ECONOMIC RESEARCH FORUM

منتدى البحوث الاقتصادية

2008

working paper series

COST BENEFIT ANALYSIS OF DESERT LOCUSTS' CONTROL: A MULTICOUNTRY PERSPECTIVE

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Working Paper No. 0801

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January 2008

Financial support from Sida is gratefully acknowledged. We would like to thank Sultan Abou-Ali and Sofiane Ghali for helpful comments that improved the paper substantially. The usual disclaimer applies.

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Abstract

During the campaigns of the fifties through the nineties, spraying desert locust (DL) was considered to be the only effective instrument in the sense of reducing agricultural damage. Nevertheless, this strategy has been criticized by FAO, donors and affected countries partly because this strategy is connected with considerable resources and partly because spraying may lead to harmful effects to farmers and their environment. However, depending on the lack and scarcity of reliable data both on the effects of spraying as well as their costs and it is not easy to unambiguously change control strategy and concentrate on alternative methods to deal with DL plagues. To close this gap, the objective of this study is to shed light on this problem, to study whether the Moroccan, the Sudanese and the Eritreans agricultural sectors suffered from DL invasions of the eighties and nineties, and to compare the benefits and costs of DL control campaigns. The contingent valuation method (CVM) is used here to estimate total benefits of not using insecticides and to compensate farmers in the case of DL invasion. The results of the CVM show that instead of using insecticides farmers are willing to pay an amount per year to a fund that can compensate them for the losses caused by desert locusts.

ملخص

أثناء حملات الخمسينيات مرورا بالتسعينيات كان رش الجراد الصحراوي يعتبر الوسيلة الوحيدة الفعالة لتقليل الخسائر الزراعية. ومع ذلك فقد انتقدت منظمة الأغذية والزراعة التابعة للأمم المتحدة والدول المانحة والدول المتأثرة هذه الاستراتيجية لأنها من ناحية ما متعلقة بموارد كثيرة ومن ناحية أخرى لأن الرش ربما يسبب تأثيرات ضارة بالنسبة للفلاحين وبيئتهم. إلا أنه مع ندرة البيانات التي يمكن التعويل عليها في المقارنة بين فوائد وتكاليف المكافحة فإنه من الصعب تغيير استراتيجية المكافحة بشكل واضح والتركيز على طرق بديلة للتعامل مع أسراب الجراد الصحراوي. ولملئ هذه الفجوة فإن هذه الدراسة تهدف إلى إلقاء الضوء على هذه المشكلة، ودراسة ما إذا كانت القطاعات الزراعية في المغرب والسودان وإريتريا قد عانت من اجتياحات الجراد الصحراوي في الثمانينيات والتسعينيات. وتهدف الدراسة أيضا إلى المقارنة بين فوائد وتكاليف حملات مكافحة الجراد الصحراوي. تُستخدم طريقة التقييم الاحتمالي هنا لتقدير الفوائد الكلية لعدم استخدام المبيدات الحشرية ولتعويض الفلاحين في حالة اجتياح الجراد الصحراوي. تظهر نتائج طريقة التقييم الاحتمالي أنه بدلا من استخدام المبيدات الحشرية فإن الفلاحين مستعدين لدفع مبلغ من المال سنوياً إلى صندوق يمكن أن يعوضهم عن الخسائر التي يسببها الجراد الصحراوي.

Introduction

Within a time span of 20 to 30 years the desert locust causes serious damage to crops and grazing land. During the campaigns of the fifties through the seventies, the spraying was considered to be the only effective instrument in the sense of reducing crop damage. Nevertheless, this strategy has been criticized by FAO, donors and affected countries for the following reasons (Joffe,1995): The rational for control tends to be based as much on political considerations and emotive arguments as realistic assessment of risks to agricultural production and livelihood; Second, the emergency status of recent operations has largely been a function of unpreparedness on all sides; The lack of clarity and consistency in technical strategy; Chemical spray campaigns as currently employed can be costly and wasteful of resources.

Moreover, a recent focus of attention is the general question mark as to the efficiency of spraying, considering not only the cost of spraying operation, but also the wider social and ecological costs encompassing all external effects on humans, livestock, agricultural products and the environment. Depending on lack or scarcity of reliable data, many studies, such as Herok and Krall (1995) and Joffe (1995) made a supra-regional cost-benefit analysis based, in general, on assumptions and the results were derived through simulation. Therefore, the results, which in general support the use of different alternative strategies to spraying insecticides over agricultural land, were for the most part questioned.
Hence, the objective of this study is to shed light on the desert locust problem in Morocco, Sudan and Eritrea, to analyze the overall economic impacts of the control operations and to compare the costs and benefits of not using insecticides but to compensate farmers for the losses caused by DL invasions. This is done using contingent valuation method (CVM). The remainder of the paper is organised as follows: Section 2 defines and describes DL, Section 3 portrays the survey. In Section 4, CVM is used to estimate the benefits of not using insecticides but to compensate farmers when damaged. In Section 5 benefits and costs of DL control are compared. Section 6 concludes.

2. Country Profiles and the Desert Locust

2.1 Definition and Description of Desert Locusts

The desert locust (Schistocerca gregaria) is a solitary insect that appears in desert and scrub regions of northern Africa, the Sahel (region including the countries of Burkina Faso, Chad, Mali, Mauritania, and Niger), the Arabian Peninsula (e.g., Saudi Arabia, Yemen, Oman), and parts of Asia to western India (Steedman (1988) in Showler (1998)). During the solitary phase (heavy shaded area on the map) locust populations are marginal and do not menace agricultural production.

However, when conditions are favorable the risk for a desert locust upsurge (outbreak) increases. An upsurge which is in general defined as a transition from solitary phase to plague phase includes three phases (Huis, 1994). The first phase, known as the concentration phase, is characterized by an increase in adult numbers and densities in an area where rain has fallen for several weeks previously and where young vegetation is available. The second phase, that is multiplication, is the change in number of individuals in a population as a result of breeding. It can be considered in three development stages, maturation and oviposition, the egg, and the hopper phase. The last phase is the gregarization. It is the sum of the processes by which individual locust form cohesive groups as a result of their conditioning to one another. Rapid population buildups and competition for food occasionally result in a transformation from solitary behavior to gregarious behavior on a regional scale (light shaded area on the map; in Showler, (1998)). Following this transformation, which can occur over two or three generations,[1] the potential invasion area of the gregarious insects extends across more than 50 countries and comprises a land area of 29 million km^2 Herok and Krall (1995). The geographical distribution of regions where gregarization was recorded in the period 1926-76 (i.e., rectangles in map) has followed the same broad pattern since that time (Roffy (1993) in Huis (1994)).

Plagues and Recent Campaigns

The systematic collection, mapping and analysis of DL infestations began between 1929 and 1930. Wallof ((1966) and (1976) in Huis (1994)) identified eight major plagues between 1860 and 1973. They varied in length from one to 22 years, with intervening recessions lasting from less than a year to seven years during the study period.

In 1986, a desert locust outbreak occurred in Sudan, Eritrea, and Ethiopia. Largely because of armed conflict in those countries, adequate control could not be conducted resulting in massive swarms' movement to the west across the Sahel.[2] From 1986 to 1989, over 17 million hectares were treated against DL, using over 12 million litres of liquid pesticide and over 5 000 tons of pesticide dust. Donor contributions amounted to over USD 200 million (Gruys in Huis (1994)).

In late 1992, a clear desert locust outbreak began along the Red Sea coastal plains of Sudan and Eritrea. Swarms that escaped control moved eastward across the Red Sea and from Sudan westward across the northern Sahel. While climatic factors played a role in modulating the dynamic of the 1992-1994 outbreaks, it appears likely that control operations made important contributions toward containing the outbreak. In contrast to the 1986-1989 campaign, 4 million *ha* were sprayed during the 1992-1994 campaign at a cost of USD 18.75 million.

In 1995, conditions in Sudan's interior and/or north-eastern Chad resulted in the production of mobile swarms by the end of the summer. Control operations were being conducted in Sudan, but they were not sufficient to prevent swarms from moving into Eritrea and Saudi Arabia. Though the figures have not yet been tabulated, the area treated with insecticides, and the cost to the international donor community is far smaller than the areas treated and costs of the 1986-1989 and 1992-1994 campaigns.

The locust control campaign of the 1992-94 gave better results because intervention in the Red Sea region, where most DL outbreaks begin, was considered to be successful. Therefore, FAO, locust affected countries and the international donor community considered to support a plan for an early intervention to be centred in the Red Sea region.

Until 50 years ago, most arthropod pests, diseases, and weeds were still controlled mainly by cultural methods. The era of synthetic chemical pesticides truly began in about 1940 when the organoclorine and organophosphorus insecticides were discovered and synthetic-hormone-based herbicides were developed. These chemicals and others that were developed subsequently seemed to be so successful in controlling pests that there was extremely rapid adoption of their use (Pimental and Lehman (1993)). There was little anxiety as to possible human, ecological, or environmental hazards until the late 1950s and early 1960s, when attention was attracted to the issue by the publication of Rachel Carson’s Silent Spring (1962).

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[1] Durations of locust life cycles are variable, depending on species and environmental conditions; in Africa, (there are generally 3-5 generations per year) locusts often form dense bands of flightless nymphs and swarms of winged adults that can devastate agricultural areas.

[2] For more detail on breeding regions see Magor, J. I., in Huis, v. A. (1994).

The only available and effective control tactic against DL is insecticides. Prior to the late 1980's, chlorinated hydrocarbon insecticides, such as dieldrin and lindane, were sprayed on vegetation to create barriers against marching and feeding nymphal bands. This was a critical method of preventive control because of the persistence, the efficacy, and the mode of application (in bands or barriers) of these chemicals if used in desert locust breeding areas. However, as a result of concerns about the fate of such insecticides in the environment, the use of these chemicals has largely been discontinued. The 1986-1989 emergency crop protection campaign was pivotal in the sense that it was conducted when persistent chlorinated hydrocarbon insecticides were being phased out of the insecticide arsenal, and reliance on more selective, but less persistent, insecticides (for example, malathion and chlorpyrifos), became the rule (Showler (1998)).

Most agricultural practices tend in general to decrease the biodiversity of plants and animals. Pesticides in particular have major impacts in decreasing the biodiversity of agricultural ecosystems (Pimental and Lehman (1993)). Hence, controlling desert locust outbreaks and plagues with insecticides can, of course, pose environmental hazards. Up to now few studies have examined the impacts of anti-locust insecticides on the environment. However, it has been ascertained through studies in Mali, Sudan, Morocco, and Senegal that terrestrial and aquatic life could, depending on the insecticide, be adversely affected. The impact of anti-locust insecticides on humans occurs not only during DL campaigns but also afterwards. During campaigns the effects were noted mainly among pesticide handlers and applicators. When the campaigns are over large stocks of unusable, obsolete, environmentally undesirable or banned insecticides have accumulated in many locust affected countries. These stocks are a problem since they are stored in deteriorating containers that may leak and they may be used for pest control when stocks of preferred pesticides are exhausted. Moreover, in addition to potential environmental and human health risks associated with spraying and large stocks of unwanted pesticides, there is the problem of dealing with empty pesticide containers and their use by the general public as storage containers, including food and water (Showler, (1998)).

2.2 Desert Locust and Agriculture

Morocco

The Moroccan economy has two distinct and unequal parts, which may be termed the traditional and modern. The basis of the traditional economy is the agriculture that has evolved to satisfy the subsistence wants of more or less self contained rural communities. The farming sector is crucial to the economy. It employs about 40 percent (in 1995-96) of the working population. There are two types of farming: the large traditional subsistence sector and the smaller modern sector concerned with cash and export crops. The climate, particularly rainfall, influences the pattern of agriculture and leads to considerable fluctuations in production from year to year.

As concerns DL infestation the country has not seen any infestations during the periods 1977-1965, 1990-1991 and 1995. However, when analysing the effect of DL invasions on agriculture, results from agricultural production function analysis do not show any negative impact at the national level (Belhaj, 2002). In 1993, for instance, which was a DL year, Morocco have had higher cereal production compared to in average years.

Sudan

The Sudanese population was 11.3 million in 1960 and increased to 28 million in 1998. The share of rural population has decreased from about 89 percent in 1961 to 66 percent in 1998. When it comes to agricultural production, it has fluctuated since the sixties and it is difficult to assign fractions to a specific factor such as drought or DL. As far as DL infestation is concerned, the country (according to PPD Sudan) has not seen any infestations during the periods 1961-1966, 1984, 1994 and 1996.

Eritrea

Similar to the majority of LDC economies, Eritrea's economy has two distinct but unequal parts where the traditional one is based on agriculture with a population around 80 percent of the total. The farming sector is crucial to the economy and it employs 77.5 percent of the working population in 2000.

At the national level the agricultural production indices[3] depicted in Table 1 reveal a non stable agricultural production since Eritrea's independence, where the reasons may be several such as drought, desert locust invasions etc. However, in order to estimate the reasons for the decreased agricultural production, estimations should be done at the household level in order to assess if the average farmer has been hurt by DL.

Using a household production function, the results show that large DL swarms have a significant and negative impact on cereal production; an increase in the magnitude of swarms by 1 percent would decrease cereal production by 0.3 percent. Medium and low level swarms have similar negative effects on cereal production. When estimating a household production function by regions -northeastern lowlands, highlands, and southeastern lowlands- a different result is found for the southeastern lowlands, where DL impacts are not significant. This result may be seen as a paradox for a non-DL expert. However, as discussed above historically data shows that cereal production during DL years is in general higher than in years without DL. This is because rain in the highlands and the derived flooding in the lowlands are sufficient. The reasons for this outcome are several and include the farmer's incentives to make use of more land, the damage after DL is corrected as DL leave, and since DL attacks are random, and the average farmer may not suffer much from the invasions. However, although the average farmer in the southeastern lowlands did not suffer from DL invasions the findings may not imply that the 1997 invasion did not affect some farmers to the point that they lost everything, where the outcomes may be severe socio-economic consequences? For further details on this issue see Belhaj (2002).

3. The Contingent Valuation Surveys

3.1 Sample

Morocco

The whole country may be in a risk zone for DL outbreaks. In July 1998 and with the assistance of DL authorities in Morocco we selected the regions where the study could be conducted. These include the Sous plain with Inzgane and Ait Baha regions, the Saharan facing slopes with Ouarzazate and Errachidia regions, Taourirt of the Eastern plateau and Béni Mellal region in the Moroccan Meseta. Except the Sous plain which has been subject to several DL attacks, the Eastern plateau is subject to attacks of both DL and grasshoppers. The sample size was limited to one thousand households. Fifteen percent was then used to conduct a pilot study, in the Sous plain, in order to on the one hand to discuss the

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[3] Net Production Index Number (PIN) presents Net Production (Production - Feed - Seed) indices. All indices are calculated by the Laspeyres formula. Net production quantities of each commodity are weighted by 1989-91 average international commodity prices and summed for each year. To obtain the index, the aggregate for a given year is divided by the average aggregate for the base period 1989-91. Indices are calculated from net production data presented on a calendar year basis.

questionnaire and its formulation with the interviewee, to correct misunderstanding and to include other relevant questions. On the other hand the objective of the pilot study was to decide the starting prices which were then used in the final interviews. The mean and standard error of the WTP obtained from the pilot was used as a bench mark for the starting prices which were used in the final study and calculated so that they correspond to two lower values and two upper values arrayed around the mean as such:

75	100	Mean =125	150	175

Sudan

The whole Sudan is an at risk zone for DL outbreaks. In May 1999 and with the assistance of PPD Sudan a random sample was selected and a contingent valuation study in 2 regions was conducted; the first one in the Tokar delta which is a winter area for DL outbreaks and the second one in the River Nile which is a summer region. The sample size was supposed to be one thousand households. Fifteen percent of the sample served to conduct a pilot study in the winter region. The aim of the pilot study was twofold. On the one hand it helped to discuss the relevance of the questions with the farmers and to correct for misunderstanding, if there were any. On the other hand the pilot study served to decide the starting prices to be used later on in the final interviews. The starting prices (in Sudanese Dinars)[4], which were used in the final study, were calculated so that they correspond to two lower values and two upper values arrayed around the mean such as:

1000	1500	Mean = 2000	2500	3000

Eritrea

In May 2000 and with the help of technical officers of the Ministry of Agriculture, 18 villages located in the southeastern lowlands and the highlands were randomly chosen to make a survey. In each village some households where selected randomly and questions related to contingent valuation method were asked. To start with a pilot study including 100 households was carried out. The purpose of the pilot study was twofold: firstly, to discuss the questionnaire and its formulation with the interviewers in order to correct misunderstanding and include other relevant questions to the study; and secondly, the pilot study served to decide the starting bids, which were used in the final interviews. From the pilot study the mean WTP for the insurance was 50 Nakfa (USD 5). The starting bids which were used in the final study were calculated so that they correspond to two lower values and two upper values arrayed around the mean such as:

10	30	50 (mean)	70	90

3.2 The Questionnaire and Data Description

The questionnaire included a letter, which described the hypothetical market and why the study was being conducted.[5] It was conducted face to face and began by asking the respondents questions related to environmental problems in the region, whether or not DL

[4] 1 Sudanese Dinar (SD) = 0.004 USD

[5] The fact that the questionnaire is based on a hypothetical market implies that respondents are not obliged to pay. However, although they will not pay or they cannot pay, the results from the study highlight the farmers' incentives to deal with DL.

control using insecticides causes any problems and if DL per se is an environmental problem. It also contained 56 questions for the three parts of the CVM framework.

The hypothetical market constructed in the questionnaire consisted on the one hand of a simple environment good. That is the reduction of insecticide use, by way of an insurance payment. On the other hand the hypothetical market consisted of asking the respondents their willingness to pay for DL control if the state stops investing in DL control. Finally, the bidding was designed so that dichotomous choice values could be estimated from the same data as those of the iterative bidding[6]. This design allows at least for a partial comparison using the same respondents. However, it is also worth pointing out that the iterative bidding approach generates a scenario most similar to that encountered by the consumers in their usual market transactions. They do not face a "take it or leave it" situation when buying but rather a negotiation or a bargaining situation.

Morocco

848 persons, almost hundred percent answered all questions. Only two respondents refused to answer the questions. As shown in Table 2, total mean income, it is DH 35 327 per year or DH 2 944 per month. This value sounds reasonable in Morocco where the “minimum” wage is DH 1510. Using the dichotomous choice, 36 percent of the respondents accepted the proposed prices.

Turning to the harvest damaged by DL, 44 percent of the households have been attacked by DL. The mean damage per household during the last invasion was equivalent to DH 4540 or USD 504. As concerns the respondent’s main occupation, 65 percent are farmers. Here it is worth mentioning that 28 percent of the respondents are farmers that are also dependant on working as agricultural workers and are dependent on salaries.

Sudan

In Sudan, 624 farmers were interviewed. Table 2 shows the characteristic of the sample (both regions). The number of times damaged during the last 20 years by DL attacks is estimated to be 3.55 in average.

Total income the last agricultural year has been equal to around SD 60 thousand. However, comparing this average to the best yield during the last 20 years, the differences are very significant. The last year’s average yield is about 31 percent of the best average yield. This gives an idea about the variance of yields in Sudan and may be the reason why farmers are willing to pay for an insurance in order to be compensated for the losses and thereby reduce the variance of average agricultural yield.
As far as the dichotomous choice question is concerned, where the respondents answered yes or no to the proposed bid, 62 percent have had an affirmative response. All farmers have had experiences of DL attacks. As regards if farmers pay for the use of land, 43 percent are renting the land. Turning to the question of whether DL is a major threat to the respondents yield only 18 percent of the whole sample have had an affirmative answer.

As regards whether farmers have any secondary occupation, 20 percent of them have one. This finding may be a sign that farmers are risk averse since they combine farming with other

[6] The respondent was given a value which he accepted or rejected that is, dichotomous choice. If the value presented was accepted (or rejected), higher (lower) values were presented. If the respondent says yes (no) to the highest (lowest) value, then he was asked to give his maximum (minimum) bid. This last value constitutes then the willingness to pay in the iterative choice.

tasks in order to avoid reduced income that may be caused, for instance, by drought and DL attacks.

Eritrea

The questionnaire was conducted face to face and a total of 702 households answered the questions.

Since the south-eastern lowlands is one of the most invaded regions by DL, this part of the study will concentrate on it. Table 2 shows some characteristics of the sample. The number of times the average household have been damaged by DL during the last 20 years is less than one. Looking at the average yearly WTP using the iterative bidding method, the average value to be given to obtain a compensation for losses generated by DL, is 36 Nakfa that is equivalent to USD 3.6. As for payments for land use the households that are engaged in this activity, there are very few.

Although two females were engaged in data collection in order to avoid a high men' representation, most of the respondents were men and around 30 percent of them had a second occupation. When it comes to farmers' preferences for pesticides and the impacts of these on the farmer and his environment, 63 percent of the farmers dislike pesticides and 80 percent are aware of the negative impacts of the chemicals. As for the proportions of households replying affirmatively to the suggested bid they are 44 percent.

4. Contingent Valuation Method and Estimation Methodology

4.1. Modeling the Willingness to Pay For an Insurance Against DL Attacks

4.1.1 The Model

To value the total benefits[7] of a product that is not traded in a private market, different direct and indirect methods have been developed. The contingent valuation method, (CVM) is a direct[8] way of using surveys to value public goods. The CVM is a relatively new technique[9] built up on the idea of a hypothetical market scenario where a public good is transacted. An auctioneer represented by an interviewer is then presenting the good to the members of the hypothetical market (i.e., the sample) to elicit their willingness to pay, (WTP) for the good in question. This method is called contingent[10] because it depends upon the hypothetical market presented to the interviewed.

Normally, the next step, after conducting the interviews, in the CVM procedure is the estimation of the willingness to pay. As mentioned in the previous section, the attacks by DL are random and may lead to socio-economic catastrophes for some households; farmers are willing to pay an amount of money to insure themselves for the sake of stability and reduction of production fluctuations.

The WTP for an insurance against DL attacks is modeled assuming that the farmer's agricultural production depends not only on the customary production factors such as labor

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[7] The concept of total benefit value or total economic value includes not only direct use values such as agriculture it also includes: indirect use values e.g., nutrient retention and option and quasi-option value e.g., potential future uses. The total economic value includes also non-use values such as existence value e.g., biodiversity.

[8] Indirect methods include hedonic prices and transport cost.

[9] The economist Robert K. Davis was the first in the early 1960s to use the questionnaire to estimate the benefits of outdoor recreation in a Maine area.

[10] It has been also called the survey method, the interview method, the direct questioning method, the hypothetical demand curve estimation method, the difference mapping method, and the preference elicitation method.

and agricultural requisites but also on the policy instruments for example, insurance available to him.

The farmer's indirect utility function takes the following form:

$$V = (p_x , y / I_j),\ j = 1,0$$

where p_x is cereal price, y household income and I_j is the insurance premium where $j= 1$ depicts a positive acceptance of the sum proposed and 0 reflects a situation where the farmer either he cannot afford to or his unwilling to pay. His unwillingness may also be a result of his beliefs related to the authority's responsibility that is, that the state should pay.

Recall, however, that farmers are always engaged in some kind of insurance to reduce instability of their income. This non-market insurance may take the form of having a second work, to invest in livestock or to rely on social contacts that the farmer counts on in crisis' situations. However, this kind of insurance may not be enough and the farmer is willing to pay and relay on market insurance. The market insurance also has at least two positive side effects that are: they compensate the farmer for the loss experienced and they increase the probability of getting bank loans.

Since the impact of DL invasions have a marginal effect on the average farmer, payment of an insurance premium (which of course depends on its magnitude) would reduce the farmer's income by the premiums amount. The change in income generates the following;

$$\Delta V = V(p_x , y^1 / I_1) - V(p_x , y^0 / I_0)$$

The amount of money paid for the insurance premium defines the compensation variation. This is the willingness to pay to stabilize farmer's production and thereby his income. The *WTP* is the amount of money that reduces farmer's income such as:

$$\Delta V = V(p_x , y^1 - WTP / I_1) - V(p_x , y^0 / I_0)$$

where the reduced form based on separability with respect to *WTP* is;

$$WTP = f(\beta x)$$

The equation to be estimated is;

$$WTP = \alpha + \beta x + \varepsilon$$

where α, β and x are respectively, vectors of parameters to be estimated and explanatory variables of WTP given by the farmers. ε is an error term.

4.1.2 Insurance Against DL Invasions

The basic idea of DL insurance in Africa including Morocco, Sudan and Eritrea would be a state insurance to compensate farmers for the losses in cereal production caused by DL invasions. This insurance would be conditional on a preventive control program to be conducted in order to mitigate the impact of DL invasions. Therefore, the cost of the preventive program would be supported by the insurance fund into which farmers pay an annual premium. Furthermore, insurance programs would be mandatory rather than optional. Mandatory participation is required because preventive control concerns all lands regardless of size and ownership. Unless mandatory, "free rider" tendencies would result in uninsured farmers becoming beneficiary to preventive control applied to DL. Another reason for promoting a mandatory DL insurance is the possibility of risk pooling. The idea of pooling is to bring several risks together for insurance purposes in order to balance the consequences of the realization of each farmer risk.

There are in general different kinds of crop insurance including the general multiple peril insurance, drought insurance and the special case of hail insurance. Each of these insurances has positive and negative sides. However, the most dominant reasons for crop insurance' failure have been two types of asymmetric information problems they are, moral hazard and adverse selection. These both rise expected indemnity payments relative to premiums, undermining the financial soundness of the insurer.

Moral hazard refers to a situation where an insured person, without the knowledge of the insurer, changes behavior after purchasing insurance in a way that increases the probability of receiving an indemnity payment. When it comes to DL insurance, moral hazard would not emerge since farmers' individual actions cannot affect the risk of being invaded by DL. In the case of an efficient preventive control moral hazard cannot be a serious problem either since the objective of preventive control is to deal with DL in remote areas and not to conduct control on farmland.

Adverse selection refers to the fact that people who are more likely to suffer the insured event will be more willing to insure at a given rate. However, adverse selection may not be a serious phenomenon if an efficient preventive control is in place. Nevertheless, if there is no preventive control or if the applied preventive control is not efficient, adverse selection may be a serious problem.

4.2. Estimation Results

A part from the fact that we are interested in the mean and median willingness to pay for, on the one hand the insurance, and on the other hand the contributions if the state stops investing in DL control, we are also interested in the variables that have impact on the given bid. These variables include various socio-economic characteristics of the household notably income and household composition. Also important are such variables as education, if the household owns its land or rents it, if the agricultural year has been damaged by DL and if DL is used by farmers, and their livestock.

Using dichotomous choice where the dependant variable is binary, estimation with ordinary least square would not be efficient because the dependant variable includes a large number of zeros. Therefore a probit model is used.

As for the variables included in the model, there is little guidance from economic theory about which characteristics such as age, gender etc. should be included for estimation. Thus, many explanatory variables, even though not significant are included for estimation.

Morocco

As shown in Table 3 total income and literacy are highly significant. An increase in income would increase WTP for an insurance to compensate for total losses in the case of a DL outbreak. A higher degree of education would increase WTP if DL is consumed and/or if they are given to livestock. The variables age, if the farmer owns his land, are also significant at a 5 percent level. The variable use DL is negative and significant at 5 percent level, indicating the high correlation between WTP and DL use. To pay for not having pesticides would lead to an increase in the consumption of DL by farmers and their livestock. An increase in the consumption of DL would decrease WTP. This can be seen as if consumption of DL by farmers and their livestock in general is a compensation for the losses.

Sudan

Table 3 shows that family size's estimate is highly significant but the income is not. This result may be explained by the fact that since incomes are low and family members are numerous the responsible member of the family is willing to pay for an insurance in order to avoid agricultural losses since these may lead to food shortage and hunger for the whole family. The other variable that is very significant is if the farmer pays for the use of agricultural land. The parameter estimate is negative meaning that the farmer would pay less. Since the rent of land varies between 25 and 75 percent of total yield, the net income for agricultural activity would be too low to afford other costs such as an insurance against DL.

The variable, DL are major traitor to yield is positive and highly significant. This means that farmers are willing to pay for insurance in order to avoid losses in their agricultural yield. Moreover, if the farmer is aware of the negative impacts of pesticides on humans, plants and livestock, his WTP for an insurance that can compensate him in the event of DL using only preventive control is positive.

As for the starting price it is significant at a 10 percent level while studying the whole sample. Fortunately, bids given to farmers did not have high impact on the farmers WTP and thereby did not bias the results significantly.

Eritrea

Table 3 shows the estimated results for the south-eastern lowlands where WTP increases with the number of times the household agricultural production has been damaged. However, the parameter estimates for the high lands are not significant and therefore we concentrate on the south-eastern lowlands. These results confirm the earlier findings where households in the low lands are the most damaged and they are the ones which are willing to contribute most for an insurance to avoid the use of chemicals on their farm land and to be compensated in the case of DL invasions. Unfortunately, the starting bid is significant. By rotating the starting bids among the respondents we tried to avoid this result but our efforts did not seem to give the desired results.

Turning to the other characteristics, the number of children is negative and significant at 5 percent level, implying a lower WTP when the number of kids increases. These results reflect the income constraints faced by families with larger numbers of child. However, if the size of the household is large and includes other adults that may contribute to the living, the parameter estimate for this variable is positive and significant only in the low lands. As for total income it is positive and significant in all regions implying a higher WTP if incomes increase.

As for the variable "if ever damaged by DL" one would expect a close relation between this variable and the WTP. The parameters estimates are negative and significant at a 15 percent level. Since exposure to pesticides is judged to lead to negative effects, households in the lowlands would increase their WTP in order to avoid these chemicals. Having a second occupation serves to increase income and to informally insure the farmer in the case of production instability. The parameter estimate for this variable is positive and significant at a 15 percent level in the low lands.

4.3 Welfare Estimation

Following Hanemann (1984) and Kriström (1990) we use a parametric approach to estimate the mean WTP in a probit model. For any distribution function F_v and utility difference ΔU, the mean willingness to pay takes the form:

$E(WTP) = \int_{-\infty}^{\infty} AU_m f_v[\Delta U(A)]dA = \int_{-\infty}^{\infty} Ag_{wtp}(A)dA$ Where $U_y = \delta U / \delta y$ and y, f_v, g_{wtp} denotes income, densities of *v* and WTP respectively. The middle part of the equation says that E(WTP) is obtained by weighting each bid A with the probability $f_v(\Delta U(A))$ and the marginal utility of income. Hence, if the random variable v has expected value zero and the utility function is linear in income,

$U_I = \alpha_I + \beta_y$, implying $\Delta U = \alpha - \beta A$, then the expected value of the willingness to pay takes the form[11] $E(WTP) = \alpha / \beta$.

Morocco

Using probit estimates for the whole sample where α i.e., intercept is equal to –0.19 and β *i.e.,* the starting price's marginal effect is equal to –0.001, the mean and median WTP are equal to DH 190.

Sudan

Using the parametric approach the yearly mean WTP is estimated for the dichotomous choice model and the result is of SD 2051 (USD 8.2). Comparing the yearly mean WTP for the whole sample in Sudan to the corresponding one in Morocco that is, USD 17.7, the Sudanese average is less than half the average in Morocco. Surprisingly, even though the Sudanese farmers are less wealthy than the Moroccan ones they are willing to contribute with a high amount in order to insure themselves against DL attacks. One reason for this finding would be the higher frequency of DL attacks in Sudan and that they are high risk averse.

Eritrea

In Eritrea, using probit estimates the mean WTP is equal to Nakfa 45 (USD 4.5). On the other hand, the average WTP of farmers that lost all cereal yield at least one time the last 20 years is Nakfa 47 (USD 4.7).

5. Comparing Benefits and Costs

The objective of (CBA) is to value whether or not a project is profitable from a socio-economic point of view. In general, a full CBA includes[12]. (i) Definition of a project, (ii) Identification of project impacts, (iii) Which impacts are economically relevant, (iv) Physical qualification of relevant impacts, (v) Monetary valuation of relevant effects, (vi) Discounting of costs and benefit flows, (vii) Applying the net present value test, and (viii), Sensitivity analysis.

Depending on the non-availability of data relative to all these stages, following them step by step would be impossible. Therefore we limit ourselves to on the one hand comparing the benefits and costs of an insurance scheme proposed to compensate farmers in the case of DL outbreak. On the other hand and for the sake of comparison, we use avoidance of farmer losses as a surrogate for monetary benefits. Doing so would permit us to compare different benefit and cost values.

[11] See Kriström (1990) for more details.

[12] Hanley and Spash (1993)

5.1 DL Control Costs

Morocco 1986-95

The total cost of DL management for different years is presented in Table 4. This data which was given by the Centre National de Lutte Antiacridienne in Morocco includes:

- Fixed costs which originate from two sources in Morocco during the period 1986-96; the Ministry of Interior and the Ministry of Agriculture. These costs are expanded to maintain a fixed capacity for DL survey and control including costs of research and development and training etc.
- Variable costs which include costs of control campaigns. They originated in 1988 on the one hand from the Ministries of Interior (special account), the Ministry of Agriculture and the Ministry of Defence. On the other hand these costs also include emergency aid coming from different countries and international organizations such as FAO and UNDP.

For 1986-89 campaigns, for instance, costs of medicine and medical personnel totaled DH 5.9 or 0.8 (1990 USD) million, respectively, (on the basis of regular blood testing, more than 1000 persons removed from spray operations temporarily or permanently during 1986-89 period (Belhaj et al 1997). These costs are, according to Mr. Ghaout Said of the Centre National de Lutte Antiacridienne in Morocco, included in the campaign costs of Table 4.

Total costs vary among the years. They are DH 776 million in 1988 a DL outbreak year and DH 0.9 million in 1996. For the period in our study that is, 1986-95 they amount to DH 958.6 million or USD 105 million.

After a discussion with Mr. Ghaout, the amount of DH 952 million is not representative of total costs during the period 1986-95 since, on the one hand only 40 percent of the pesticides have been used and the material (including plains) bought in 1988 is still available. Based on this, we may assume that only half of the value of 1988 that is, DH 388 million, can be used in the calculation of the total costs of the period 1986-95. Hence, the total campaign cost of 1986-95 would be DH 564 million or USD 62.6 million.

Furthermore, the expenditures of 1988 are very special and would not occur if preventive control has been efficient. Assuming 1988 being a normal year with an average control cost of DH 30 million, total costs for the campaign period 1986-95 would be DH 206 million or USD 22.9 million. Notice, however, that total costs are only monetary ones. Impacts on the environment and health hazards are not included. Including them would increase total control costs.

Sudan 1988-1998

As discussed while presenting the Moroccan case, total costs for DL management includes fixed and variable costs. In the case of Sudan we assume an average campaign cost of USD 10 per ha. This value is used in order to avoid discussing high level and low level costs as data lacks of detail specification.

In Joffe (1997), USD 19 is used. According to Joffe the estimated cost which is based on pesticide cost of USD 5.5/ha incorporates more comprehensive assessment of actual campaign costs including per diems, fuel, vehicle maintenance, food and other provisions, medical equipment etc. As for PPD Sudan their calculations of 1997-1998 campaigns gave an average cost of USD 12. However, since in general it is not clear how much of the fixed costs that is, equipment is allocated to the campaigns; USD 19 may be seen as a high value. Therefore we use USD 10 such as an average for campaign costs in Sudan. Table 5 shows campaign costs for almost all years during the period 1988-1999.

Eritrea

Since most data collected is for the agricultural year 1997/98 and since we are merely interested in this year, the comparison of benefits and costs are related to the same period. There are no exact values concerning the costs of the campaigns of 1997-1998 but data on the number of treated hectares is shown in Table 6.

In the agricultural year 1997-98 a total of 18 565 *ha* were treated against DL in Eritrea. 400 *ha* were treated in 1997 and 18165 *ha* were treated in 1997/98. Assuming an average total cost of 10 USD[13] per hectare, the total campaign cost of 1997-98 is estimated to 185650 USD.

5.2 Comparing Benefits and Costs

As discussed above and using CVM an insurance contingent on an efficient preventive control in remote areas would compensate the damaged farmer in the case of DL invasions. Since CVM is a tool for cost benefit analysis its role is to provide aggregate benefits. However, expanding the sample values to the whole farmer population may imply biases if proportions of non-respondents is high (see Loomis 1987). In this study (and may be depending on the face to face procedure to collect data), we did not experience a high rate of non-respondents. Thus, using the averages of the Probit's estimates is a good practice.

Morocco

As discussed total benefits for not using insecticides against DL and instead compensate farmers for their losses depend on over which population we make aggregation. Since Béni Mellal region, although not invaded by DL for a long time, had a positive WTP, we believe that aggregating over the total agrarian population is the most adequate procedure. Therefore total adult population is used in this study. We believe also that individuals only represent themselves and not their households.

The total benefits of an insurance to compensate for losses in the case of a DL invasion would be DH 914 million or USD 102 million per year. Notice that this value is in the same range as the value for total control costs for the period 1986-95. Consequently if outbreaks happened each year total benefits would be equivalent to total costs for the studied period. But this is not the case since outbreaks may take place each second year, each third year, each fifth year etc. If outbreaks happened each second year[14], then total benefits of not using insecticides and compensate farmers for the losses would be twice as high as total control costs for the whole period 1986-95. Using the same reasoning, if invasions occurred each third or fifth year, total benefits would be respectively, three times or five times higher than total control costs. Based on this, we can conclude in this case that using insecticides to control DL is not an efficient way since total benefits of not using them are higher than total control costs.

If only 50 percent of 1988 control costs are used, total benefits (i.e., DH 914 million) would be less than total costs (i.e., DH 564 million) when outbreaks take place each year. But this is not realistic. However, if outbreaks take place at least each second year, total benefits of not using pesticides would be higher than total control costs. If total costs of DH 206 million are

[13] Values in the range of 10 to 16 USD are used to estimate the campaign costs per hectare. These costs include fixed costs that are used irrespective of DL invasions, and variable costs including additive efforts, and pesticides.

[14] For the sake of simplicity the values are not discounted.

used for the comparison, 4 years at least would be needed between DL attacks for total benefits to equate total costs.

As for insurance in Morocco, the Mutuelle Agricole Marocaine d'Assurance has been operational in the country since 1942. It is a state owned and insures mainly against drought and frost. Regarding drought the insurance is for cereals only. The purpose of the insurance is to promote investments in the cereal sector to increase yield and to enhance farmer's economical situation. There are no transaction costs and the state pays the difference if the costs are higher than the collected money. Table below shows the conditions and prices:

Based on these details, our results have some policy implications. Given that desert control strategies of the eighties and nineties in Morocco have been economically non-efficient and given that farmers, in general are against spraying insecticides, this does not mean that DL control should be stopped. Control strategies should, instead focus on preventive control only and solve the problem in remote regions. Moreover, control should be systematic and regular since this strategy may lead to both agricultural and environmental lower costs.

Sudan

As discussed above and using CVM, an insurance to compensate farmers in the case of DL attacks would be a substitute for not using insecticides on cropland. Since we did not experience a high rate of non-respondents, and since average WTP in the regions studied are roughly in the same range, the mean value to be used in the estimations is the one for the whole sample. As in the Moroccan case two alternatives that is, CVM benefits will be used and compared to the campaign costs for the period 1988-1999.

Including all regions will give an idea of the total benefits for the whole country. Assuming our sample is representative for all farmers in Sudan total benefits for an insurance to compensate farmers in the case of DL attacks would be SD 5 837 million (USD 23 million). We are aware of the fact that the probability of being attacked by DL may have an impact on the willingness to pay for an insurance, however, the regression analysis of section 4 do not confirm this assumption.

As discussed above we believe that the population over which the aggregation is made concerns all adults in the region. The number of adults is estimated to be 7.116 million. Using SD 2051 (USD 8.2) as an average WTP for not using pesticides and to compensate farmers for agricultural damage, the total benefit, as shown in Table 8 are estimated to USD 58 million per year. This value is 3.6 times the campaign cost[15] of the period 1988-1998. Assuming that our sample is representative for all regions and thereby the WTP by farmers, the benefits of not using insecticides against DL are much higher than the costs. Hence, using spraying cropland against DL is not an efficient way to deal with these insects in all Sudan. Moreover, even if aggregation is done over the number of households in the country (2.846 million) the benefits of not using insecticides would remain higher than campaign costs.

Eritrea

In Eritrea the average WTP is Nakfa 47 (USD 4.7), the total[16] of 2063850 USD/year would be collected. One reason for aggregating over the whole Eritrean agricultural household

[15] Since it is not clear which is the base year for the received campaign costs it is impossible to unambiguously transform the costs to USD for a specific year. Our cost values that concern 11 years are twice as high as the values reported by Joffe 1997, which are given in 1995 dollars**.**

[16] Agricultural population is assumed by FAO to be 2 986 000 in year 2000. Assuming an average household of 6.80 (from this study) the total number of households would be equal to 439117.

population is based on the fact that the entire country constitutes a risk zone for DL invasions. The other reason for including all households is the positive WTP in all regions.

As shown in Table 9 benefits of not spraying agricultural land (including crop land and pastoral land) is more than eleven times the campaign cost of 1997-1998. Based on this evidence and similar to the findings in Morocco and Sudan, using chemicals on agricultural land to control DL invasions is not an efficient policy since total benefits of not spraying is higher than total cost.

6. Summary and Conclusions

This study presents several pieces of evidence showing that farmers in Morocco, Sudan and Eritrea are willing to pay high amounts of money to avoid spraying insecticides but to be compensated for the losses generated by desert locust invasions. Farmers in general are against using insecticides against DL because spraying has negative impacts on the environment and human health and because when DL are sprayed they can not be consumed by farmers and their livestock. For instance a farmer could not understand why DL being a source of protein for both humans and livestock, is spoiled by chemical products when the damage they cause is much lower than the benefits. This observation is supported by the fact that 87 and 16 percent of the Moroccan and Sudanese respondents have preferences for preventive control of DL, respectively. However, 72 percent of the Sudanese farmers are for strategic control. Moroccan Farmers are also willing to pay DH 606 or USD 67, per year if the state stops investing in DL control. If this value is aggregated over the whole agrarian households in Morocco, the total contribution would be higher than the most costly DL campaign in the country i.e., 1986-89. Similar results are found for Sudan and Eritrea where benefits are around three folds higher than costs.

Using the parametric approach the yearly mean WTP is estimated for the dichotomous choice model to be $17.7, $8.2 and $4.7 for morocco, Sudan, and Eritrea, respectively. Comparing the yearly mean WTP for the whole sample in Sudan to the corresponding one in Morocco that is, USD 17.7, the Sudanese average is less than half the average in Morocco. Surprisingly, even though the Sudanese farmers are less wealthy than the Moroccan ones they are willing to contribute with high amount in order to insure themselves against DL attacks. One reason for this finding would be the higher frequency of DL in Sudan and that the Sudanese farmers are high risk averse.

Given that desert control strategies of the eighties and nineties in the studied countries have been economically non-efficient and given that farmers, in general are against spraying insecticides, this does not mean that DL control should be stopped. Control strategies should, instead focus on preventive control only and solve the problem in remote regions. Moreover, control should be systematic and regular since this strategy may lead to both agricultural and environmental lower costs.

Preventive control is in line with policies in locust-affected countries, FAO and donor countries. For instance, Morocco is supporting Mauritanian campaigns in order to mitigate damage to Moroccan agriculture. The more recently formed Team Maghrebine composed of Algerian, Tunisian, Moroccan, Libyan, and Mauritanian personnel are conducting terrestrial survey and preventive control in the Maghreb and in neighboring Sahelian countries. For the period April 1996 to January 1997 the campaign costs in Mauritania, for instance amounted to USD 159138, (Lagnaoui (1997)). Moreover, control operations of the 1992-1994 outbreaks, centered in the Red Sea region made important contributions toward limiting DL invasions to other regions. The outcome of the 1992-1994 locust control campaign provided enough incentive for FAO, locust affected countries, and the international donor community to seriously consider supporting a plan for preventive control. Moreover, the FAO has a program to improve early warning systems known as the Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases, EMPRES.

As for the insurance to be used to compensate the damaged farmers, it is a challenging policy instruments in this part of the world where agricultural market insurance does not exist in many countries. According to Quarantelli (1978), Davis (1978, 1986), Anderson and Woodrow (1989) and Blaikie *et al* (1994) a disaster occurs when its two main components, hazard and vulnerability coincide in time and place. According to this discourse, until they are met by vulnerabilities such as an unsafe environment, fragile socioeconomic structures, or lack of disaster preparedness, hazards would remain only as natural phenomena. For example, when DL invades an uninhabited place, this is only a natural hazard not a disaster. When grasshoppers invade the farmland in the USA, they do not usually experience these as a major disaster because of the country's preparedness and mitigation measures for example, insurance.

The basic idea of DL insurance in Africa including Morocco, Sudan and Eritrea would be a state insurance to compensate farmers for the losses in cereal production caused by DL invasions. This insurance would be conditional on a preventive control program to be conducted in order to mitigate the impact of DL invasions. Therefore, the cost of the preventive program would be supported by the insurance fund into which farmers pay annual premium. Furthermore, insurance programs would have been mandatory rather than optional. Mandatory participation is required because preventive control concerns all lands regardless of size and ownership. Unless mandatory, “free rider” tendencies would result in an uninsured farmer becoming beneficiary of preventive control applied to DL. Another reason for promoting a mandatory DL insurance is the possibility of risk pooling. The idea of pooling is to bring several risks together for insurance purposes in order to balance the consequences of the realization of each farmer's risk.

References

Belhaj, M., Forsund, F., Lundberg, Å. and Wiktelius, S. (1997)"Environmental Economics and the Desert Locust" Draft, Göteborgs University.

Belhaj, M (2002): Environmental Economics of Desert Locusts: The Cases of Morocco, Sudan and Eritrea. *Department of Economics, Göteborg University.*

Hanemann, W.M. (1984) "Welfare Evaluations in Contingent Valuation Experiments with Discrete Responses". *American Journal of Agricultural Economics*, 66, p. 332-341.

Hanley, N and Spash, C. L. (1993) "Cost Benefit Analysis and the Environment" Edward Elgar Publishing Company

Herok, C. A. and Krall, S. (1995) "Economics of Desert Locust Control" GTZ.

Huis, v. A. (1994) "Desert Locust Control with Existing Techniques" Wageningen Agricultural University, Wageningen, The Netherlands.

Joffe, S.R. (1995) "Desert Locust Management, A Time for Change" World Bank Discussion Papers No, 284

Joffe, S.R. (1997) "Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases (EMPRES): Desert Locust Component". Workshop on Economics in Desert Locust Management, Cairo, Egypt 21-22 September 1997.

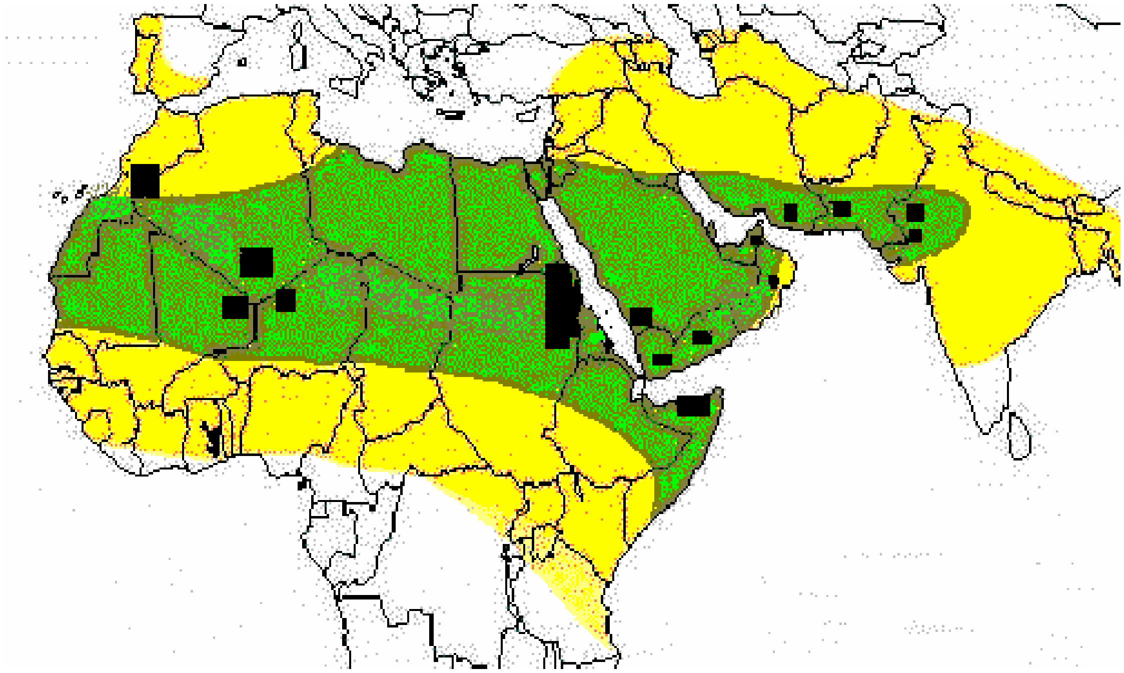
Kriström, B. (1990) "Valuing Environmental Benefits using the Contingent Valuation Methods - An Econometric Analysis". Ph.D. thesis, Umeå Economic Studies, No 219, University of Umeå.

Lagnaoui, S. (1997) "Mission d'Assistance à la Lutte contre le Criquet Pelerin in Mauritanie" FAO,

Pimental, D. and Lehman, H. (1993) "The Pesticide Question, Environment, Economics and Ethics". Chapman and Hall.

Showler, A. T. (1998): The Desert Locust in Africa and Western Asia: Complexities of War, Politics, Perilous Terrain, and Development http://ipmworld.umn.edu/chapters/Showler.htm

Figure 1: Regions of Solitary Phase (heavy-shaded) and Potential Gregarization (light shaded) and Sites of Observed Gregarization (rectangles) (source: Roffy, J. 1993 and Showler 1998[17])



[17] http://ipmworld.umn.edu/chapters/Showler.htm.

Table 1: Agricultural Production Indices

	1993	1994	1995	1996	1997	1998	1999	2000
Cereals	83.1	278.9	162.1	83.5	92.2	487	285.2	285.2

Source: FAO

Table 2: Characteristics of the samples

Variable	Specification	Morocco	Sudan	Eritrea
Sample size		848	624	398
SP	Starting price	126DH (28)		52.61Nakfa
Ldamage	Damage caused by desert locust (DL) in the last invasion	4540 DH (25644)		
Ndamage	Number of time damaged		3.55	0.87
Male	Gender Dummy = 1 if male	1	0.92	0.95
Age	Respondents age	47 (17)	43.96	54.1
Civil	Categorical variable indicating the civil status of the respondent			1.13
Kids	Number of children in the household	4 (3)	3.83	4.69
Hhsize	Household size	8 (4)	7.48	7.21
Own land		3 (5)		
Rent Land	Rent to pay for the land use	813DH (4287)		
Income	Total household income	35327 DH (248095)	60877.6	3558 Na
Hdamage	Dummy = 1 if harvest ever damaged by DL	0.44		0.73
UseDL	Dummy =1 if household use the desert locust			
PPesticide	Have preference for pesticides		0.1	0.63
Pesticide	Dummy for the externality of pesticides	0.57	0.23	0.8
Status	Household status	0.82		
Moccupation	Dummy = 1 if main occupation is agriculture	0.65		
Soccupation	Dummy = 1 if have secondary occupation		0.19	0.3
Literacy	Dummy = 1 if the respondent is literate	0.45		
RentL	Dummy =1 if paying for land use or rent use	0.16	0.43	0.04
DLMtraitor	DL major traitor to yield		0.18	

Table 3: Probit Estimation Results

Variable	Morocco Parameter estimate	Morocco Marginal effect	Morocco P-V	Sudan Parameter estimate	Sudan Marginal effect	Sudan P-V	Eritrea Parameter estimate	Eritrea Marginal effect	Eritrea P-V
Intercept	-0.54	-0.19	0.47	-0.28714	-0.09925	0.58	-0.27	-0.09	0.79
SP	-0.002	-0.001	0.06	-0.0014	-4.9E-05	0.08	-0.006	-0.002	0.33
Ldamage	-.00001	-.000003	0.77						
Ndamage				0.023908	0.0083	0.32	0.63	0.21	0.05
Male	0.41	0.15	0.56	0.640628	0.221432	0.08	0.61	0.21	0.39
Age	-0.01	-0.002	0.12	-0.00639	-0.00221	0.14	-0.02	-0.007	0.03
Civil				-0.01838	-0.00635	0.69	-0.16	-0.06	0.46
Kids	-0.004	-0.002	0.84	-0.03334	-0.01153	0.26	-0.08	-0.03	0.41
HHsize	-0.01	-0.003	0.44	0.08308	0.028717	0.00	0.09	0.03	0.29
Own land	0.02	0.01	0.13						
Rent Land	0.00001	0.000002	0.71						
Income	0.000002	0.000001	0.00	1.20E-06	4.15E-07	0.14	-1.6E-05	-5.46E-06	0.44
Hdamage	0.06	0.02	0.58				-0.08	-0.03	0.86
UseDL	-0.19	-0.07	0.07						
PPesticide				-0.23846	-0.08242	0.21	0.02	0.01	0.92
Pesticide	0.04	0.01	0.69	0.564359	0.19507	0.00	0.78	0.27	0.00
Status	0.21	0.07	0.17						
Moccupation	0.09	0.03	0.38						
Soccupation				0.067515	0.023337	0.64	0.32	0.11	0.17
Literacy	0.37	0.13	0.00						
RentL	0.13	0.05	0.38	-0.41039	-0.14185	0.00	0.45	0.15	0.39
DLMtraitor				0.334803	0.115724	0.02			

Table 4: Campaign Costs 1986-96 (Current 000 DH)

Year	Fixed costs	Variable costs	Emergency aid	Total
1986	3 720	0	0	3 720
1987	2 880	0	25 968	28 848
1988	6 855	608 511	161 042	776 408
1989	943	23 543	107	24 584
1990	800	31 625	3 166	35 592
1991	3 295	426	505	4 226
1992	4 900	0	0	4 900
1993	6 530	523	0	7 053
1994	6 010	23 663	2 550	32 223
1995	7 219	25172	2 338	34 728
1996	6 902	1 843	0	8 747

Table 5: Control Costs (in thousand SD)

Season	1988/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	Total
Treated area in hectare	1100	125.45	4.9	0.612	94	159.28	23.02	38.239	38.44	55.23	45.858	1685.033
Campaign costs	11000*	1254.5	49	6.12	940	1592.8	230.2	382.39	384.43	552.3	458.58	16850.33

Source: PPD Sudan. *) According to PPD Sudan total campaign cost for all regions was estimated to USD 8.8 million.

Table 6: Treated Hectares in 1996-1998

	1996/97	1997	1997/98
Hectares	0	400	18165

Table 7: Condition and Prices

Yield (quintal/hectare)	8	16	24
Price (DH/hectare)	102	204	306

Table 8: Total Yearly Benefits (million)

Population	Total*	Total benefits	
		SD	USD
Households	2.846	5 837	23
Adults	7.116	14 595	58

* Using FAO data (see http://apps.fao.org/) and assuming a yearly growth of 0.8 percent the rural population in 1999 would be 18.785 million. Assuming also a family size of 6.6 such as in Morocco, the number of the Sudanese farmer-households would be 2.846 million. If adults per household are 2.49, the agricultural adults would be 7.116 million. This last value corresponds to the total economic active population in agriculture, as shown in FAO statistics.

Table 9: Benefits and Costs of the 1997/98 Campaign (USD)

Region	Benefits	Costs	Benefits/costs
All regions	2063850	185650	11.1
Low lands	412768	185650	2.2