CROP PROTECTION PROGRAMME

Identifying the factors causing outbreaks of armyworm as part of improved monitoring and forecasting systems

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FINAL TECHNICAL REPORT

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Executive Summary

Twenty two participants, representing farmers, District Agricultural Officers, chemical suppliers, extension officers and various government departments such as pesticide registration and district management, attended a workshop in Arusha, Tanzania to make plans to further develop existing armyworm forecasting methods. A key outcome was to explore alternative models for the forecasting process, involving various degrees of decentralisation, to complement rather than replace the existing national system.

The national system requires real-time, spatially accurate rainstorm information. Derived from Meteosat images, the likelihood of storms on each day and in each district of Tanzania has been made available to the national forecaster. An armyworm web site provides this information. Pheromone trap, rain gauge and Meteosat data can now be stored and collated so that the information can be compared by the national forecaster to make the weekly forecast for each district. The software to do this, 'Windows Armyworm Database Interface' (WADI) was developed in Access 2000.

A socioeconomic survey assessed whether farmers would be interested in carrying out their own armyworm forecasting (using a rain gauge and pheromone trap located in the village), and in what way they are willing to respond to forecasts, either local or national. Community based pilot schemes were set up in 5 villages in Kilosa District, an armyworm 'hot-spot'. The design of the community-based forecasting was shared by the communities themselves and during the first year of the pilot study, traps were successfully run and forecasts made in all of the participating villages.

Forecasting rules were developed and initial results indicated that the approach providing good forecasting accuracy even before trap calibration (only possible once data exist for the traps concerned). A forecasting pack in both Kiswahili and English has been produced to accompany training in community forecasting. This includes basic information about armyworms and how they can be forecast, instructions on how to operate the pheromone trap, the rain gauge, and how to record and interpret the data to make the forecast.

An analysis of national records of armyworm outbreaks, and trap catches showed that the national network of traps gave a good indication of periods when armyworm activity was generally high. The details of the prediction were, however, frequently inaccurate, with outbreaks occurring in different weeks and in different districts to those predicted. This is partly because spatial variation is high relative to the density of traps. A key future need is to follow the accuracy of the community traps.

The socioeconomic survey involved the assessment of yield losses and benefits derived from control with insecticides. A cost benefit analysis of the value of armyworm control, and of the value of following a forecast, revealed that when an armyworm infestation occurred, highest returns were obtained when spraying was carried out but not replanting. This was the case despite frequently poor timing of application and therefore poor spray efficacy. A useful outcome of the community-based forecasting pilot was that farmers tended to become aware of armyworm infestations in their fields at an earlier stage and so increase the opportunity for timely control.

Background

The constraints the project sought to address related to the production of cereals, staple crops in east Africa but with yields that are highly variable due to the unpredictability of climate and pest attack. This variability is a key constraint to rural development, causing periodic crisis and hardship for rural communities. Improved forecasting of sporadic but serious crop pests is at the heart of the approach to reduce this variability. The losses due to armyworm, *Spodoptera exempta*, are virtually zero in some years and immense in others (Scott 1991). A reduction in the impact of armyworm attack, hinges around the timely supply and use of effective agro-chemicals (which are also safe and environmentally benign). Forecasting is directed toward improving the supply, targeting and timing of pesticide use.

The demand for the work came from the RNRKS programme management which called for research to identify the factors causing outbreaks of armyworm in order to allow the development of improved monitoring and forecasting systems. This need was highlighted in the DFID-sponsored workshop to identify research priorities for migrant pests (Rosenberg, Cheke & Kieser 1999). At the workshop, Mr. W. Mushobozi (pers comm.) described the extent of the problems caused in 1989/99 by armyworm outbreaks in Tanzania. Following the 1989/99 armyworm outbreak, Iles and Dewhurst (2002) confirm that poor monitoring and forecasting continues to constrain efficient control operations in many parts of east Africa. The demand for continued R & D support of the forecasting service in Tanzania was a clear message from the Tanzanian authorities.

To meet this demand, it was planned that the project would provide a means by which armyworm control could be costed and justified for the appropriate stakeholders to improve the availability of pesticides for rural communities at the time and place that they are needed. This will reduce the yield instability caused by armyworm attack. Approaches will be provided to predict with greater accuracy the location of imminent outbreaks as well as to relate these to the economic value of the crop production where the outbreaks occur. This will help to improve the efficiency of control operations, and improve yield stability.

The main target institutions are the village communities whose crops suffer armyworm attack as well as the armyworm control services in Tanzania. The latter includes the central forecasting station (Arusha) and the regional and district agricultural offices. The policy outputs in particular are also targeted at the Ministry of Agriculture and at international agencies involved in funding and organising armyworm control (DLCO-EA, RLCO-SA). The Pest Control Services (PCS) of the Tanzanian Ministry of Agriculture already runs a forecasting service. The new forecasting tools will extend the capabilities and increase the efficiency of their operation. The new tools will be developed with the forecasting services through a process of evaluation and feedback in a series of mini-workshops during the course of the project.

Armyworm causes devastating but highly localised damage to cereal crops and grassland (Scott 1991). It is a problem mainly in east Africa but also occurs in southern Africa. Insecticides or biopesticides can control the pest but only if these are applied within a narrow time window after the eggs hatch but before the larvae become large enough to cause significant damage. Control can be either tactical to protect the crops on which the outbreak occurs, or strategic where control measures are applied to prevent the dispersal of armyworm to cause subsequent outbreaks elsewhere. The adult moths arrive in large numbers at new locations being borne by prevailing winds and concentrated by convergent wind-flows associated with rainstorms (Rose *et al*. 1987; Rose *et al*. 1995). Thus, eggs are laid at high densities and larvae emerge to destroy crops where previously no armyworm was present. The protection of crops from armyworm requires a) that intensive scouting is carried out in areas of high outbreak risk and b) that insecticides and government application teams or farmers are at the right place at the right time to treat the localised but often large areas which are infested. Forecasting has a key role in both tactical and strategic control: short-term forecasting to guide scouting operations and medium-term forecasting to manage the control logistics.

Existing forecast procedures in Tanzania involve an institutional hierarchy of operations: farmers and local extension officers, district agricultural officers, central government, regional organisations. (Odiyo 1990; Day and Knight 1995). Forecasting is carried out at more centralised levels based on information obtained from lower levels and the forecast is passed back from central to lower levels for action. The system relies therefore on participation at all levels and on rapid information flow. There is a need to re-examine the roles and needs of the stakeholders at each level and to develop forecasting tools and structures which can operate at the local level and in so doing also encourage participation at more centralised levels. Historical information of armyworm outbreaks and trap catches is of central importance in maintaining the forecasting system. There is a need to continually update and analyse these data to maintain accurate risk assessments.

The research reported here builds on the existing forecasting services operating in Tanzania and draws on a wealth of information provided from a research previously funded by DFID and others. This includes work on armyworm ecology (Rose *et al*. 1995), migration (Reynolds and Riley 1997), control economics (Cheke and Tucker, 1995), data management (Day *et al*. 1996), utilisation of remotely sensed rainfall data (Tucker 1997) and the development of forecasting models (Holt and Day 1993). The database, WORMBASE, developed to aid armyworm forecasting (Day *et al*. 1996) remains a key component of current forecasting operations in Tanzania (Tucker and Holt 1999; Holt, Mushobozi, Tucker and Venn, 2000).

Under a previous project, R6762, ‘Decision tools to aid armyworm surveillance and outbreak prediction’ (completed March 1999), a system for the weekly processing and provision of Meteosta data was developed and implemented, allowing PCS forecasters to compare remote-sensed CCD data with moth catch reports as part of the forecasting process. This was implemented at a one-degree square resolution such that results could to be transferred to PCS within an email via a third party. A model of armyworm population dynamics developed in this project (Holt *et al*.1999) was used to automate the process of relating CCD data to armyworm risk and so now can allow a forecast to be made at a much higher resolution.

At the start of the current project, a number of areas where forecasting can be improved were identified: i) *Resolution*. There is a need for a higher resolution short-term forecast of those areas at high armyworm outbreak risk. This will lead directly to improved operational efficiency by control teams as less time will be spent locating outbreaks. ii) *Accuracy*. The short-term forecast also needs to be more accurate and improved models are required to link rainfall patterns to armyworm trap catches. iii) *Prioritisation*. Under a widespread armyworm outbreak, resources may be very limited and some means of rational prioritisation of resources (pesticide and labour) is required. iv) *Resource allocation*. Resources for armyworm control are always in short supply and expenditure must be justified. There is a need to examine the costs and benefits of armyworm control for appropriate stakeholders.

Project Purpose

The purpose of the project was to develop strategies to improve forecasting and reduce the impact of migrant pests in semi-arid cropping systems, for benefit of poor people. The project aimed to provide new forecasting tools to relieve the information constraints to effective armyworm control, help with effective deployment of limited resources and provide a justification for specific levels of expenditure that can be related directly to the benefits gained in agricultural production.

Activities

Activity 1. Problems and research activities defined and updated.

Scoping workshop

Carried out in the early stages of the project, this played an important role in planning future work and indeed, project priorities changed as a result. The three-day problem specification and planning workshop was held at Arusha, Tanzania, from 9th to 11th October 2001. 22 participants attended the workshop, representing farmers, District Agricultural Officers, chemical suppliers, extension officers and various Government departments such as pesticide registration and district management. There were also scientists from Kenya and the U.K.

The main aim of the workshop was to explore the current state of armyworm control with regard to forecasting and the control methods used (Fig. 1). This information was then used to develop appropriate plans, a) for the testing and introduction of novel control methods such as the use of nuclear polyhedrosis virus and b) for the further development of existing forecasting methods for the early warning of armyworm outbreaks

Context for the workshop was provided by two technical presentations, one on forecasting and one on novel methods for control. The current intentions of the two projects on these topics were also summarised and it was stressed that the activities of the projects would be reviewed in the light of the workshop. A role-playing game proved effective in engaging all workshop participants in the possible problems faced by the farmer in making decisions about armyworm monitoring and control and whether to alter their behaviour on receipt of an armyworm outbreak forecast. Brainstorming was used to identify key variables affecting all aspects of armyworm management. Trends in these variables over the last 30 years were estimated. The occurrence of armyworm outbreaks was examined in relation to the cycle of activities over the farming year and regional differences within Tanzania.

Alternatives to the current (National) model for the operation of the armyworm forecasting service were considered. These involved various degrees of decentralisation to district level and community level organisation.

Appropriate approaches to novel control methods were explored by considering the benefits and constraints of different controls and application technologies that might pertain to three categories of farmers with different levels of resources (see Annex 1 for full workshop report).

Fig. 1. Small groups discussed the issues. Each then reporting back to the whole workshop in a series of short presentations

Socioeconomic survey

Following the workshop, a socioeconomic survey was carried out; the workshop having helped to define the issues it should address. In particular, the need to examine the feasibility of community-based forecasting, motivation to control armyworm in the context of the farmers other problems, and the resources available to different groups of farmers to carry out control were examined.

The survey collected information from 289 individual farmers and 25 farmer groups in four districts. The central goal was to determine a feasible route forward for the implementation for both novel control and forecasting. There were five overall objectives.

1. To determine the effectiveness, problems and constraints of the current forecasting service, particularly from the farmers' point of view.

Although centralized forecasting is designed to provide information for government agricultural officers, the warnings of impending outbreaks are also intended to reach farmers, so that they can take appropriate action. Previous surveys had collected little information from farmers on their perceptions regarding the forecasting service, but the project inception workshop identified this as an important area to be assessed during the survey. Problems and constraints with running the service are also summarized.

2. To determine farmers' armyworm control measures and the potential for adoption of novel control methods.

Understanding farmers' constraints and decision making regarding armyworm outbreaks and control measures is important both for improving the value of the forecasting service, and for developing and implementing novel control methods. A forecast is only valuable to farmers if they are in a position to act on it and undertake control activities. Novel control measures must compare favourably with current options if they are to be adopted.

3. *To determine farmers' perceptions of the costs and benefits of armyworm control measures.*

Farmers' decision making is likely to be determined by several factors including their assessment of yield losses caused by armyworm outbreaks, the costs of control (both monetary and indirect), and the effectiveness of the control in terms of reduction of crop loss. The actual yield loss in a particular field will be a complex function of many factors, so no attempt was made to unravel all the complexities. Rather, an attempt was made in this study to determine the farmers' perceptions, and how they affect decision behaviour.

4. To ascertain farmers' views on the potential of community based forecasting and control.

The participants at the October 2001 project inception workshop assessed a number of possible options for forecasting systems, and recommended that community based forecasting be investigated further. During the survey the possibility of forecasting was introduced, and the farmers' ideas on how it might be implemented were gathered.

5. To determine how resource endowment and socio-economic status of farmers affects their perceptions and decision behaviour with regard to armyworm outbreaks and control.

The resources a farmer has at their disposal is likely to affect how they view and tackle any problem, including armyworm attack. Resource poor farmers are likely to be more vulnerable to armyworm outbreaks, so it is important to take resource endowment into consideration when devising improved forecasting and control.

Mini - workshops

Two workshops were held during the course of the project. Their objective was to discuss project activities and results and to consider the future needs of the work together with any resulting implications for project activities and funding. The workshops were held at NRI Chatham with representatives of all collaborators for both the forecasting, and the novel control, projects.

The first workshop concentrated on discussion of the initial results from the socioeconomic work, the planning of the community-based forecasting pilot study, the design of the information pack to accompany the pilot, and discussion of options for a new armyworm data management system.

In the second workshop, the draft results from the socioeconomic survey, progress on database (WADI) development, and initial results from the community-based forecasting were discussed. Possible routes forward for the future development of the community-forecasting approach were also discussed.

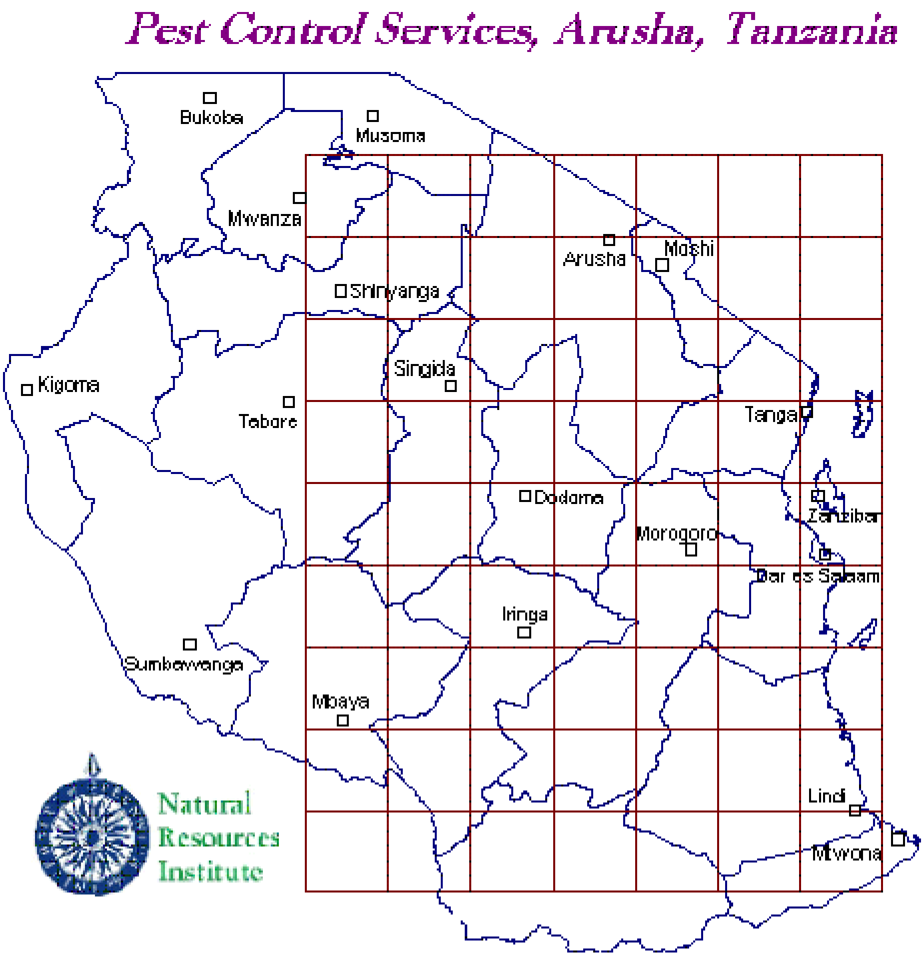
Activity 2. Armyworm outbreak risk forecast developed

Satellite Remote Sensing

Armyworm outbreak forecasting relies on the comparison of information from various sources. Armyworm pheromone trap catches provide information about the timing, location an abundance of moths. Even at a time or place when moths are abundant, however, armyworm outbreaks will not occur, if the rainfall conditions (and the associated vegetation conditions) are not suitable.

Rainstorms depositing sufficient rain to stimulate grass and/or crop growth are required. Such rain is usually associated with large storm clouds, and such storm clouds have the further effect of creating air movements which act to concentrate and deposit airborne moths. It is therefore the detection of such rainstorms that is one of the key elements of the national forecasting system. The role of the satellite remote sensing in the project was to provide detailed spatio-temporal information of storm clouds and the project has developed the capture, processing, display and provision of this information as a component of the forecast.

Fig. 2. Tanzania districts and satellite data collection grid covering the area most affected by armyworm



The satellite data gives an estimate of meteorological risk, an indicator of the quality of the conditions for moth concentration and deposition, egg hatching and larval growth. Initially the data were processed and displayed as a rectangular grid of degree squares covering the armyworm-affected areas of Tanzania (Fig. 2). During the course of the project the whole exercise was reconfigured on the geographical boundaries of districts because the final forecast, which integrates all information sources, is issued on a district by district basis.

The Meteosat satellite is in geo-stationary orbit over the equator and the meridian line, so that a receiving dish in Tanzania would point to the West. Sensor sweep is from South to North, and all of the data for Africa are acquired before those for Europe. Data are received on channels for infrared, visible light and water vapour.

We use the infrared channel, which is calibrated to give an instantaneous thermal record of the Earth and cloud tops scanned. A -50°C threshold is chosen to indicate rain from storm clouds. The satellite does not measure rain not associated with storm clouds. The sensor sweeps every half-hour and the data acquired is the number of hours that rain was recorded in a day. This is called daily Cold Cloud Duration, with values varying from 0 to 24.

These data are stored in the form of a false-colour image of the area acquired and can be displayed with coastline and political boundaries as reference (Fig. 3). Maximum values are extracted for each degree square in central and East Tanzania. Later this process was performed for districts rather than degree-squares. The accumulated weekly dataset is fowarded to the national armyworm forecasting service, Pest Control Services, in Arusha, Tanzania. Initially, this was done by email and read by the National forecaster at an internet café. More recently, it has been possible to introduce a more robust system and the weekly CCD data are displayed on a web site which PCS can now access via their newly-installed internet connection.

The Armyworm website

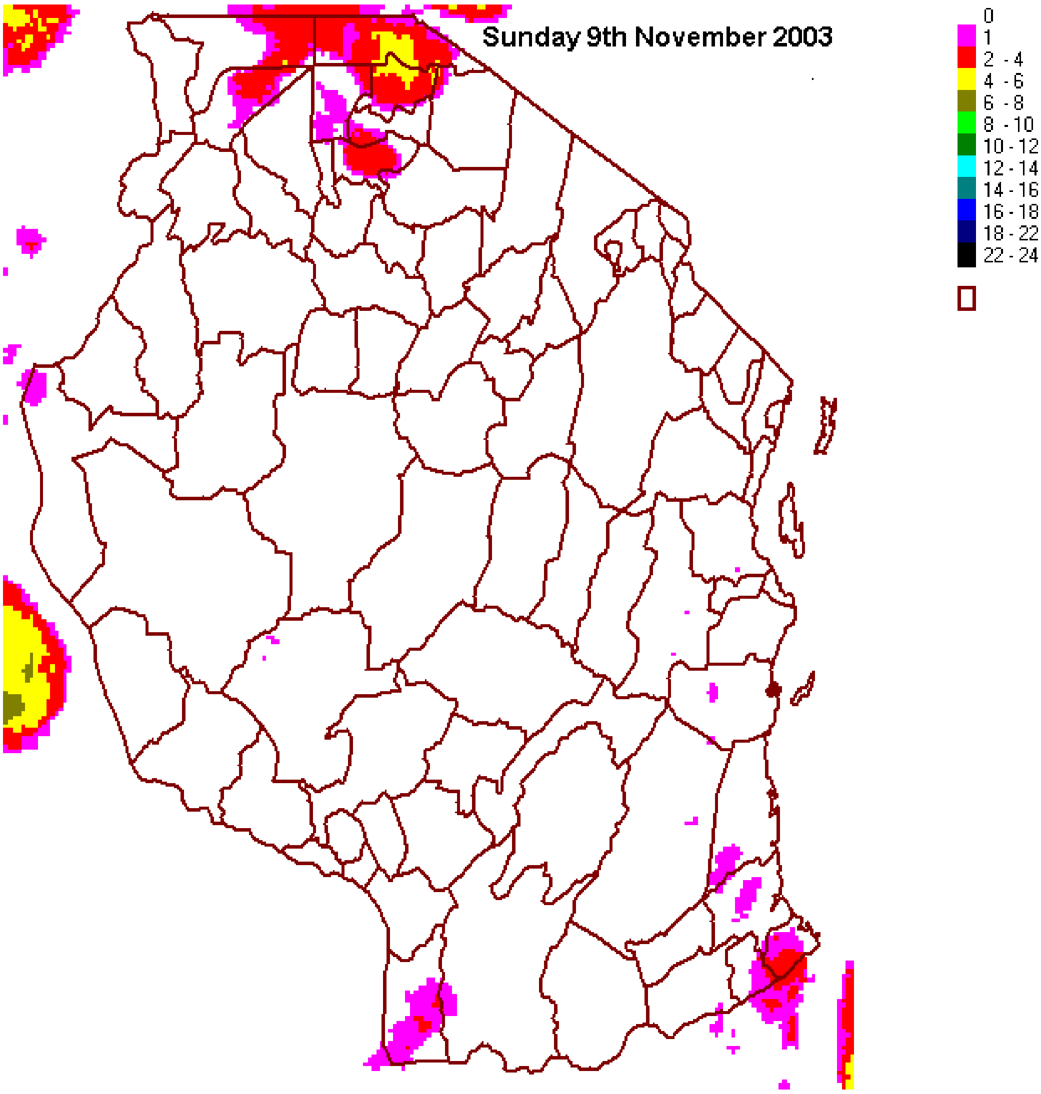
A website, hosted by the University of Greenwich was created during the course of the project. The purpose of the website was to facilitate information transfer to support the armyworm national forecasting activities in Tanzania. During the armyworm season, the website was updated weekly with the latest satellite CCD data. The corresponding armyworm outbreak risk forecasts issued by the national forecasting office in Tanzania were also added to the website as available. The national forecaster used to access the website via an internet café or hotel business centre in Arusha. At the very end of the project it was possible, using a satellite receiver installed at PCS, Tengeru, to establish a direct email / internet connection to the office of the national forecasting service.

The website address is: http://www-web.gre.ac.uk/directory/NRI/pcs/

The Pest Control Service Internet connection

A company called SatCoNet was commissioned to set up Broadband Internet Access for Pest Control Services, Tengeru. The connection operating via the IntelSat satellite provides simultaneous access for two users. A 1.2 m VSAT Antenna was installed together with associated indoor unit and cabling. The computers can be directly connected to the VSAT system using a RJ45 Ethernet / USB port.

Fig. 3. Example of CCD image of Tanzania with an overlay showing the district boundaries. Colour-code indicate the number of hours of cold cloud occurring on a particular day at each point in Tanzania



Evaluation of the national forecasting effort

The objective was to examine the relationship between moth trap catches and armyworm outbreaks in the historical records to see if this could lead to an improved interpretation of trap data. Of particular concern was to answer questions arising in relation to the community forecasting approach where relatively simple rules were necessary to allow communities to interpret their armyworm trap data to predict outbreaks. Issues include the sphere of influence of trap, the catch threshold for outbreaks, the likelihood of errors (false positives and false negatives) and how these might be reduced.

Armyworm pheromone trap records from Wormbase (Day *et al*., 1995) were examined for the 94/95 armyworm season. This season has a particularly good set of records. Time series of daily trap records together with rainfall data were plotted for those traps with long runs of data. The records were summed to give weekly moth catch totals for each trap. The trap catch and rainfall data were compared with the outbreak reports for the same period. The estimated hatch date associated with each outbreak was taken from the outbreak data.

For each district, the estimated hatch dates of outbreaks occurring in the district were compared with the moth catches for the trap or traps in that district. The hatch date of an outbreak would be expected to occur in the same week or the week after the associated moth catch. The district was used as the common unit of comparison because the geographic co-ordinates of the locations of the outbreaks were not always known.

The results are summarised in Table 1. Trap catches >0 (yellow or light shading) and >= 30 (red or medium shading) and the hatch date of outbreaks (blue or dark shading) are indicated. Traps were grouped arbitrarily into geographic clusters.

In the first cluster comprising three traps in Arusha Region, trap 33 in Hanang District gave weekly trap catches exceeding 30 four times in a six week period commencing on Week 51, but no associated outbreaks were reported in that district. Substantial rainfall was also recorded in three of the four weeks concerned. It is likely, therefore that an incorrect positive forecast would have been issued in those three weeks. In Week 4, both a high trap catch and rainfall were associated with the estimated hatch date of a reported outbreak. Conditions apparently favourable to outbreaks therefore occurred for more than one month before any outbreaks were reported. In a second trap in Hanang District (Trap 34), no catch greater than 6 moths occurred in any week. In Babati, no weekly catch totaling greater than 6 moths was observed and no outbreaks were reported in that district.

A second cluster of traps lay in Morogoro, Dodoma and part of Iringa Regions. Here, in Kilosa District, a sudden increase in catch occurred in Week 1 but the estimated hatch date of outbreaks started two weeks earlier. It is therefore likely that this trap did not detect the increase in moth numbers that led to the first reported outbreaks in this district. Both traps in Dodoma District started catching moths in the same week (Week 1) but not in large numbers. No outbreaks were reported in Dodoma district but in neighbouring Mpwapwa District, outbreaks coincided with the appearance of moths in the Dodoma traps. Unfortunately, the Mpwapwa trap was not reporting at that time. The Kilombero trap had low catches and no outbreaks were reported. Unfortunately, this trap did not start reporting until Week 19. The first Iringa trap report was on Week 2, and the estimated hatch date of an outbreak in Iringa was also in that week. The catches for this trap were zero initially and remained low throughout. It therefore appears that this trap did not detect the moths associated with this outbreak.

A third cluster of traps lay in Kilimanjaro and part of Arusha Region. Peaks in moth catches occurred in the Moshi and Arumeru traps in Week 26 but no outbreaks were associated with these moth catches despite the simultaneous occurrence of heavy rain in the case of Moshi.

The only other trap reporting large catches was at Rungwe, one of a cluster of traps in SW Tanzania. There were similarities to Trap 33 in Hanang with high moth catches and substantial rain occurring a number of weeks before any associated outbreaks were reported.

Table 1. Comparison of trap catches with subsequent outbreaks

Comparison of weekly total pheromone trap catches and estimated hatch dates of outbreaks reported in the same district as the trap for the 94/95 armyworm season in Tanzania

Region	Arusha (W)						Morogoro, Dodoma, Iringa (N)												Kilimajaro, Arusha (E)						Mbeya, Iringa (S)						Tanga			
District	Hanang		Hanang		Babati		Kilosa		Mpwapwa		Dodoma		Dodoma		Kilombero		Iringa		Moshi		Arumeru		Rombo		Mbozi		Rungwe		Njombe		Muheza		Korogwe	
Trap no./ outbreak report (R)	33	R	34	R	54	R	1	R	11	R	88	R	2	R	3	R	28	R	6	R	18	R	42	R	8	R	73	R	72	R	9	R	40	R
Week																																		
41					0		0				0																0				0			
42					0		0				0																0		0		0			
43					0		0				0																0		0		0			
44					0		0				0																0		0		0			
45					0		0				0																1		0		0			
46	0		0		0		0		0		0		0								0		0				0		0		0			
47	0		0		6		0		0		0		0								0		5				0		0		0			
48	19		0		3		0		0		0		0								0		1				0		0		0			
49	17		0		0		0		0				0								0		2				3		0		0			
50	3		0		4		0		0				0								0						65		0		0			
51	37		0		0		0		0				0								0						38		0		0			
52	57		6		6		0		0				0								0						8		0		0			
53	22		0		1		22		0				0								0						14		0		0			
1	50		2		0		235				22		3								0		0				34		0		0			
2	55		2		0		74				8		5				0				0		0		8		52		0		0		0	
3	3		0		1		4				0		2				1				0		0		5		19		0		0		5	
4	48		5		1		9				0		0				0				0		0		1		16		0		0		12	
5	10		4		0		19				5		0				2				0				4		39		0		0		3	
6			0		2		0				0		0				0				0				1		15		0		0			
7			2		1		0				0		0				0				0				0		13		0		0			
8					0		0				0		0				0				0				0		8		0		0			
9					0		0						0				0				0				1		14		0		0			
10					0		0						0				0				0				14		0		0		0			
11					0		0						0				2				0				1		0		0		0			
12					0		0						0				2				0				0		0		0		0			
13					0		0						0				0				0				1		0		0		0			
14					0		2				0		0				2				0				0		1		0		0			
15					0		1				0		0				2				0				0		0		0		0			
16					0		1				0		0				3				0				0		0		0		0			
17					0		0				0		0				1				0				0		3		0		0			
18							0				0		0				2				0						9		0		0			
19							0				0		0		0		3				0						4		0		0			
20							0				0		0		0		2				0						14		0		0			
21							0				0		0		0		1				0						66		0		0			
22							22				0				4		2				0						53		0					
23							6				0				1				5		0						91		0					
24							0				0				0				1		0						74		0					
25							3				0				0				21		8						101		0					
26							7				0				0				228		29						119		0					
27							1				0				0						0						106		0					
28							0				0				0						0						9		0					
29							0				0				0						0						2		0					
30							0				0				0						0						17		0					
31							0				0				0						0						84		0					
32							0				0				0						0						51		0					
33							0				0				0						0						0		0					
34							0				0				0						0						13		0					
35							0				0										0						7							
36							0				0																2							
37							0				0																2							
38							0				0																1							
39							0				0																3							

Activity 3. Economic risk forecast developed.

Economic data acquired form the survey were collated for the analysis carried out under both Activities 3 and 5. Agreed changes in the project from its initial conception reduced Activities 3 and 5 which are now discussed together under Activity 5.

Activity 4 Forecasting tools adapted for different levels and tested

National forecasting tools

A key output from the scoping workshop in the early part of the project was the need for a 'mixed model' in the future organization of armyworm forecasting in Tanzania. It was agreed that options for more locally-based forecasting should be explored but that there would always be a need for the centralized national service both to support local activities, to provide an overall picture, liaise with policy makers and indeed produce a forecast for places where no local forecasting takes place.

Vital to the centralized function is efficient data handling. Such data management would need also to support any locally based forecasting to allow local forecasts to be evaluated and improved. A windows-based data management system was developed during the project with the acronym WADI which stands for 'Windows Armyworm Database and Interface'. The objective of this software was to serve the data handling needs of Tanzania's national forecasting operation. The most pressing needs of the national forecaster were established to be a) a smoother data entry system, and b) a means to make direct comparisons between different types of data when formulating the weekly forecast for each district.

In drawing up the specification, the intention was to include the minimum that would constitute a self-contained and useful tool for the national forecaster. Essentially this includes a means to enter all the types of data that arrive at PCS, Tengeru plus a means to display these data in a form that is convenient to produce the weekly forecast.

Local forecasting tools: Community Based Forecasting

Community based forecasting was not originally envisaged as a major activity, though activity 4.1 was the development of forecasting tools for different users and 4.2 was local dissemination. During the project inception workshop an analysis of the problems and constraints associated with the current forecasting system led the participants to recommend a trial of a novel approach to forecasting, in which data are collected and analysed, and a forecast prepared, all at the village level.

The workshop also recommended that the possibility for community based forecasting should be included in the socioeconomic survey. As reported elsewhere, this was done, and considerable enthusiasm for the idea was expressed by the villages visited. The idea of forecasting at all was novel to over 70% of those interviewed. But once understood, the focus group discussions debated different models for its implementation, and concluded that forecasting should be undertaken by villagers (farmers), but with some level of involvement of the village extension officer and village government. The broad plan for the trial was discussed at the July 2002 project workshop at NRI (see Annex 2), and it was decided that the trial should be implemented in Kilosa district in the 2002/2003 season, in 5 villages where the socioeconomic survey had been undertaken. A further planning meeting was held at CAB International, Nairobi on 27-28 August 2002 when a detailed implementation plan was developed (see Annex 3 for the report). Six activities were undertaken to implement the trial.

a. ***Engaging the District Authorities***. A meeting was held at Kilosa District headquarters as the first step, to ensure ownership of the trial and to clarify the roles of the different stakeholders. The meeting was chaired by the District Extension Officer, and two officers (plant protection and community development) were appointed as counterparts who would be involved in the trial.

b. ***Village meetings.*** In each of the 5 villages where the trial was to be undertaken (Dumila, Madudu, Magole, Mvumi and Ilonga) a public meeting was held to re-engage the community, introduce the community forecasting trial, identify the farmer forecasters, discuss the communication of forecasts, and discuss what farmers would do on receiving a positive forecast (see Annex 4). The trial was well received, as it followed on from the survey; some farmers commented that outsiders who come to collect information are often never seen again! Each village elected their forecasters using a method of their own choosing; queuing, acclamation and secret ballot were all used. Five backpack sprayers (supplied by the Ministry of Agriculture) were provided to each village, which were rented out to villagers using a system subsequently arranged by the village leaders. Leaflets describing armyworm outbreaks, forecasting and control (in Kiswahili) were distributed (see English version in forecasting pack).

c. ***Training workshop***. In the week immediately following the village meetings, the two farmer forecasters from each village participated in a 2 day training workshop held at the Ministry of Agriculture Training Institute, Ilonga (see Annex 4). As well as the 10 farmers, the workshop was also attended by the 5 village extension officers, a technical officer from Ilonga Research Institute, and the 2 District Authority officers. The workshop placed emphasis on practical learning, but also included some classroom sessions. Participants learned about armyworm biology, how to set up and maintain a rain gauge and pheromone trap, how to collect and record data from the rain gauge and pheromone trap, how to observe vegetation suitable for armyworm outbreaks, and how to calculate and communicate the forecast each week. The workshop was conducted in Kiswahili. At the conclusion of the workshop each village was provided with a full forecasting pack (see outputs) containing the equipment, record sheets and leaflets.

d. ***Forecasting.*** On the Friday immediately following the workshop (22 November 2002), the farmer forecasters set up the rain gauge and pheromone trap, and the following day recorded the first data. Data was recorded daily, and each Friday the forecast was calculated using simple rules based on the PCS forecaster's expert opinion. The forecasting continued until the end of the March.

e. ***Mid-season monitoring/field days.*** In mid January 2003, a field day was held in each village, as part of a mid-season review of progress with the trial (see Annex 5). There were five objectives of the activity: raise awareness of the trial in the village; assess the forecasters' data recording and forecasting; review information flow when a positive forecast was issued; examine control activities; discuss with the different stakeholders how they viewed progress with the trial. The forecasting system was found to be working well. Forecasters were maintaining good records, and some were recording additional information, such as written notifications of outbreak warnings sent to the village government. Exceptionally large trap catches in some cases had made counting moths very time consuming, and it was suggested that counting was only necessary up to 100 moths; above that could be recorded as >100. Several outbreaks had been correctly forecast, though a positive forecast in Ilonga had not been followed by a nearby outbreak, though there had been one at the edge of the village. Information flow from forecasters to the extension officers and village government was good in all villages, but in some villages the onward communication was less efficient. Control of outbreaks was poor, as there was still a tendency to expect government to assist, although there is some indication that this attitude is beginning to change. As anticipated there is a clear need for effective but cheaper alternatives to synthetic pesticides, emphasizing the need for novel control methods and forecasting to be developed hand in hand.

f. ***End of season evaluation.*** In early May, one month after the armyworm season ended, a participatory evaluation was carried out in the same villages (see Annex 6). A short survey was conducted, in which a questionnaire was administered to 43 individual farmers. Group discussions were held with farmers, and private discussions were held with the forecasters, extension officers, and village government. The evaluation assessed farmers perceptions and knowledge of the forecasting system and armyworms; the dissemination of forecasts; farmers' response to receipt of forecasts; the effect of the forecast on control strategy adopted; the forecasting efficiency and accuracy; stakeholders' views of the benefits and problems with the scheme. As a result of the evaluation, recommendations were made on future implementation of the approach.

Activity 5. Policy advice tools developed and provided.

The policy advice tools focused on the development of armyworm management options at the local level. The findings are also relevant to higher levels and indeed provide government with information to enable decisions to support armyworm management at the local level.

General information was collected on farmers and farmer livelihoods so that farmers could be categorized by resource endowment. The resources available have a bearing on how farmers react to and cope with emergencies such as armyworm outbreaks; they influence what decisions are made with respect to farming activities.

Farmer estimates were obtained of maize yields in the four districts surveyed. Perceptions of differences between 'good' and 'bad' years were obtained and this has a major bearing on whether input costs including armyworm control can be justified.

Farmer access to forecasts is an important issue The National Armyworm Coordinator disseminates armyworm forecasts and warnings in both the local media and through the extension system. However, the majority of farmers who said they had received news on armyworm via the media referred to the news of current outbreaks in their own or neighbouring districts, rather than a forecast *per se*. Information reported in the local media tends to be reports of outbreaks rather than warnings because they are more 'newsworthy'. The proportion of farmers that received forecasts, warnings or news of outbreaks between 1995 and 2002 was obtained form the survey. Because farmers did not appear to draw a distinction between forecasts and news of outbreaks in neighbouring areas, information from farmers referring to forecasts is therefore taken to include news of outbreaks. To distinguish from a forecast in the strict sense, we used the term 'warning' for the farmers' understanding of forecasts.

Farmer response to forecasts was assessed by looking at the proportion of farmers that visited their fields on receiving a positive forecast, and whether they controlled any armyworm they found. The different control options used by farmers were looked at and if no control was employed, the reasons why.

Farmer economics of armyworm control

Farmers were asked to estimate costs of a number of farm inputs, including chemical control of armyworm, in order to gain some insight into the farm level economics of control. From the answers given it was clear that some farmers do not think of their farming enterprise in economic terms, particularly the poorer farmers who are growing entirely for their own consumption. Farmers in Hai district were more aware of costs, reflecting their more intense farming systems and the cultivation of more cash crops. The quantitative results reported in the outputs relate only to maize, as too few farmers grew other crops for there to be sufficient data.

Outputs

1. Problems and research activities defined and updated.

1.1. Socio-economic survey

Survey sites. The survey was implemented in four districts, Hai and Korogwe in the Northern Zone, and Dodoma and Kilosa in the Central Zone. The districts were selected during the stakeholder workshop held in October 2001. Several criteria were identified as being potential sources of variation between areas, so the districts were chosen to cover the variation anticipated. The criteria were; the risk of armyworm outbreaks, the number of cropping seasons, the general level of resource endowment, and the cropping system. In total the survey was implemented in 25 villages, as given in Table 2 below.

Table 2. Characteristics of the districts surveyed, villages where the survey was undertaken, and the number of farmers interviewed in each village

Zone	District	Armyworm risk	Resource endowment	Cropping systems	Cropping seasons/yr	Villages	No. of Interviews
Northern	Hai	High	High	Mixed	Two	Donyomurwa	11
						Mudio	18
						Mungushi	15
						Nshara	9
						Sanyajuu	22
	Korogwe	Medium	Medium	Mixed	Two	Kwemazandu	13
						Lwengera Darajani	12
						Magamba Kwalukonge	12
						Mahenge	14
						Mombo	7
						Mswaha Darajani	12
						Mtonga	12
Central	Kilosa	High	Low	Cereals, others	One	Dumila	11
						Illonga	12
						Kilangali	11
						Madudu	10
						Mvumi	7
						Zombo	11
	Dodoma	High	Low	Cereals	One	Chalinze	10
						Chibelela	10
						Chikopelo	10
						Chilonwa	7
						Chipanga	11
						Mudemu	10
						Mvumimakulu	12

In each district five to seven groups of farmers were selected randomly from a list of groups at the district agricultural office. The survey was then implemented at each group's home village, the group providing the contact point.

Survey instruments. The survey was carried out in two stages:

1. Individual farmer interviews were used to collect information under objectives 1-4 (see Activities) concerning armyworm forecasts, outbreaks, control and farm economics. Two hundred and eighty nine farmers were interviewed, as shown in Table 2. The questionnaire used is shown in Annex 7. The survey was pre-tested in Arusha and refined before the full survey.

2. Focus group discussions were held in each of the villages surveyed. The groups ranged in size from 15 to 70 people. Prior to the survey the maximum number envisaged per group was 20, but interest in armyworm from farmers sometimes brought larger groups to the discussion. The aim of the group discussions was to obtain farmers' views collectively on armyworm operations in the country, how they perceived the problem and what local solutions were available to them. Due to there being relatively little knowledge of armyworms amongst the farmers, the group discussions included a discussion on what causes armyworm outbreaks, their lifecycle, and methods of forecasting. Each group also discussed community forecasting and control and what models might be suitable for their village. The check-list of topics covered during the focus groups is attached in Annex 8.

Data Collection. Through the farmer group in each village, villagers were invited to come to a central point to take part in the survey. The participants were self selected in that they voluntarily came to the group meeting. Data collection started with the individual farmer interviews. Farmers were selected randomly from those who were present. After the interviews, the focus group discussions were held with both the interviewed and other farmers. This order was used to avoid the individual interviews being influenced by the group discussions.

In each village the survey was led by the CABI-ARC socio-economist (Dr. Jemimah Njuki) and the Tanzania National Armyworm Coordinator (Wilfred Mushobozi). In addition in each district three local extension staff acted as additional enumerators in the interviews. All the extension staff were trained for one day prior to commencement of the survey.

1.2. Forecasting tool demonstrations

The two technical presentations in the scoping workshop were used to demonstrate what had been done so far in the development of forecasting tools and novel control measures and to illustrate what possibilities existed for development. This provided a context for future discussion during the workshop as participants had a better idea of what could be done and what options exited.

1.3. Scoping workshop

There was perceived to be a decline in information flow for armyworm forecasting as well as devolution in decision-making and a decline in subsidies. There was also thought to be a trend towards larger farms and towards increased knowledge of armyworm by farmers, though very few farmers were thought to be able to recognise the early stages of armyworm larvae. For pesticide application, there was perceived to be a trend towards replacement of HV application technology with both ULV and LV. OP's and

pyrethroids were the main agents thought to be sold for armyworm control. Availability of products such as neem was thought to be very limited.
The response of the farmer to armyworm outbreaks may be strongly influenced by geographical zone. For example, in some places, replanting may be possible following armyworm attack whilst in others it may not.

Policy implementers, forecasters and trap operators, agricultural and extension officers, and farmers gathered as separate groups to consider their objectives and constraints. Some common themes emerged. Information often did not reach farmers in time for them to take action. Costs of some pesticides were high and in short supply during outbreaks. Lack of funding at all levels severely limits the ability of national and local government to offer support to farmers. Farmers tend not to budget for uncertain events like armyworm outbreaks. Some farmers lack both access to extension officers and the resources to treat armyworm infestations.

The National (current) model offers a single point of contact for everyone from the Minister of Agriculture to the farmer as well a more comprehensive forecast that can take advantage of country-wide trap information and satellite data. It is prepared by highly experienced staff using a centrally maintained historical database as a key resource, allowing continued improvements in forecasting. The national model is easy to administer with limited training implications.

The National model was compared with proposals for District and Community models in which the responsibility for day to day forecasting operations is devolved to different degrees. The Community Model is expected to overcome most communication difficulties because the forecast would be made by the same community that uses it. Increased ownership by the farmers and a good fit with present policy for farmer-led approaches are other advantages. The District model devolves forecasting to the districts. This would give clear responsibility for forecasting to the district office, and have fewer training implications than the Community model.

The type of formulation required was thought likely to be determined by any application equipment already available. Cash crop farmers were thought particularly likely to make use of NPV in LV or ULV formulations. The smallholder cereal farmers with fewest resources would probably not have any equipment or, indeed ability to buy pesticides. The idea of granular formulations of NPV was raised as an interesting possibility.

1.4. Mini-workshops

At the second workshop in particular, workshop discussion led to plans to take community-based forecasting approaches forward, having two aspects: ‘linking up’ and ‘scaling up’. Methods need to be devised to improve farmer’s ability to act in response to the new community based forecasts. This centres on locally-managed control measures, and extends the participatory approach developed for forecasting to include control. If the approach is to be widely adopted, a means of scaling-up it needs to be devised and tested.

To link forecasting and control it was proposed that participatory control trials be carried out in the five villages where participatory forecasting was initiated last season. Neem extraction and application would be offered as a possible approach. The socioeconomic suvey carried out earlier in the project revealed a very high frequency of neem trees in armyworm-affected villages. Preparation of a sprayable extract from neem leaves would be feasible in the village with simple, low cost, equipment. Village trials would be run by the villages and include other treatments as planned locally (e.g. controls and conventional pesticides).

The trials would require both socio-economic and scientific evaluation during the process. Treatment outcomes would need to be judged shortly after the armyworm control measures were applied to avoid any confounding influence of yield-effecting events later in the season. There were some doubts about the variability of neem trees in their insecticidal properties. As a check, neem leaf samples would also be collected from each village for laboratory biossays.

To scale up the participatory approach to forecasting and control, three models were discussed.

- A ‘diffusive’ model where the pilot villages spread the word to neighbouring villages. In each of the pilot villages two farmers and a village extension officer (VEO) have been trained in the forecasting methods. These three people from each of the five villages might be brought together for ‘training in training’. Each village ‘team’ would then be asked to introduce the approach to two neighbouring villages.
- A de novo model where the approach adopted in the pilot is repeated in new locations. This might be achieved by group training of trainers who could carry out the process.
- A product model where the forecasting kit (equipment and instructions and possibly a training course) may be purchased. This might be applicable to commercial farms or to community groups. A part-payment scheme, whereby a donor contributes part of the costs may be a helpful vehicle.

2. Armyworm outbreak risk forecast developed

2.1. Meteosat CCD data processing

The satellite data were collected and processed and the CCD data products were produced weekly during the three armyworm seasons of the project. Examples can be found in Annex 9, which shows screens from the website used for dissemination.

2.2. Meteorological risk at high resolution

The CCD data processing was reconfigured to provide summaries by district instead of a simple geographical grid. The examples in Annex 9 show an example of the CCD image with a district boundary overlay. An example of the tabulated data gives a district by district summary in a form ready for direct input to the national forecasting system

2.3. Predictive model improvement

Better Integration of the CCD information with that from the armyworm trap network has provided a better operational model for the national forecasting process. As a part of this, the data from various sources are now being collated and interpreted using new data management software developed during the project. Annex 10 provides full details of the armyworm data management software, including examples of the various data entry and data display screens.

An evaluation was also made of the national forecasting effort using historical data. A judgement had to made as to what the forecast would have been as no records were available of what forecast were actually issued. What general lessons can be gleaned from this analysis? In some cases, traps relatively near to each other (i.e. in the same geographic cluster) show similar temporal patterns of moth catch, e.g. traps 1 (Kilosa), 88 & 2 (both Dodoma); traps 6 (Moshi) & 18 (Arumeru) (Table 1). By 'near' in this context, we refer to the same district or neighbouring districts so, the distances concerned are several tens, up to hundreds of kilometres. In one sense, therefore, a trap probably provides relevant information over a large area because moth build-ups appear to be occurring simultaneously over a district or districts.

In another sense, however, traps are not representative of larger areas because they can miss outbreak events in the same district, e.g. traps 34 (Hanang) , 1 (Kilosa) and 28 (Iringa). Neither do high moth catches and outbreaks necessarily coincide spatially, and a number of instances occurred where conditions expected to give rise to outbreaks did not do so, e.g. traps 33 (Hanang) and 73 (Rungwe). Of course it is possible that outbreaks occurred but were not reported but it may be reasonable to expect outbreaks occurring near to the trap stations have a high chance of detection.

It should be remembered that reasons for some of the apparent errors stem from the way in which the data were examined. The basis for comparison was that the traps and the outbreaks were in the same district and so, false negatives are explicable by an outbreak occurring in one part of a district but moths failing to be caught in a trap in another part of the district. The data support the contention that this situation can occur. False positives can occur through failures in the detection and reporting of outbreaks. Neither of these sources of error should be present in the community forecasting approach where the events concerned (trap catches, rainfall & outbreaks) all occur in the same village.

Outbreaks were more clearly associated with an increase on moth catch in three cases, trap 33 (Hanang), trap 1 (Kilosa) and trap 73 (Rungwe), where the weekly catches peaked at 48, 235, and 52, respectively. This might imply that the threshold of 30 initially selected for the community forecasting traps is a reasonable starting point for a new trap. Of concern, however, were a comparable number of cases (at least five) in which catches of a similar size and accompanied by rainfall were obtained and no outbreak (or at least outbreak report) followed. It seems likely that not all these false positives can be dismissed by lack of outbreak reporting and so this situation could conceivably occur with the community forecasting approach. False negatives may also be a problem with the community traps where the so-called ‘trap factor’ is below average. Indeed, bearing in mind the spatial issues discussed above, outbreaks occurred in three districts Hanang, Mpwapwa and Iringa when associated peaks in moth catch were comparatively low: 5, 22 (in neighbouring Dodoma district) and 1, respectively.

These analyses suggest that forecasting based on the national trap network provided a good general indicator of armyworm outbreak risk in a particular season but the timing and location of outbreaks were frequently inaccurate.

2.4. Electronic communications link

A link is now actively supported by SatCom Networks Africa Ltd (Fig. 4). The maintenance contract is currently being paid by the users, Pest Control Services. This link is a key to the real-time collaborative forecasting effort and increases the potential for what could be achieved in forecast-support in the future.

Figure 4. Satellite dish installed outside the Armyworm Training and Operations Centre, Pest Control Services, Tengeru, Arusha, Tanzania

2.5. Trap data collection and dissemination

Each week during the armyworm season, Pest Control Services contacted trap operators of the armyworm trap station network to obtain reports for the week for trap catches and rain gauges. These data are initially conveyed verbally by phone or radio, followed up with a written version on monthly report cards. The data are collated and summarised for the weekly forecast using the newly developed software (Annex 10).

2.6. Armyworm outbreak risk forecast

The satellite CCD, armyworm traps catch and rain gauge data are compared each week on a district by district basis. A forecast is then issued which presents the current situation and the prognosis for the coming week. The forecast is intended to alert the extension services and farmers of the need to scout for armyworm and obtain stocks of the necessary pesticides.

3. Economic risk forecast developed.

3.1. Economic data acquired and collated

See Output 5.

3.2 Economic risk map

The survey work spanned four areas with differing conditions with respect to armyworm outbreak risk, socioeconomic and agronomic conditions so some measure of the range of situations was obtained. No mapping was undertaken as it was agreed that this activity was dropped form the project. The initial intention was to provide outputs more relevant to policy issues for centralised armyworm management, when the current trend in Tanzania government policy is to devolve control responsibility to the local level.

4. Forecasting tools adapted for different levels and tested.

4.1. Forecasting tools adapted for different levels

Forecast system for communities. In the 5 villages participating in the community-based forecasting trial, the evaluation indicated that the forecasting had been of benefit to farmers in the villages in a number of ways (see Annex 6 for the evaluation report). The performance by the forecasters (correct calculation of forecast rules) was good: 90% of positive forecasts were calculated correctly, and 98% of negative forecasts were calculated correctly (Table 3). The 10% error in positive forecasts was due to the rule concerning carry over of information from the previous week. There was a lack of clarity in the presentation of this rule, and it may be that it is not actually necessary. A full evaluation of the forecast accuracy (the extent to which events matched the forecast) was constrained by the record keeping of outbreaks by extension officers not being accurate. The data presented below are based on outbreak reports from farmers. However, the latter half of the season had very few outbreaks, so the data presented give a good overall picture.

Farmers' knowledge of armyworm had increased, more were receiving forecasts, and more were controlling outbreaks. There was indication that armyworm outbreaks were being sprayed earlier, with a much higher percentage of farmers reporting spraying first instar larvae. The percentage of farmers reporting they had replanted was lower than in the socioeconomic survey, which would be expected if chemical control is more effective. Table 4 summarizes some indicative parameters from the socioeconomic survey and evaluation of individual questionnaires.

Table 3. Forecaster performance and forecast accuracy

Correct forecast	Forecaster performance		Forecast accuracy	
	Farmer forecast		Outbreaks	
	+ve	-ve	Yes	No
+ve	90%	2%	100%	0%
-ve	10%	98%	11%	89%

Table 4. Evaluation of the community based forecasting ('Before' data are from the socioeconomic survey; 'After' data are from the evaluation survey).

Parameter	Before	After
Know that outbreaks can be forecast	32.3%	70.5%
Access to forecast information	25.8%	68.2%
Controlled most recent outbreak	32.3%	78.2
First instar larvae present when sprayed	10.3%	71.4%
Replanted after outbreak	58.0%	19.0%

A publication on the Kilosa study for a peer reviewed journal is in preparation: 'Community-based forecasting of armyworm (*Spodoptera exempta*) in Africa'. Day, R.K., Njuki, J., Kimani, M., Mushobozi, W. and Holt, J.

4.2. Local dissemination routes

Forecast pack. To support the farmer forecasters, a 'forecast pack' was prepared. The pack comprised a pheromone trap with lures for the season, a rain gauge, pencil case and stationery, and a forecasting manual. A copy of the manual is attached (Annex 11), containing instructions on operating the pheromone trap and rain gauge, data sheets, the procedure for calculating a forecast, and leaflets for distribution to the community. The material was originally prepared in English, and then translated into Kiswahili for the version distributed. The forecast pack was well received and used by the forecasters, as were the leaflets by the members of the community.

One option for further development of this output would be to establish an enterprise to produce, distribute and market the packs to villages. The financial feasibility of such an enterprise would need evaluating, including an assessment of the cost of producing the pheromone trap and rain gauge locally. Local production of the pheromone is not feasible, and this would have to be imported, but loading the pheromone into the lures could be done in East Africa.

Within-village communication. Different stakeholders perceived the trial in different ways. The village government saw the extra time to prepare for control as a benefit, but had some concerns over the cost of communication outbreak warnings, and the difficulties of access to pesticides. It was observed that farmers prefer information 'from the horse's mouth', so even after receiving a warning, went to see the forecaster for confirmation.

The status of the extension officer had been elevated, in part because she/he is a key part of the communication system. The extension officer is also called on for advice on monitoring and control of outbreaks following a warning.

The status of the forecasters themselves had also been elevated, as they had become recognized experts. This had in some cases led to unreasonable expectations by farmers, wanting advice on other problems and even assistance with control operations. There was an indication that although in general the trial had brought farmers, extension officers and village government together, some village officers felt slightly threatened by the increased status of the VEOs and forecasters.

Only one pesticide dealer was found in the five villages, who purchased pesticides from town to sell in smaller quantities to farmers. Although he provided pesticides on credit to farmers (who repay at the end of the season in cash or kind), he could not purchase his pesticide on credit, so due to the resulting cash flow problems he could not always meet the farmers' demand. He was thus interested in a credit scheme that would allow him to purchase more pesticides.

4.3. Forecasting system protocol and testing

Following specification of WADI, the database software to support the national forecasting, the main task of software development was carried out by two members of the project team. Other team members provided a software testing role, reporting back problems and suggestions for improvements to the developers. A series of visits to PCS, Tengeru where made by staff from NRI and IC. The software was installed at PCS, Tengeru, training given and so far, there have been no operational problems.

4.4. Capability transfer

The success of the community-based forecasting trail trial has generated interest and additional funding. USAID has supported a similar trial in Moshi District during the 2003/04 season, and the Government of Tanzania has given the approach its backing. As well as funding the 5 sprayers per village, it has requested PCS to implement CBF in other districts.

Three issues need to be addressed for this approach to be sustainable and widely applicable.

Forecast pack provision. A mechanism needs to be developed for the production and distribution of forecast packs, as mentioned above. Private Sector involvement would be desirable.

Community mobilization and training. For wide scale implementation of this approach, a training of trainers' programme would be necessary, with provision for quality control to ensure that the effective participatory approaches were used.

Improved control options. Forecasting is of no value if farmers are unable to act on the information. Currently they are constrained by the price and availability of control options, which was recognized at the outset of the trial as an important area, but not one that could be addressed immediately.

4.5 Explore options for an updated 'Wormbase', and 4.6 Develop new national data management software prototype

Full details of WADI's functions and examples of the various data entry and display screens are given in Annex 10. An example of one of WADI's screens, the 'forecasting form' (Fig. 5) handles this display function and also includes the provision to record the forecast for each district at the time that it is made.

The DOS-based software, WORMBASE (Day *et al*), is in some ways a predecessor to WADI. WADI, however, contains none of the historical data summary and analysis features that are contained in Wormbase.

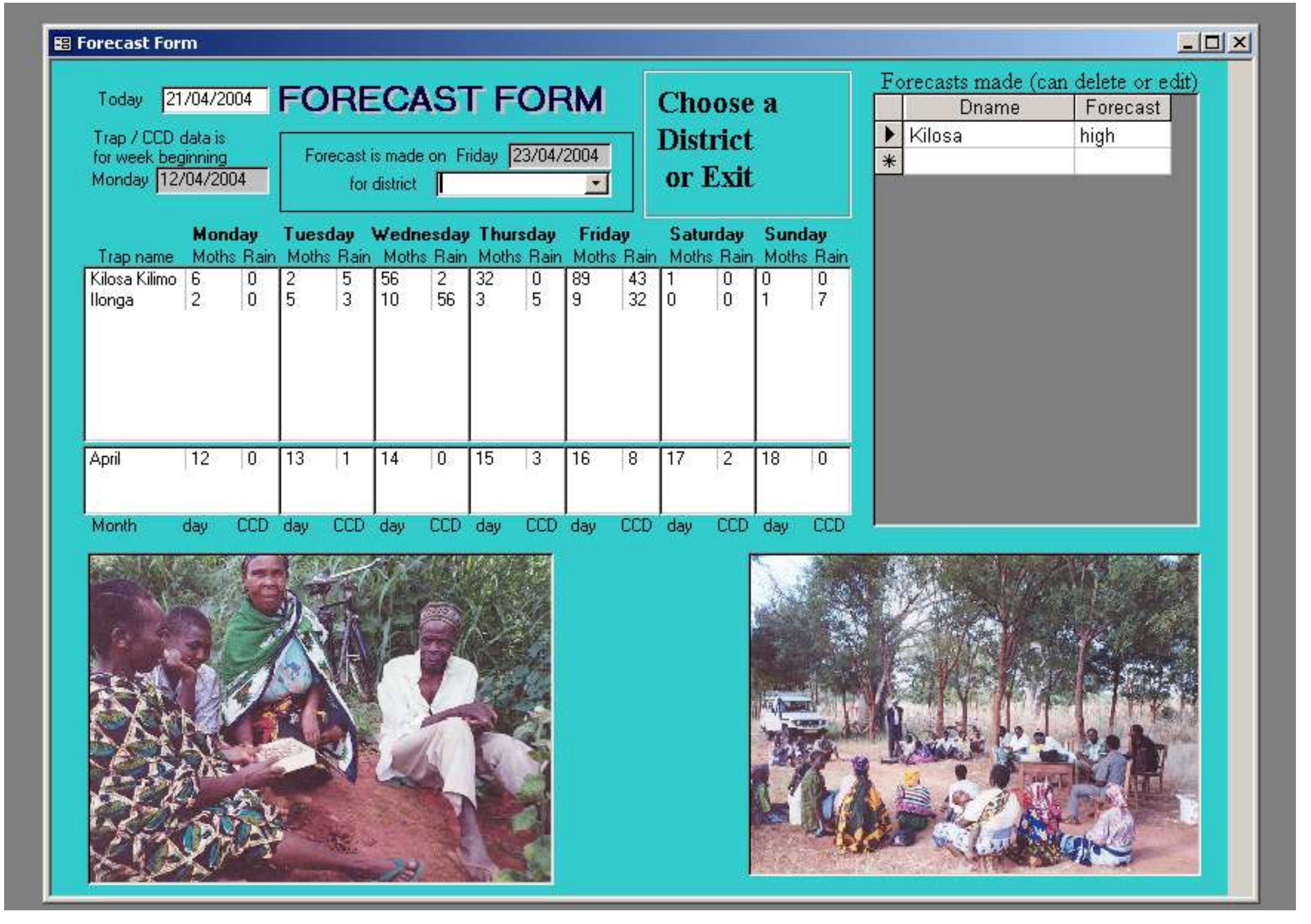
Built in Microsoft Access, however, WADI offers considerable flexibility for future development. Even as it stands, new queries can be generated using the standard features available within the software. An important part of the development process was to train the national forecaster in Access use to provide more control over the software and its use to the principal user.

4.7 Monitor and evaluate community forecasting pilot study

The approach to armyworm forecasting tested during the project was novel, and had never been attempted before. From the attached reports and summary of the evaluation presented above, we conclude that the approach is viable. The following factors were key to the success of the trial:

Community participation. The approach used was highly participatory, and facilitated by a scientist skilled and experienced in community mobilization. This promoted ownership of the activity, beginning with the focus group discussions during the socio-economic survey, and continuing with the village meetings before, during and after the armyworm season. The selection of farmers to be trained as the forecasters illustrates the approach; the project suggested some criteria for their selection, but the community also had their criteria, and used a selection process of their own preference, different in different villages.

Fig. 5. Example of one of the screens from the WADI data management software



Appropriate technology. Although much research had previously gone into the identification and synthesis of the armyworm pheromone, and the design of the trap, the technology as presented to the farmer forecasters was straightforward. Thus the data recording and forecast calculation was undertaken with a high degree of efficiency. The few errors that were made occurred due to an easily corrected misunderstanding.

Empowerment. The long established approach to armyworm forecasting has viewed communities as data collectors and forecast recipients. In contrast, this trial empowered farmers as interpreters of data and decision makers. It was noted that the farmer forecasters acquired some status in the village, and as a result of their short training were being asked for advice not only on armyworm but also other agricultural issues.

4.8 Visit by the Tanzania National forecaster to the UK to take part in specification and initial development of Access system

During a three-week visit, an intensive period of training in Microsoft Access was carried out. The idea was to give the national forecaster more direct control over the use of the new database system, so that the forecaster would have the capability to augment the capabilities of the system directly by, for example, designing his own queries. The training was productive and a good level of capability with Access attained. As well as the general Access training, time was spent applying the database skills to various aspects of WADI development.

5. Policy advice tools developed and provided.

5.1 Cost benefit analysis

Input costs. Farmers reported use of both hybrid and local maize seed varieties. In Dodoma and Korogwe almost all the maize planted was local varieties, but in Hai and Kilosa the planting was evenly split between hybrid and local varieties. The cost of the local varieties in Dodoma and Korogwe was around 400 Tsh/kg. In Hai the mean cost for the hybrid and local varieties was 1909 Tsh/kg and 204 Tsh/kg. It is not clear whether the hybrid seed in Kilosa was the same as that in Hai costing over three times as much. The quantity of seed used was generally in the range 7-12 kg/acre, with a mean of 9.9 kg/acre. Only three farmers outside Hai district reported using fertilizer, while most Hai farmers do use fertilizer. However, the application rate was 45.8 kg/acre for hybrid maize, but only 5.7 kg/acre for local varieties. The mean cost of fertilizer in Hai was 221 Tsh/kg, with a range of 180-380 Tsh/kg.

Hired labour ranged from zero to as much as 55,000 Tsh/acre for the season. The average was around 17,000 Tsh/acre in Hai, Dodoma and Korogwe, but 26,000 Tsh/acre in Kilosa. Only in Hai was there sufficient data on the cost of pesticides, where the mean cost was 8,453 Tsh/litre. The amount used depended on the area infested. It is not uncommon for outbreaks to be patchy, so part of a farm may have a high density that merits spraying, while for a lower density patch the farmer might decide it wasn't worth spraying. Application rates of around 0.5-1.0 litre of product per acre were reported.

Gross margins. Yields were estimated by farmers for good years and bad years, and the equivalent values for kg/ha are used in the calculations below. Values for the inputs were not always available but we take Hai as the example, as data for that district are most complete. The seed is assumed to be hybrid maize, so the total costs for seed, fertilizer and labour are 24,292, 45,358 and 40,800 Tsh/ha respectively, giving a total of 110,450 Tsh/ha.

In Hai a good year was estimated to yield 2,489 kg/ha. The wholesale price of maize varies between years and between areas, but is often the range 100-150 Tsh/kg. Assuming a price of 125 Tsh/kg, a good year would therefore produce a gross return of 311,125 Tsh/ha. In a bad year the gross return would be 115,750 Tsh/ha. Subtracting the costs gives a gross margin of 200,675 Tsh/ha in a good year, but only 5,300 Tsh/ha in a bad year.

The profitability of maize production is thus sensitive to yield and the growing conditions. We have taken a high input example (hybrid maize in Hai), and it would be appropriate with more accurate data to examine the gross margin under a range of conditions such as pertaining in different districts. Growing local varieties should produce a lower yield, but would cost less because the seed is cheaper, and less fertilizer is required.

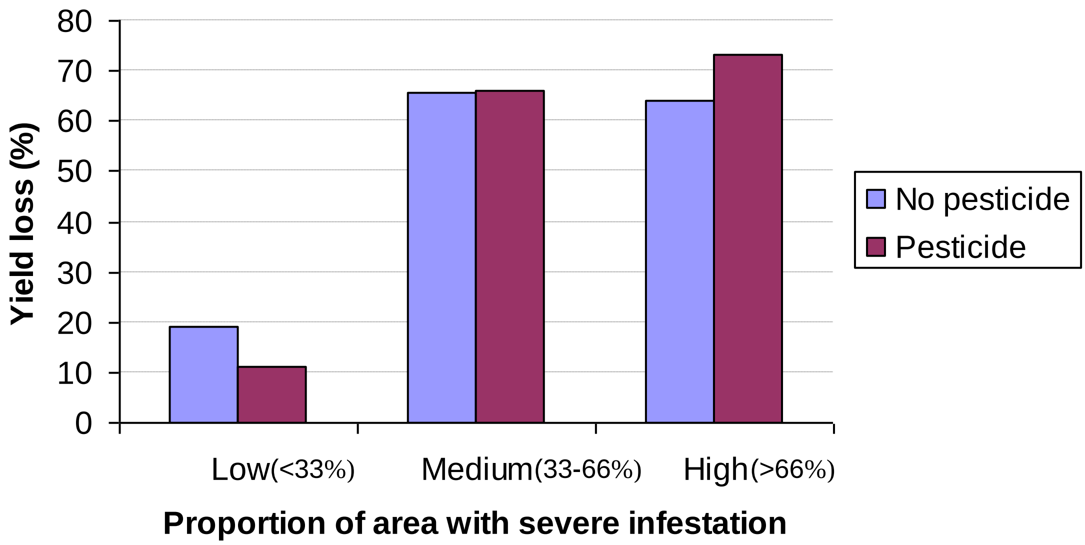


Figure 6. Farmer estimates of losses due to armyworm in the last outbreak they experienced. (See text for explanation).

Cost of armyworm outbreaks. Farmers were asked to estimate the yield loss the last time they had an outbreak in maize. At the same time they were asked to assess what proportion of their maize was severely infested, and what proportion was only mildly attacked. Thirdly, whether they sprayed or not was recorded. For Fig. 6 the proportion of the plot that was severely infested has been categorized into low (<33% severe), medium (33-66%) and high (>66% severe).

From Fig. 6, average losses from a medium to high severity infestation are around 66%, while a milder infestation can cause around 20% loss. It is interesting to note that even for those who sprayed a pesticide, the loss was estimated to be similar to those who didn't spray. It may be that spraying does not reduce losses if the pesticide is applied when the larvae are already late instar, and much of the damage has already been caused. However, it is unlikely that farmers would apply pesticide unless they perceived it to be of value in reducing damage.

The cost of insecticide in Hai was 8,453 Tsh/litre, so with an application rate of say 2 litres/ha, and a price for maize of 125 Tsh/kg, the application would break even with a yield saving of 135 kg, excluding application costs. In a 'good' year in Hai, this is equivalent to only 5.4% of expected yield, meaning that the application would be economically justifiable if it reduced yield loss by 5.4%. However, in a 'bad' year in Hai, the reduction in crop loss would need to be 14.6%. If only 20% yield loss is expected with a mild infestation, then there would be minimal economic benefit in spraying.

While the farmers' perceptions do not indicate savings from spraying at present, the high losses from medium and severe infestations mean that even in 'bad' years such infestations would be worth spraying if the application could be organized in time.

5.2 Control policy assessments and tools

Effectiveness, problems and constraints of the current forecasting service, particularly from the farmers' point of view.

The survey showed clearly that the forecast service as it was originally conceived (Odiyo, 1979, 1990) is not currently meeting the needs of the farmers who suffer from armyworm outbreaks. Less than 25% of all farmers interviewed could recall ever having received a forecast, and further questioning revealed that often what was interpreted as a forecast was actually news of outbreaks in neighbouring areas. This is certainly useful information, as reports of an outbreak in the district increases the probability that there is an outbreak on a particular farm. However, it is not a forecast in the way the service was intended, and does not give the time to prepare for outbreaks that a forecast does.

As a result, most of the 'forecasts' received were through the radio, some actual forecasts issued by the forecasting service, others warnings based on the occurrence of outbreaks. 79% of farmers interviewed have radios with a higher percentage in Hai, the 'wealthiest' district surveyed. However, farmers prefer personal information sources, such as extension officers, because follow up questions can be asked, which the radio doesn't allow.

When forecasts or warnings were received, the survey found evidence that they are of value. Farmers who received a forecast or warning were more likely to monitor their crops for armyworm larvae, and were also more likely to end up controlling outbreaks. Thus improvements to the forecasting service should have desirable impacts at the farm level, providing the issues related to control can also be addressed (Annex 12 and below).

Farmers' armyworm control measures and the potential for adoption of novel control methods

Over 95% of all farmers had experienced armyworm outbreaks at some time during the last seven years. The frequency of outbreaks during that time appeared to be increasing, but this could be an artefact of poor recollection, as farmers are known to rate more recent experience more highly in their perceptions. In the most recent season at least 50% of farmers had experienced outbreaks, with over 90% reporting outbreaks in Hai district. Thus armyworm was confirmed to be a problem that many farmers have to deal with at one time or another.

However, despite the high proportion of farmers experiencing outbreaks, much fewer controlled the outbreaks. In Hai district over 95% had used control methods at some time, but in all the other districts less than 35% of farmers had ever controlled armyworm and only 15% in Dodoma. There was evidence that the tendency to control is related to wealth, and the ownership of spraying equipment. Only in Hai district was there significant ownership of sprayers, where 45% reported they had a sprayer, often for use on other crops such as coffee.

Farmers reported a range of reasons for not controlling, but the main one was lack of money. Other reasons cited were lack of knowledge, and finding armyworm larvae too late. Thus farmers would control the armyworm if they could, but they are currently constrained by various factors (Annex 12 gives full details). In discussion with farmers there was also some indication that they would be prepared to take more responsibility for their control operations, although the government still likes to be seen to be assisting farmers in this respect, despite the fact that it usually has insufficient resources to do so.

An alternative or complementary strategy to pesticide treatment of outbreaks is replanting, for which some seed is saved at the start of the season. Two thirds of farmers had replanted following an armyworm outbreak, but given the low percentage attempting control, replanting was probably the only option to try and secure some yield. Generally the same crop was replanted. However, in Hai district, the proportion of farmers replanting was much lower, corresponding to the much higher use of pesticides, which can be assumed to be effective if replanting was not often needed.

There is awareness of the health and environmental hazards of pesticides, but despite this less than 20% of farmers wear safety gear of any kind. This is in part due to the cost of safety gear. Thus there was considerable interest in alternative control methods, and surprisingly 80% of farmers said they would be willing to pay the same price for an alternative to pesticides, despite the fact that they can't buy them now! There is some awareness (20-45%) of alternative control methods, except in Hai where over 85% of farmers were aware. There have been IPM and other projects in Hai area, including the promotion of neem, so over 55% of farmers there had tried neem, mainly for storage pest control. In other districts less than 35% had tried neem, although in all districts except Hai, neem was quite widespread, 50-80% of farmers having one or more neem trees on their farms.

The general picture appears to be one of considerable constraint (except in Hai). Farmers are too poor to purchase pesticides, and even if they can, they are aware of the dangers but know of no suitable alternative. There appears to be scope for the development of neem, including the use of farmers' own neem trees, but knowledge is lacking. However, the formulation of neem would need to be such that it could be applied without spray equipment, if it was to be useable by the poorer farmers. The same condition would apply to the use of NPV. A cautionary note for the promotion of either neem or NPV is that some farmers expressed dissatisfaction with organisations promoting neem for other uses, but which farmers had found to be not effective.

Farmers' perceptions of the costs and benefits of armyworm control measures.

The data on farm level economics of armyworm outbreak and control confirm that the pest is serious, causing an average of 60-70% loss in more severe infestations, and around 10-20% loss in milder outbreaks. While this is the farmers' perception rather than measured yield, with experience farmers should know what they can expect from their land, and so these figures are not unrealistic. When a farmer obtains virtually no yield following an outbreak, the loss is clearly very high.

In Hai district, where maize production is more intensive that other districts, the cost of the pesticide for a single treatment of armyworm was considerably less than the other major inputs; seed fertilizer and labour, corresponding to around 5-15% of yield. Under such circumstances spraying is likely to pay, provided it is implemented early enough. However, based on the estimates of farmers' losses who did and didn't spray, there was no apparent benefit of spraying, suggesting either spraying may be late, or that farmers perceptions of the effect of spraying are inaccurate.

In poorer areas where local varieties of seed are grown, and no fertilizer is applied, the cost of chemical for armyworm control becomes the major item of input expenditure, so it is not surprising that farmers say they cannot afford the chemical. However, the data suggest that if they were able to purchase the chemical and apply it in time (which forecasting should facilitate), then it would be economically viable. Thus schemes which availed micro credit to farmers quickly could be beneficial.

Farmers' views on the potential of community based forecasting and control.

Farmers knowledge about armyworms was generally low. Although there was some knowledge of the connection between armyworm outbreaks and rainfall, the causal relationship was not understood. Thus most people (over 70%) were unaware that it was even possible to forecast outbreaks. Thus community based forecasting should incorporate a public awareness component at the village level.

Once the idea of forecasting within the community was introduced, there was considerable enthusiasm for implementing it. In the group discussions in each village, different possible models were assessed, including farmer managed, extensionist managed and village council/government managed. A number of advantages and disadvantages were envisaged under each arrangement, but most of the villages eventually favoured the farmer managed model, but with the involvement of the local extensionist and the village government.

Various routes for communicating forecasts within the village were also discussed. A number of options already exist, as the village governments need to communicate to the village members on different issues. A notice board, a 'runner/announcer', schools and churches/mosques are all used, so a trial of community based forecasting should draw on the existing communication systems in the individual villages in the trial.

A number of potential constraints to the value of community based forecasting were noted, particularly in relation to the ability of farmers to control outbreaks, even if they act on a forecast and find the young larvae. The group discussions confirmed the results of the individual questionnaires, which showed that a shortage of cash to buy pesticide is a major limitation. Because there is a limited market, often there are no pesticide vendors in a village, and sprayer ownership was very low in the poorer districts, but around 45% in Hai. Thus for community based forecasting to be valuable, strategies for improving the ability to control outbreaks will be required. However, this applies to forecasting at whatever level, although at the community level the issue is brought more sharply into focus.

Resource endowment, socio-economic status of farmers and their perceptions and decision behaviour with regard to armyworm outbreaks and control.

The overall wealth ranking system indicated Kilosa to have the most farmers with low resource endowment and the least farmers in the high endowment category. Dodoma had the most farmers in the high category due to a few farmers with large herds of goats, but Dodoma also had the second highest proportion of farmers with low endowment. Korogwe and Hai had the least farmers in the low category. Thus there was no consistent difference in overall wealth scores.

However, for individual resources there were major differences, some of which relate directly to the farmers decision processes on armyworm control. For example, in Hai over 45% of farmers owned a sprayer, while in Dodoma less than 3% did. Not surprisingly, in Hai over 95% had sprayed an outbreak on their farm, while in Dodoma, only 15% had. Similarly in Hai over 85% had purchased pesticides, but less than 15% in Dodoma. Thus there are clear differences in the way in which farmers respond to outbreaks, and this appears to be related to resource endowment. As a result, armyworm outbreaks can be expected to have a disproportionate effect on the poorest farmers, and this needs to be taken into consideration when developing novel control methods.

As a result of this difference in resources, other differences in coping with armyworm outbreaks were observed. In Hai, presumably as a result of the higher incidence of pesticide application, few farmers replanted crops following outbreaks, while in poorer areas farmers saved seed for possible replanting. This appears to be economically less beneficial, but without the resources to purchase and apply pesticides, the poorer farmers have little option. Financial inability was the most important reason for not controlling, and over 50% of farmers cited this reason in Dodoma.

Under the current system farmers in Hai are also receiving forecast (or warnings) more than in other districts. This could be because they have a higher number of radios, but it may be that they are generally more aware. However, for farmers who had received a forecast, those in Hai showed the lowest tendency to monitor their fields as a result (just under 70%). Possible reasons for this are the greater distance to the fields in Hai, relatively lower importance of maize, or reliance on local information rather than centrally issued forecasts. Farmers in Hai are also more aware of the potential of neem as a pesticide, with nearly 60% having used it previously, while in Kilosa only 11% have ever used neem. This is due to the presence of projects promoting neem in the area, though even in the other districts, farmers with better resource endowment are more likely to have tried neem. Thus if neem is to be promoted as an alternative control method, awareness raising needs to be targeted at the poorer farmers. On the other hand, more wealthy farmers are more likely to be innovators, as the risks are less.

The distribution of neem trees provides opportunities for promoting home preparations for the control of armyworm. The lowest proportion of farmers with neem was in Hai (<30%) but in Dodoma, 80% of farmers have one or more neem trees on their farm.

Contribution of Outputs to developmental impact

How the outputs will contribute towards DFID's developmental goals

The project has had a strong emphasis on the empowerment of rural communities though better information generation and dissemination for improved crop protection. This has been shown to give direct benefits through the more appropriate, timely and effective use of agricultural inputs with net benefits in improved yields giving higher household incomes, greater income stability and improved livelihoods. The project has fostered greater community collaboration and community development. There has been improved integration of VEO & DEO activities with farmer objectives because CBF is farmer-driven and engages local government in the training and implementation process.

The identified promotion pathways to target institutions and beneficiaries

The most important promotion pathway is directly to the villages being trained in CBF. Word of mouth has spread interest in the approach to neighbouring villages by farmers and the activities of local government officers, chiefly the VEO's. Promotion at higher government levels has occurred through the national armyworm forecaster who maintains a watching and supporting role over the CBF activities.

For the forecasting tools which have been designed to be used at the national level, Pest Control Services is the target institution. The beneficiaries are the forecast recipients. As has been established in the project, these recipients tend to be in district agricultural offices rather than local communities. A very important recipient of the national forecast is central government who rely on the service to plan any supporting response, including that given to CBF.

What follow up action/research is necessary to promote the findings of the work to achieve their development benefit?

a. What further market studies need to be done?

A further pilot study has been proposed in Kenya to learn lessons for regional scaling up and to introduce the CBF approach at an institutional level in a second country. This forms part of a proposal currently under consideration for CPP funding. CBF is likely to be appropriate throughout the armyworm-affected countries of the region but the approach will need to be tailored to suit the social and institutional structures in each country.

Irrespective of country, CBF is likely only to be appropriate in localities with a relatively high frequency of occurrence of armyworm attack. Clearly, where a community only gets armyworm outbreaks one year in ten, CBF is unlikely to be sustainable. Quite what the outbreak frequency threshold for CBF to be feasible needs to be established and may vary according to local conditions.

b. How the outputs will be made available to intended users?

A possible approach for scaling up the CBF approach might involve training of trainers combined with further institutionalisation with Tanzania as well as expansion to other countries. For example, teams of EO's from across the armyworm-affected districts could attend a specially designed training course to provide skills in a combination of participatory methods and CBF. The trainers could then run training workshops locally in their home districts. A key part of scaling up is likely to involve engaging existing institutions as fully as possible. Only if CBF is institutionalised within the Ministries of Agriculture is it likely to be possible to reach the very large numbers of communities that could benefit. The first steps have already been taken through involvement of VEO's in the training. At the ministry level, support has been expressed for the CBF initiative.

Especially in localities which suffer armyworm outbreaks only occasionally, the need for an effective national level forecast remains. The new Access database software will allow central data handling to be maintained. A new email link installed by the project at the national armyworm training and operations centre will ease communication to some extent as some District Offices also have email.

c. What further stages will be needed to develop, test and establish manufacture of a product?

Mechansims for scaling up need to be researched and refined. This might include devising a training course to be used to groups of EO's, establishing mechanisms to institutionalise CBF at different levels in local and national government. There may also be scope to investigate public-private partnerships as well as making the forecasting pack and training course commercially available as an 'off he shelf' product; for some large commercial farms this might be a viable option.

In parallel to this project, the CPP also supported work on the development novel armyworm control technologies, chiefly NPV. NPV production is not likely to be possible at a village level, but rather the product would have to be supplied or purchased in much the same way as do commercial pesticides. It is therefore envisaged that farmers participating in CBF could switch from conventional pesticides to NPV if and when it becomes available. Whilst therefore, there is little scope for a direct link in the development and implementation of CBF and novel control, CBF-trained villages might provide good locations for future farmer testing of NPV. One key benefit of CBF is that farmers spotted armyworm larvae at an early enough stage to allow time for NPV to be an effective treatment.

Issues of sustainability also need to be examined and addressed. After the initial training and support during the first year of operations, the pilot villages were left to proceed on their own. The national forecaster delivered new pheromone lures at the start of the previous season but the villages were otherwise left to their own devices. Proposed in the project extension currently under consideration, is to monitor activities in these original villages and so establish what needs to be done to facilitate CBF as self-sustaining activity. Initial indications are that CBF did at least carry on in all five pilot villages without repeated visits by project staff.

d. How and by whom, will the further stages be carried out and paid for?

The proposal recently submitted to NRInternational for DFID funding would extend the project reported here for a further year to allow both a CBF pilot to be carried out in an armyworm-prone district in Kenya, and to evaluate the long term sustainability issues for CBF in the Kilosa villages trained during this project.

In addition to DFID funding, USAID last year funded a CBF pilot in a second district in Tanzania (Moshi) which has rather different socioeconomic conditions from Kilosa. Other issues such as the potential for local pheromone trap supply, and modifications to the role of central forecasting were also considered.

The Tanzania Government has embraced the idea of community-based forecasting to the extent that it now appears as an item in agricultural budgetary planning activities. Thus, although government funds are necessarily limited, some support is forthcoming to help sustain, and potentially expand, the CBF initiative.

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