atomizers); 5 million l of pesticides of which 3 million l have been sprayed; 500 plant protection technicians, and 1500 general workers (drivers, guides operators).

On the financial side, the control operations needed more than U.S. $36 million to meet the cost of pesticides and hired airplanes.

(c) The results and the weaknesses of the general mobilization

In tackling a national disaster such as a locust plague, it is difficult to quantify or even estimate all the positive results, therefore we concentrate on two main apparent effects. The first and most spectacular one was the successful protection of the major productive

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

agricultural lands that cover the northern zone, and the range lands and main irrigated areas of the central and eastern Sahara. Some damage has been noticed in the natural pasture lands of the western Sahara, in irrigated agricultural land of the Imperial Valley in the Saoura region (southwest Algeria), and in the bee-keeping farms that have not been protected against the aerial spraying. The second and more indirect effect is the considerable decrease of the locust potential, which could have reestablished in the Sahelian summer breeding zones if the Maghreb countries, mainly Algeria, had not made a major effort particularly in hopper control. Indeed, in Algeria alone, more than 700000 ha of hopper bands were treated during June and July 1988. Thereby the life cycle of the gregarious Desert Locust has been disturbed and even cut.

Even though the actions were successful, the field operations against the Desert Locust have been hampered by the lack of bio-ecological real time information on the migrant pest and of real time and precise observations on the prevailing meteorological conditions over the vast source and target areas. This hindered the making of medium term forecasts of swarm movements, the strategic deployment of control equipment and the most efficient use of chemical spraying. In fact, the protection of the agricultural potential led the organization in charge of control of this plague to set up some techniques, means and procedures that were certainly efficient, but that left some negative effects on the environment by accumulating some pesticide residues in the water and food chain.

Although the efforts made by the countries of the Maghreb and of West Africa have been considerable and costly, better control of the locust phenomenon should in future be obtained through a strict coordination of the general prevention programmes, not only between these two subregions of Africa, but also between them and the central regions of East Africa and the Middle East. In this respect, the role of the international (FAO, ECLO, Organization for African Unity (OAU)) and regional organizations (CLCPANO, OCLALAV, DLCO-EA) appears predominant in locust information collection and its transmission and treatment. This is in addition to the training of specialists in control techniques and the coordination of the necessary field research.

3. The coordination at the regional and bilateral level

To be able to take charge of the prevention and the control of Desert Locust plagues, the four Maghreb countries created in 1972, under the aegis of FAO, a regional specialized commission named CLCPANO (Desert Locust Control Commission for northwest Africa). In 1988 Mauritania joined the commission. Its members are the Agriculture Ministries in charge of Desert Locust prevention and control. An executive committee composed of experts from each country meets every year in recession periods and as often as necessary during invasion situations. The secretary of the commission installed in Algiers is in charge of the coordination with FAO, and the collection and regular dissemination of locust and meteorological information.

This commission has been very active in the training of locust specialists, the organization of workshops on locust control and on meteorological needs for better preventive control. It has been prominent in the conception of guides and manuals, and the conduct of locust prospection campaigns in summer breeding areas such as southern Algeria, northern Niger, Mali and Mauritania.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

During the invasion period of 1987–1989, the Maghreb commission organized or contributed to meetings or seminars in:

(i) Tunis (Tunisia), March 1988; a common strategy for the control of Desert Locust.

(ii) Rabat (Morocco), April 1988; adoption of a strategy for the period May–September 1988.

(iii) Tamanrasset (Algeria), May 1988; coordination of the financial means for a common preventive strategy. During this meeting the creation of a Maghreb task force was agreed together with the strengthening of the meteorological observing network over all the summer breeding Saharan area with a focal point at Tamanrasset Regional Meteorological Centre.

(iv) Nouakchott (Mauritania), June 1988: a common Maghreb strategy was adopted at the ministerial level and presented by the Ministry of Agriculture of Mauritania to the Desert Locust Control Committee of FAO.

(v) Rabat (Morocco), September 1988.

These meetings have permitted the establishment of a Maghreb fund and a Maghreb prevention task force, which started working in association with neighbouring countries (Niger, Mali, Mauritania).

On the other hand, the CLCPANO commission has contributed to the conception of an inter-regional project for Desert Locust control, which aims to strengthen the plant protection services of eight countries from the Sahel and the Maghreb, which may be financed by FIDA (International Fund for Agricultural Development) and executed by FAO.

In addition to this regional system of coordination many bilateral agreements have been elaborated by Algeria and signed with Morocco, Tunisia, Libya, Niger, Mali and Mauritania. This was done, to coordinate the control effort, to normalize the observing system, to exchange locust forecasts and also to make rational use of mobile equipment, mainly in the border regions.

4. Meteorological assistance to the Desert Locust control

In addition to a seminar on hydrological resources in the Sahara, a conference held in Tamanrasset in May 1980 on the need for meteorological data for Desert Locust Survey helped identify the necessity for reinforcement of the meteorological network in the border zones. A programme to install eight meteorological stations was made for data collection in central Sahara with the assistance of the National Plant Protection Institute.

Many seminars on acrido-meteorology have been organized and financed by the CLCPANO. These seminars have allowed preparations to progress for meteorological assistance in locust prospection and control.

Moreover, at the beginning of the first Desert Locust warning in August 1986, a new call for the reinforcement of the meteorological watch system in the summer breeding zones was made. Following an Algerian proposal, the African Regional Association of WMO adopted a resolution appointing a rapporteur for acrido-meteorological questions (Harare, December 1986) to suggest a pilot project to WMO/FAO to finalize these proposals for meteorological assistance to Desert Locust prevention and control.

This first alert has allowed the Algerian meteorological service to request and obtain a telecommunication line between Algiers, Dakar and Cairo (October 1986, December 1986). This is in addition to the existing links with Niamey (Niger) and Jeddah (Saudi Arabia).

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Thus the Algerian meteorological service was linked to all centres of the regions concerned with Desert Locust problems. The first forecast of Desert Locust movement was made for the October 1987 invasion. On that occasion, the regional meteorological centres (Tamanrasset and the border stations of Tindouf. In Guezzam and Bordj Bordji Mokhtar), played a major role, but in spite of all the means involved, two main deficiencies were identified which are:

(i) The very low density of the meteorological network in the Saharan zone situated between the 15° and 25° north and between the Atlantic and the Red Sea. This is the main breeding and development area for the Desert Locust swarms before their invasion of the Maghreb region.

(ii) The lack of knowledge of the meteorological phenomena in the dry tropical zone and the difficulty to make a reliable medium range numerical weather forecasts (5–10 days) even by the most advanced meteorological centres.

From November 1987 onwards, information from the ECMWF was requested for humanitarian and emergency purposes, and this arrived three months later (February 1988). From the beginning of March and thanks to a link by telefax with ECMWF, the five-day forecasts of wind fields and rainfall at ground level and 850 hpa over the Maghreb area have been used for Desert Locust control. This was organized at the level of the central headquarters, bringing together all the services concerned (plant protection, aviation, meteorology, telecommunication, logistics). Later on, the importance of the plague on the regional side gave rise to a request for the numerical products of the U.K. Meteorological Office. These products covered the gregarious zone from India to the Atlantic via the Red Sea, which allowed a better understanding of the general situation and a better forecast for successive invasion five days in advance. These products, together with the experience gained in the field, have been used by members of the same team of meteorological forecasters from September 1988 onwards successively to reinforce the specialized services of FAO/ECLO. This action has been running now for 18 months and has been considered as advantageous by the Plant Protection Direction of FAO.

This experience, which has been going on intensively for two years, has proved that the meteorological products available at the local and especially at the European level, have contributed significantly to the organization of the Desert Locust prevention and control effort. The meteorological phenomena at the synoptic scale proved to be the major factors in the Desert Locust tragedy. The quick availability of these meteorological products by telefax transmission from the European meteorological centres to the national meteorological centre and then to the local control centres has been decisive in that a wind map is more expressive than a long telex. This technique of meteorological dissemination gave help in real time and enabled specification of some relations between the meteorological conditions and movement of the swarms.

However, some shortcomings have been felt and they concern mainly the meteorological conditions, which affect the locust reproduction in Sahara regions, and the effect of mesoscale meteorological phenomena on the aerial spraying of locust swarms. In view of those deficiencies, the need for a Desert Locust strategy was discussed at the regional seminar at Tamanrasset (May 1988), and later, at the international workshop on acrido-meteorology in Tunis (WMO/FAO, July 1988), it was decided to develop a permanent integrated meteorological and Desert Locust monitoring system to provide the necessary assistance for plant protection survey teams. This system, which will strengthen the World Weather Watch

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

network, should be fully integrated into the actual monitoring network of each country and may be structured as:

(i) A regional meteorological centre for the Saharan area built on the strategic site of Tamanrasset which is in the heart of the Desert Locust breeding area common to Algeria, Niger and Mali and which hosts an old locust research base.

(ii) A national climatic network to complement the actual network in central Sahara, limited in the north by the Saharan Atlas, and which will help to improve the aerial assessment of the rainfall and of air corridors necessary for the development and progression of the Desert Locust.

(iii) A regional synoptic network consisting of 50 automatic weather stations fitted with data collection platforms for transmission via Meteosat and covering the whole area of Desert Locust activity from the north and central Sahara to the Atlantic and the Red Sea (the north of Chad, Niger, Mali, Mauritania, southern Algeria and Libya).

(iv) Five mobile meteorological 'centres', which will complement the basic network in areas where the access is extremely difficult, but which represent important sources during the invasion or remission periods.

This regional and national meteorological monitoring network will rely on and also strengthen the integrated system of the World Weather Watch. In parallel, the Desert Locust control plan should allow for the following actions:

(i) Establish a permanent locust watch (monitoring) system as a main component of the plan of action to strengthen and reorganize the preventive control of the Desert Locust plague at the national, regional and international scale. As a matter of fact, the Desert Locust research base of Tamanrasset could well present an important focal point because of its strategic position in the main Saharan breeding zone.

(ii) Maintain permanently the prospection teams in the field, to allow them, supported by the past, present and forecast meteorological information, to go through all the potential breeding areas where the ecological conditions might be favourable to Desert Locust development. When searching the large desert areas, contact could be made with the nomads or travellers, and even the newly settled peasants, to complete the survey and to cover wider areas.

(iii) Develop plans to train observers and scouts, plant protection inspectors, meteorologists, peasants and even local administrative authorities to build a unified team for locust control. Because of the wide development of agricultural production in the Sahara, all of these have a vested interest in such control.

(iv) Finally, the plant protection services of the different countries should develop a permanent system for the free exchange and dissemination in real time of locust observations and forecasts of their movement. Such exchange should be modelled after the World Weather Watch, which is coordinated by WMO and has already proven its efficacy as an example of international cooperation. This coordination, for instance between the national Maghreb services, should be done by the Regional Desert Locust Commission (CLCPANO) and may take advantage of the FAO regional Desert Locust control project, which is planned to cover eight neighbouring countries of the Maghreb and the Sahel. An exchange of basic locust information could be done directly between the regional centres of north Africa, the Sahel and the Red Sea, the international coordination being left to FAO/ECLO in Rome.

In conclusion, and having in mind the recent field experience of the 1987/1989 Desert

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Locust plague, it is extremely urgent to consolidate and perpetuate an integrated monitoring system for locusts and meteorology (acrido-meteorology), knowing that the Desert Locust is a permanent calamity and a constant threat over a long time. This integrated system should allow a minimal use of pesticide, which used in large quantities represents another threat to the environment. Besides this important objective, the meteorological network covering those Saharan areas will also enable better use of the water resources, the range land and the development of agriculture for a better life for the local population.

Discussion

K. A. Browning, F.R.S. (*Meteorological Office, Bracknell, U.K.*). Most of the meteorological data that Mr Boulahya was using were synoptic data. There wasn't much said about mesoscale or local scale data, or about the smaller scale information obtainable from satellites. Is this kind of information used?

M. S. Boulahya. I started at the regional scale only because it is very important. On the local scale, satellite data are used to follow rainfall events. We were grateful in September 1988 to receive a satellite receiving system from the U.K. Government, which has been installed at Tamanrasset. There, it is being used to monitor probable rainfall distribution, with ground teams scouting to verify the information. Secondly, an automatic station transmitting through Meteosat (Data Collection Platform, DCP) was installed at In Guezzam, 400 km south of Tamanrasset at about 20° N, so ground proof of this rainfall information via satellite is also received. This local scale information is used mainly for rainfall distribution and for directing aircraft operations, forecasting low-level winds, etc., for where and when the planes should fly. But forecasting for general aviation was not new in Algeria, only its application to the anti-Desert Locust campaign.

D. E. Pedgley (*ODNRI, Chatham, U.K.*). We cannot fail to be impressed by the energy with which Mr Boulahya has tackled the severe and sudden problems faced by Algeria during the swarm invasions of 1988. He has made use of forecast wind fields, temperature and rainfall, derived from global numerical models, but I wonder to what extent he has found them to be realistic? I ask this because there is a pressing need to validate these forecasts in some parts of the world, not least over Africa.

K. A. Browning, F.R.S. As Mr Boulahya answers Mr Pedgley's point, could he also perhaps comment on the accuracy of the rainfall forecasts, which may be even more vulnerable to errors.

M. S. Boulahya. For winds, pressures and temperatures, the numerical forecasts were alright for our needs up to five days ahead, by using the products of Bracknell and Reading. The rainfall forecasts are not sensitive enough for the locust work, it is necessary to know where grass is going to grow and where the soil is wet enough for egg laying.

W. H. Lyne (*Meteorological Office, Bracknell, U.K.*). The Meteorological Office is a supplier of some of the products used by the Algerian Meteorological Service for locust and weather monitoring, and it was gratifying to learn of the good use to which they are being put by

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Mr Boulahya and his colleagues. These products are sent only to Algeria at present, communications being a major problem in the supply of numerical weather prediction products to the African continent.

The Meteosat Meteorological Data Distribution (MDD) mission, now entering its demonstration phase, should provide a means of making such products more readily available to meteorological services within Africa and the Middle East. As well as the standard meteorological products, specialized products more directly related to the locust problem could be transmitted. Examples might include vertical velocity and convergence or divergence. The allied DCP mission should also enable more observational data from Africa both to reach the Numerical Weather Prediction (NWP) centres and to be redistributed back to the continent by MDD.

One of the more specialized products the Meteorological Office supplies is trajectory data, and these have recently been utilized by Mr Thomas of the Food and Agriculture Organization in an investigation into the arrival of locusts in the West Indies in the autumn of 1988. These trajectories were calculated from analysed data archived routinely at Bracknell from the numerical forecast model.

Numerical forecast models are under continuous development, with the present version to be replaced later in 1990. This will have a higher resolution, improved parameterization of physical processes, and should lead to improvements in the quality as well as the range of products.

M. S. Boulahya. We are working with Bracknell and the European Centre on the existing trajectory models for following air pollution and nuclear fallout, to refine them for use on the Desert Locust. They need to be more precise because the Desert Locust is an active element and not a passive one. We plan to do this work with colleagues from biological backgrounds. The existing model gives some idea, but not the right one, because it doesn't assume that the locusts stop flying at night, for instance, so we have to stop it at a certain time and then start it again at another time; we don't know how to do this within the present model.

The locust watch system started during the plague years and we hope to continue with it, as it is the best way to assist preventative control.

D. Rijks (*World Meteorological Organization, Geneva, Switzerland*). On behalf of Professor Obasi, Secretary-General of WMO, I thank the organizers of the meeting for the invitation to participate in the discussions. Mr Boulahya has mentioned the role of weather information in the preparation of forecasts for the development and movement of Desert Locusts, and proposed arrangements to enhance this role. Such use of weather information is one of the public services that is being promoted under the Application of Meteorology Programme of WMO, that can show the economic and social benefits of the use of meteorological information. These economic benefits include not only the timely mobilization of resources for locust control, but also the timely demobilization. A demobilization coming too late can be quite costly. Meteorological information is used to increase the efficiency of the tactical movements of intervention forces. Spray pilots estimate that during the past campaign they spent about two thirds of their flying time in conveyance and one third on actual spraying. The total amount paid for flying time was about $100 million. Therefore, even a modest increase in efficiency of conveyance, through the use of trajectory estimates of expected locust movements, could mean a decrease of millions of dollars in spraying costs. Use of such trajectory estimates would also increase the number of

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

hours of possible treatment of swarms, before flight. Other benefits of a social or environmental nature are more difficult to quantify in monetary terms, but they are recognized by national decision makers as important.

Although improvements in the forecasting of development and movement of Desert Locusts certainly need to be and will be made, the present capabilities have credibility. Therefore the step from a curative to a more permanent preventive locust observing and warning system seems feasible.

Mr Boulahya has stressed the need for a regional approach, which appears to be the only one practicable. To facilitate this, a coding of acrido-meteorological information on the meteorological communication system has been proposed, and will probably soon become operational. This would help to achieve a 'global Desert Locust watch' analogous to the world weather watch of WMO. In addition to this international cooperation, there is need for interdisciplinary cooperation (such as shown by the participants in the meeting in Tunis in July 1988, organized jointly by FAO and WMO), and increased cooperation between European and African scientists and technicians (as witnessed by Mr Boulahya's presence at this meeting). The results of actions on the recommendations of the Tunis workshop have been described in a circular letter from the Secretary-General of WMO, dated 13 October 1989, ref. WMO 36.229/M/AGDL.

The implementation of the 'Desert Locust Watch' does need the installation of about 50 automatic weather stations, transmitting via satellite links, to complement the existing synoptic network and to provide the ground-based information that enhances the value of remotely sensed information and vice versa. A start on the installation of this network has been made in cooperation with bilateral donor agencies. The payoff of such a network will not only be in Desert Locust control, but also in many other fields, including Climate System Monitoring and studies on climatic change.

WMO fully supports the training proposals made by Mr Boulahya. Perhaps, in addition, spray-pilots could be helped to understand better the physiology and habits of Desert Locusts, to help them achieve the highest possible efficiency in control operations. Such type of 'training' for agricultural aviation operators is generally provided and required for operation in the U.S.A.

The most important lesson from a locust control operation that cost about $300 million in the past few years, is that a permanent locust watch, capable of preventive control, at the cost of 1% or less of the curative operation, is a sensible proposition, to be implemented as rapidly as possible. It should, and can use the existing meteorological infrastructure, and provide for complementary infrastructure, if and where requested.

P. M. Symmons (*FAO, Rome, Italy*). FAO is obtaining a trajectory model; which will push swarms around by using the winds at varying heights. The work that will be done on our model will be primarily to explain past events. If the present location of the locusts is known, one can usually tell where they've come from, but that's very different from saying where they are going to go. Work on solitary locusts is even more problematic. We know very little about the controlling mechanisms that will cause non-swarming locusts to take off into the night sky. Predictions of the type Mr Boulahya has been talking about are certainly useful for the direct deployment of aircraft for swarm control, but then it is necessary to predict, to a scale of tens of kilometres in space. I would emphasize that one can go a long way if the reporting and reporting-back system for the control is working well.

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