Socio-economics of Desert Locust Control in Sudan

A Micro Level Case Study

Final Draft Report

By

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List of Abbreviations

AE	Adult-equivalent
DL	Desert Locust (*Schistocerca gregaria*)
EMPRES/CR	Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases in the Central Region (Egypt, Eritrea, Ethiopia, Oman, Saudi Arabia, Sudan and Yemen)
FAO	Food and Agriculture Organization of the United Nations
Group1	Highly affected area by DL
Group2	Slightly affected area by DL
Group3	Area not affected by DL, Control area
Ha	Hectare
HH	Household
Kg	Kilogram
Log	Logarithm
LN	Natural Logarithm
ME	Man-equivalent
PPD	Plant Protection Directorate of the Ministry of Agriculture of Sudan
PPS	Plant Protection Services of the States
PRA	Participatory Rural Appraisal
R^2	Coefficient of Determination
TLU	Tropical Livestock Unit
VIF	Variance Inflation Factor

1. Introduction

The Desert Locust (*Schistocerca gregaria*) has been the most feared agricultural pest in northern part of Africa for thousands of years. Its invasion area ranges from India and Pakistan to the Arabian Peninsula and all the ways across Africa to Mauritania and Moroco. The Desert Locust (DL) lives as harmless solitarious individuals during recession periods. But once environmental conditions become more favourable (sufficient precipitation and humidity), mass reproduction takes place resulting in changes in the insects' behaviour. The increasing population density stimulates a gregarious phase, which forms hopper bands and swarms of billions of insects, which are able to migrate several 100 kms per day and endanger agricultural production of the affected countries. The nature of this pest is to a high degree unpredictable due to its behaviour and mobility (Krall and Herok, 1997).

Rough estimates of crop losses caused by the DL are considerable. For instance, Bullen (1970), as cited by Wewetzer, et al. (1993), estimated the crop loss inflicted by locust at 90% in Morocco during 1955. But Herok and Krall (1995, p.3) quoted the crop loss due to DL in Sudan of about 1% in all crops and 5% in cereals. Such disparities in the levels of crop losses during different years in different countries led to controversy in cost effectiveness of the conventional DL control. To contain the pest, the governments of the affected countries, the international donor community and aid organizations spent more than US$ 500 million between 1987 and 1996 (Joffe, 1998). During 1986 - 89 campaign alone, donor contributions earmarked for preventive and reactive control were estimated at US$ 300 million (Schroeder, 1999).

The locust control measures are mainly based on the use of pesticides since the 1950's. The concern on the cost effectiveness of conventional control strategies and their impact on the environment was growing in particular after the 1986 – 89 plague. It has been argued that the locust population is more influenced by natural factors than by the effect of the control intervention. In this regard Magor (1989), for instance, argued that about 50% of the locust population during the 1988/89 died of natural reasons such as low temperature and insufficient rainfall whereas only 20% of the reduction of the population was credited to the effect of locust control operations. Herok and Krall (1995) and Joffe (1995) also questioned the economic efficiency of the current control strategy although their analyses exclude external costs and benefits. Moreover, the simulation based on historical data applied by Joffe (1998) resulted in a positive net benefit only in 20% and 10% in all cases.

Most economic studies criticizing the current control strategy were based on incomplete and scarce data from only few affected countries. The results were more biased by the damage caused by DL on high value crops than losses on low value cereal crops such as millet and sorghum as cultivated by the majority of the farmers. The small subsistence farmers have limited market integration. Therefore they are left with few options to DL control to protect their crops. This means that although less in terms of economic values the impact of DL control on the livelihood of subsistence farmers is likely to be higher.

As the studies mentioned above were based on national data, the threat posed by DL to the rural food security in marginal subsistence areas and impacts on the welfare of the farming community and the externalities associated with DL control were not assessed. As a result, the demand for assessing the socio-economic and environmental impact of DL control increased. Although achieving this objective is by no means an easy task, due to lack of data and the difficulties to generate them, combined efforts have been made under the umbrella of the FAO-EMPRES Programme to generate data at farm- and macro-levels. In order to fill some of the gaps, this study was conducted in Sudan under the EMPRES/CR Programme to assess the socio-economic impacts of the DL control at farm household level.

2. Objectives of the Study

One of the objectives of the EMPRES/CR is to investigate the economic impacts of the Desert Locust Control, as a necessary input towards developing more cost effective and environmentally friendly control strategies. It can be understood from the conclusions of the meeting of the Ad hoc Committee on Desert Locust Economics, held in June 2000 in Rome, that previous studies such as Joffe (1998) were criticized, among others, for lacking micro-level data that may facilitate the estimation of the economic impact of DL at farm level. Although methodological approaches have been developed (e.g. Herok and Krall, 1995 and Hardeweg, 2001), previous studies were missing the analysis of the social and environmental impacts of

DL control. It was also noted that the perception of farming community and nomads regarding the impact of conventional DL control has not been adequately assessed.

Therefore, it was recommended to apply a bottom-up approach to evaluate the risks of DL threat at the local level. This study was proposed to contribute to fill some of the gaps by assessing the perception of the rural community on the importance of the DL threat and the efficiency of conventional control measures on the example of Sudan. The major objectives of the study were:

1. To assess the perception of the farm community on DL threat and the impact of conventional control tactics;
2. To assess the impact on human health and the environmental costs of locust control;
3. To quantify the total economic losses including externalities and losses caused by the DL at the micro level; and
4. To contribute to the identification of alternative locust control strategies, including self-help and damage compensation schemes.

3. Methodology

3.1 Data Collection

Two methods of data collection were used. Firstly, a participatory rural appraisal (PRA)[1] was conducted in six villages in order to identify the production systems, sources of income, units of measurements for the different activities employed by the household, the prevalence of the Desert Locust as well as the extent of the damage caused by this pest and its impacts such as food shortage, mechanisms of coping with food shortage due to DL, changes in food prices, etc. The main advantage of a PRA is that reliable information is obtained since the discussion is made with groups of farmers and the data generated represent the community rather than individuals. The major constituent of the PRA checklist is attached in Appendix 1. The PPD in Sudan

[1] PRA is a method used to learn about key issues in the community and elicit local opinions and priorities. (FAO, 1996, p61).

assisted in selecting the sample sites where the PRA should best be conducted. Accordingly, 6 villages, namely Abudolo, Al-Mansir, Killewa, Sidoun, Alkemilin and Ed Dewem were visited for the purpose. In addition, community level information was gathered from groups of farmers during the formal survey.

Secondly, a survey was conducted at household level. A stratified random sampling method was used. In order to generate data necessary to meet the objectives of the study stated above, three distinct areas were identified based on the extent of risk associated with DL. Based on the information obtained from the PPD, areas such as the River Nile, the Red Sea Coast, Northern States, Kassala, Northern Darfur and Kordofan States were found to be highly prone to DL infestation. There are about a million farm households with an average family size of 6 persons in these states. Some parts of Darfur, Khartoum and White Nile States, with about 820,000 farm households, are only slightly affected by DL. On the other hand, areas like Gazira, some parts of Khartoum, and the Southern States, encompassing 43% of the rural households, are not affected by the DL. Accordingly, those areas that suffered repeatedly from DL invasions in the past were defined as *highly affected* and designated as "*Group1*". Those areas only occasionally infested by DL, and were no major control campaign was carried out during the recent years, were defined as *slightly affected* and designated as "*Group2*". Farmer of areas not invaded by the DL were used as *control group* and designated as "*Group3*". Fig.1 shows the approximate location of the study area.

One state each was selected from the *highly*- and *slightly affected* areas. For that reason, the River Nile state was chosen to represent the *highly affected* farmers since they been subject to the DL infestation during both winter and summer seasons, and major control campaigns were conducted. On the other hand, White Nile state is located near the Northern Kordofan state, which is the major summer breeding area in Central Sudan. DL swarms usually pass across the White Nile state causing damages to the crops. Considerable damage occurred in 1988; but since then locust infestation was quite limited. Hence, the households selected from this state are considered as slightly affected with limited control intervention in the area belong to "*Group2*" hereafter. Most parts of the central and the southern regions of Sudan are normally not invaded by the DL. The *none-affected* areas were used as control group. Accordingly households were sampled from Gazira and Khartoum states. The households from these states are designated as "*Group3*" hereafter.

After the identification of the sample states of the study, local leaders and the PPD staff of each of the states were asked to identify villages where the survey should be conducted. For that reason, 21 villages i.e. 13 villages in the River Nile state, 4 villages in the White Nile state, 3 villages in the Gazira and one in Khartoum states and a total of 336 households were randomly selected (Table 1). Since there were no lists of the households existing, the local leaders were asked prepared the list from which the households were randomly selected.

Fig.1: Approximate location of the study areas

Table 1. Distribution of sample households by group

	Group1	*Group2*	*Group3*	*Total*
Selected states	River Nile	White Nile	Al-Gazira and Khartoum	4
No. of villages surveyed	13	4	4	21
No. of households	194	85	57	336
Proportion of the household (%)	58	25	17	100

A pre-tested questionnaire was used to collect data on the resource situation, production systems, sources of income including off-farm activities, the DL infestation during the past years that the farmers might have remembered, control measures, damages caused by the pests and impacts thereof, attitude of the farmers towards alternative DL management methods. Farmers were asked to evaluate the effectiveness of the DL control operation carried out by the PPD and the traditional practices they use to prevent or reduce crop damage due to DL. Furthermore, they were asked for their opinion on compensation for crop damages as a substitute for locust control.

Drought, locusts and other pests are important factors of crop damage and losses. According to Bullen (1970), the ratio of crops damaged by locust and by other pests is 1:60 (as cited by Wewetzer, et al., 1993). For this reason, it was found necessary to collect also data related to other pests. The variables included in the questionnaire are given in Appendix 2.

Five enumerators were hired from the PPD of the Ministry of Agriculture of Sudan to help in conducting the survey. Moreover, secondary information (such as rainfall, pesticides and costs) relevant for the assessment of the DL control was collected from different organizations including the PPD.[2]

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[2] Unfortunately, secondary data were not available in a complete form. Moreover, data are not easily accessible.

3.2 Data Analysis

In this study, the farmer is brought to the centre of the analysis. It followed the approach of Desert Locust damage assessment described by Hardeweg (2001) where the farm-household is a basic decision unit given its socio-economic environment. In order to assess the impact of the DL control and the damage caused, the analysis was made for the three groups of farmers defined above: highly affected (*Group1*), slightly affected (*Group2*) and the control group (*Group3*).

Differences in relevant variables such as crop damages, socio-economic variables, the cropping system, and coping strategies against food shortage among the three groups were statistically tested and compared. Non-linear econometric models were defined and fitted to estimate parameters of productivity, crop damage, and willingness to pay for DL control. In addition, a farm budgeting technique was applied to compute the economic efficiency of DL control operations. Also attempts were made to assess the farmers' perception of alternative DL management methods. When the locusts are not contained in the breeding areas and invade the pasture and cropping areas, the PPD undertakes campaigns to minimize crop losses. Farmers also apply traditional locust control methods such as burying DL hopper bands, smoking in the field and making puzzling noise.

4. Overview of Desert Locust Situation in Sudan

Sudan is considered to be one of the key countries for DL breeding. Its vast winter breeding quarters stretch 147,200 km^2 along the Red Sea, and the summer breeding habitat in central Sudan covers an area of 956,360 km^2 (El-Tom, 1993). Thus, the DL Control Service is one of the most important services within the National Plant Protection Directorate (PPD) of Sudan. The Ministry of Agriculture allocates 26-39 % of the annual budget of the PPD for DL operation and 40% of all pesticides are used in DL control.

The population dynamics of the DL depends on favourable rainfall, soil humidity, and the vegetation density. The study area in the River Nile state lies along the valley on both sides of the Atbara river. The soil is productive due to the topsoil deposit that has been transported from the upland. As it lies between the summer breeding areas of the central Sudan (especially Northern Kordofan) and to the south of the winter breeding area along the red sea coast, the River Nile state is one of the most DL affected states in Sudan.

During the study, attempts were made to quantify how often the farmers experienced DL invasion. Most of the interviewed farmers recalled swarms having invaded their farms in 1988 and 1998. Some farmers also reported the presence of DL in 1994-96. The overall picture revealed that the year 1988 was perceived as the most serious DL year, followed by 1998 and then by 1994, 1995 and 1996. The farmers' response was consistent with the recorded amount of pesticide used during the last 14 years.

Table 2 shows the amount of chemicals used to control DL and other pests such as sorghum bugs, quelea birds, armyworm, and rodents. The use of pesticides against DL was high during the plague and upsurge years of 1988-1989 and 1997-1999. There was also limited DL control during the 1994–1996. Comparatively, the use of pesticides against other pests consumed over 60% of the pesticide imports. Table 2 also shows the area treated during the respective year. Due to lack of adequate record of the area invaded by the DL, the extent of the area treated during the respective years was not known.

Table 2. Insecticide used in Sudan

Year	Desert Locust			Other Pests		
	Area (ha)	Dust (ton)	Spray (l)	Area (ha)	Dust (ton)	Spray (l)
1986/87		146	27,930			
1987/88		47	7,400			
1988/89	1,010,000	509	583,823	10,9291.5	34	0
1989/90	12,100	5.28	5,230	60,265	58	0
1990/91				10,382	34	0
1991/92				55,972	51	0
1992/93				5,359,281	10,694	4,370
1993/94				38,628	63	1,292
1994/95		12	17,500	283,818	202	58,636
1995/96		9	11,425	18,272	28	78,948
1996/97	120	2	-	450,636	176	800
1997/98	47,940	16	27,830	24,927	47	5,597
1998/99	11,466	11	40,027	278,508	69	2,704

Source: Plant Protection Directorate, Unpublished Data, Khartoum (2001)

The locust management involves monitoring of the DL in the breeding areas and early control intervention to avoid outbreak and upsurges. This requires considerable investment in fixed assets, which forms fixed cost of the control intervention. Joffe (1998) estimated the average yearly fixed cost of DL control in Sudan at US$ 366,183. This includes the depreciation costs on capital investment such as vehicles, application equipment and aircraft and recurrent costs for maintenance. Some portion of the cost is born by the government. According to Joffe (1998), Sudan's financial capacity to control locusts during the 1987-1996 was only up to 28%. This means that the major DL control cost was covered by donors. However, considerable investment is being taken care of by the Government of Sudan. The annual cost of chemicals used for locust control is given in Table 3. In further analysis, the annual cost and the area sprayed by the sample farmers during the 1998 was used to estimate the unit cost of chemical use in the subsequent economic cost calculations.

Table 3. Cost of pesticides for locust control (US$)

Year	EC / ULV	Dust	Total
1994/95	243,075	37,610	280,685
1995/96	158,693	26,640	185,333
1996/97		6,268	6,268
1997/98	386,559	49,206	435,765
1998/99	555,975	33,426	589,401

Source: Plant Protection Directorate, Unpublished Data, Khartoum (2001)

The actual responsibility of crop protection rests basically with the Plant Protection Services (PPS) of the States. The federal Head Office in Khartoum, the PPD, coordinates the crop protection activities, provides pesticides, aircraft support, and equipment if necessary, and is responsible for migratory pest control, in particular locust control in the winter breeding areas. The PPS report locust observations in their locality to the PPD in Khartoum. The capacities of the local PPS to conduct surveys and/or control operations by their own are very limited. For that reason, the central PPD is often obliged to intervene also during the summer breeding seasons in order to assist in the local governments to carry out their duties.

5. Socio-economic Analysis

The livelihood of the farm households is affected by many factors such as natural resources, markets, epidemic diseases and pests, rainfall, flood, etc. Some of these factors are under the scope of the management of the household itself while others are environment induced. For instance, natural resources, markets, epidemic diseases and pests, rainfall, flood, etc. influence the welfare of the households and yet are beyond their control. The magnitude of resource endowment may also be determined by the environment. In a semi-arid environment, where vegetation cover is poor and the rainfall is erratic, the potential for crop production is low. On the other hand in an area where the population density is higher, the cultivable area under disposal of the farm household is small. In the study area, the three study areas are located at different agro-ecological areas and showed considerable variation in land holding and animal resources per household. Besides, selection of the type of crops grown, crop protection approaches and risk mitigating strategies are endogenous variables. In the following, the characteristics of the sample households are described so as to identify factors affecting productivity and hence the welfare of the household.

5.1 Household Characteristics

The farm household is the basic production and consumption unit. The household provides labour and management for the agricultural production. The family size in the study area is high with an average of about 9 persons per household. The family members were converted into adult equivalents that take the sex and age of each of the member of the households into account. A standard conversion factor, which was developed based on subsistence requirement of each member of the household relative to an adult man, was used to compute the adult equivalent (AE) (Storck et al., 1991).[3] Accordingly, the average size is 7.5 AE per household. There is not significant difference in family size per household expressed in terms of AE of the

[3] The conversion factors were: 0.6 for children below 10, 0.8 and 0.9 for male and female between 10 and 13 years respectively, 1 and 0.75 for male and female above 14 years, respectively (Storck, et al., 1991, p.188).

three sample groups. The labour supply expressed in terms of man equivalent[4] constitutes about 68% of the household size in *Group 1* and 82% in *Group 2* indicating a high dependency ratio.

Farming experience and level of education of the household heads are important factors, which enables the farmer to make better decisions that reduce crop failure and increase income to enhance the livelihood of the family. The results showed that most farmers started farming at the age of 15, and there was positive correlation between the age and the farming experience of the heads of the households. Thus, age has been used as a proxy to farming experience in further analysis. The average age of the head of the sample household in the study area is about 50 (Table 4).

Table 4. Composition of the households (average)

Category	*Group1*	*Group2*	*Group3*	*Average*
Family size, total No.	8.8	9.9[b]	8.8	9.1
Adult equivalent	7.1	8.2[b]	7.5	7.5
Labour force, man equivalent	4.9	5.2	5.1	5.0
Children of less than 15	4.0	5.2[a]	4.1**	4.3
No. of children in school	1.9	2.0	3.4a***	2.1
Age of the family head	48.8	50.2	51.2	49.6

a, *b*, and *c* significantly different from *Group1* at 1%, 5% and 10% respectively

*, ** Figures are significantly different from that of *Group2* at 1% and 5% level respectively

Source: Own survey (2001)

There is variation among the groups in terms of the level of education. The proportion of the heads of households without any formal education is as high as 69% in the *Group 2* area and as low as 32% in the *Group 3* area (Table 5). In the *Group 1* area, 58% of the households had access to formal education. It could be expected that education leads to a better decision making, also in plant protection, and hence improved production and reduced crop damage.

[4] Standard conversion factors that account for the age and sex of the different members of the household were used to calculate the man equivalent. The conversion factor is as follows: children of 10 to 13 years take a factor of 0.2, male and female of 14 to 16 year take 0.5 and 0.4 respectively, male and female of 17 to 50 years take 1 and 0.8 respectively while male and female over 50 years take 0.7 and 0.5 respectively (Emana, 2000, p.193).

Table 5. Education level of the heads of the households (%)

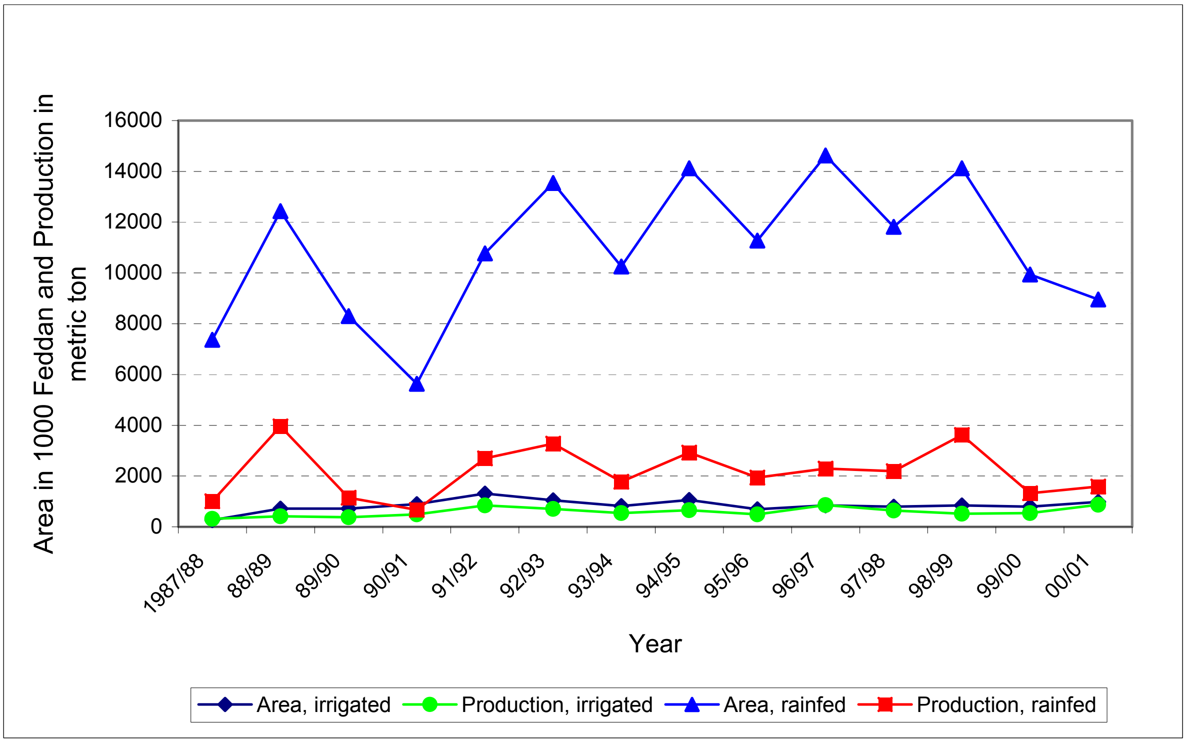
Education level	*Group 1*	*Group 2*	*Group 3*	*Average*
Illiterate	43	69	32	47
Elementary	37	27	50	36
Secondary	20	5	14	15
Above secondary	1		4	1

Source: Own survey (2001)

5.2 Cropping System

Sudan's economy is mainly based on agricultural production. Most of the population make their living from crop and livestock production. Sorghum is the major staple crop in Sudan occupying large portion of arable land. The area allocated to sorghum and the total production during 1987/88 to 2000/01 seasons is displayed in Fig. 2.

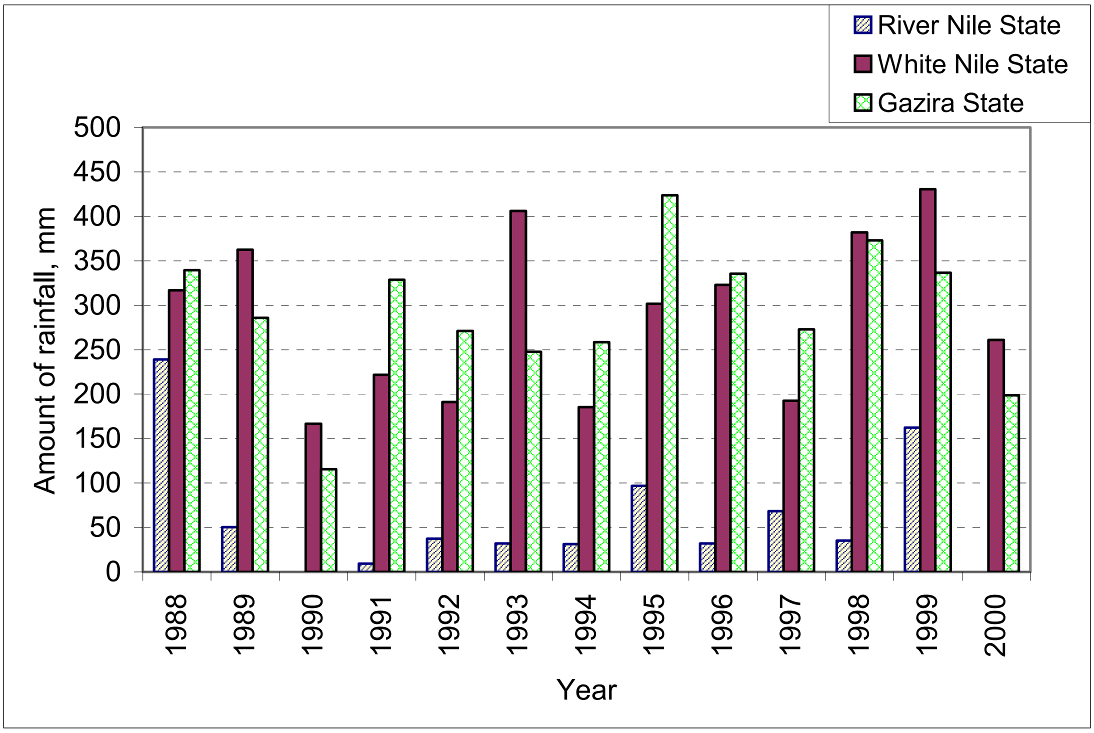
Fig. 2: Area of sorghum under irrigation and rain fed systems



Source: Ministry of Agriculture and Forestry, Agricultural Statistics, July 2001

The level of crop production is largely dependent on the amount and distribution of rainfall. But the amount of rain and its distribution are very erratic (Fig.3). As a result, crop yields in the rainfed system are as low as 2 Quintals per Feddan[5]. But agricultural production depends also on irrigation and moisture held in the delta transported by Blue Nile and Atbara rivers from the upland area in the east. The flooded area and the irrigated area are more productive compared to the rainfed production system. According to the national production statistics of Sudan (2001), the average cereal yield on irrigated area is about 10 quintals per feddan.

Fig. 3: Rainfall of selected states



Source: Meteorological Authority of Sudan (2001)

Although sorghum is a dominant crop in all of the investigated farming systems, there are differences in the cropping system among the households in the three areas. Crop production is more diversified in the *Group1* area. This may partly be explained by the high probability of risk of crop damage as a result of environmental factors including DL. A diversified production allows adjusting the cropping pattern, and enables a continuous use of production resources including labour during slack seasons. A crop schedule that is spread over a wider period reduces the chance of total crop damage by seasonal pests.

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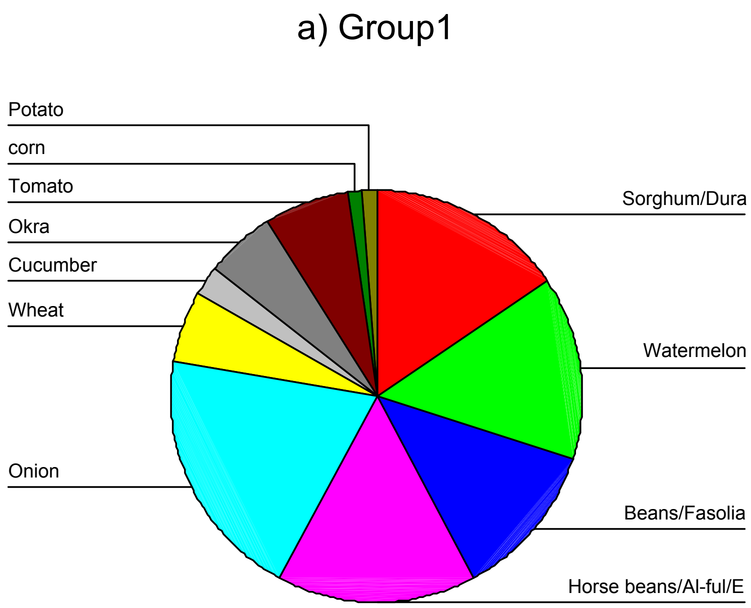
[5] Feddan is a local unit of land measurement (1 Feddan = 0.42 ha) and 1 Quintal is equivalent to 100 kg of grain.

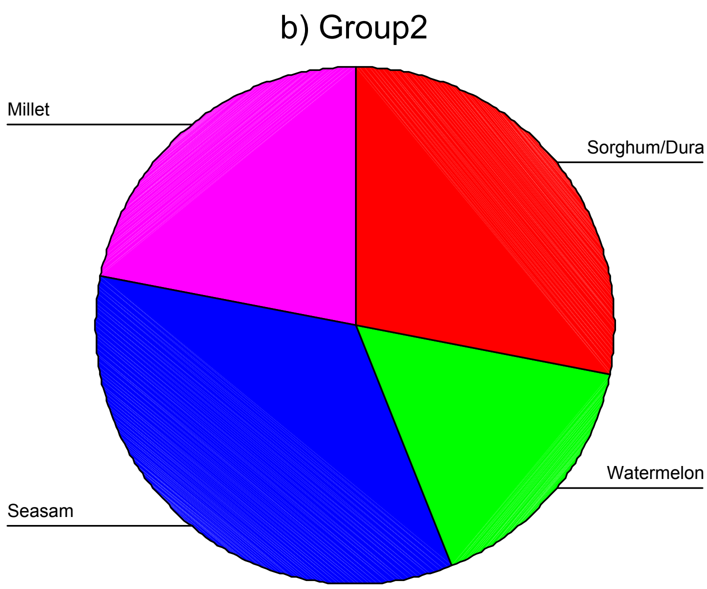
The survey results showed that sorghum, onion and beans are the major crops grown in the *Group 1* area whereas sorghum, millet and sesame dominated the cropping system in the *Group 2* area (Fig. 4, see also Appendix 3 for the PRA result). Besides, other minor crops such as watermelon, cucumber, okra, wheat, potatoes, tomato, etc were grown by the farmers of *Group 1*. Crops like onion and pulses, which mature in a shorter period of time, were considered as security crops since they help the farmers to overcome food shortages.

As shown in Table 6, the planting and harvesting time for the different crops was moderately distributed over different months. Such a wide production schedule surely helps to secure yield of some of the crops. For example, most of the farmers mentioned that the harvest in 1998 was as high as in 1999, which could mean that if there had been no DL invasion during the 1998, yields could have been probably higher in 1998. The reasons for the paradox observation of high DL damage and high yield could be the following:

1. There was conducive rainfall both for the crops and other vegetations providing enough food for the DL before entering the crops. It has been indicated, for example, that DL appeared in the River Nile State during the last week of October of 1998 and invaded the cropped areas one week later after they fed on the pastures around the fields.
2. Due to diversified cropping system some of the sorghum could be harvested before the DL entered the crops. This was also the case during the plague year of 1988 and the upsurge in 1998. Some of the crops were already matured while others were still at seedling stage and could rejuvenate when damaged. Some others could be replanted.

Fig. 4: Proportion of farmers involved in the production of the crops, 1998





Source: Own field survey

Table 6. Cropping calendar for major crops in the highly affected area and plant stage during DL invasion (1988 & 1998)

Cropping system	Planting	Harvesting	Remark	Stage of plant growth when DL appeared in 1988	Stage of plant growth when DL appeared in 1998
Rainfed system:					
1. Sorghum	2^{nd} July. – 2^{nd} Sept.	1^{st} Nov. – 4^{th} Dec.	The calendar is dictated by rainfall. Less than 10% of the farmland in the valley is rainfed while the rest could be irrigable (from river or flood from upland).	Some of the crops were at maturity stage. DL invasion occurred on 15^{th} of Oct., lasted for 4-5 days, destroyed crops, migrated to East and Northern States	Maturity, DL appeared last week of October; control started a week after the invasion of the fields.
Irrigated/Flood system:					
1. Sorghum	2^{nd} Sept. – 1^{st} Oct.	3^{rd} Dec. - 2^{nd} Jan.		Seedling: Nearly all fields destroyed, but almost all fields re-planted	Most at milky stage. Crops in some fields are matured
2. Onion	Seedbed: 2^{nd} Oct. Transplanting: 2^{nd} Nov – 2^{nd} Dec.	3^{rd} March - June	Extending the harvest time aims at benefiting from higher market prices	Not yet planted	Not yet planted
3. Beans	1^{st}. – 2^{nd} Nov.	1^{st} – 2^{nd} Feb.			Seedling

* 1^{st}, 2^{nd}, 3^{rd} and 4^{th} represent the weeks of the month.

Source: Own survey, 2001

The major crops grown in the *Group 2* area were sorghum, millet and sesame. Unlike in the other two groups, intercropping of sorghum and millet was common. The cropping period in the *Group 2* area was between 1st July and end of October. Hence it was possible that some of the early maturing sorghum varieties could be harvested when the DL arrived. In the *Group 3* area, the cropping calendar extends from June to November for sorghum and groundnuts, and from July to March for cotton.

5.3 Resource Allocation

The results of the study also indicate that there are significant differences between the three groups in terms of land use and investment (Table 7). The households of *Group 1* owned significantly less agricultural area than the farmers of the other two groups. However, this area is located mostly in the valleys following Atbara River with high fertility value of alluvial soil transported from the highlands. High rainfall and flood provide a good condition for higher production in this area.

Table 7. Average use of crop inputs in 1998

Variables	***Group 1***	***Group 2***	***Group 3***
Cultivated area (Feddan)[1]	13	47[a]	31[b]
Fertilizer (US$/Feddan)[2]	8	0.0[a]	12[b]*
Pesticide (US$/Feddan)	0.8	0.1[a]	3.5[a]*
Tractor (Hrs/Feddan)	2	0.5[a]	1.7**
Labour (man-days/Feddan)	12	4[a]	22*
Seed (US$/Feddan)	5	.5[b]	7[b]

a, *b*, and *c* significantly different from *Group1* at 1%, 5% and 10% level respectively

*, ** Figures are significantly different from that of *Group2* at 1% and 5% level respectively

[1] 2.4 Feddan = 1 ha

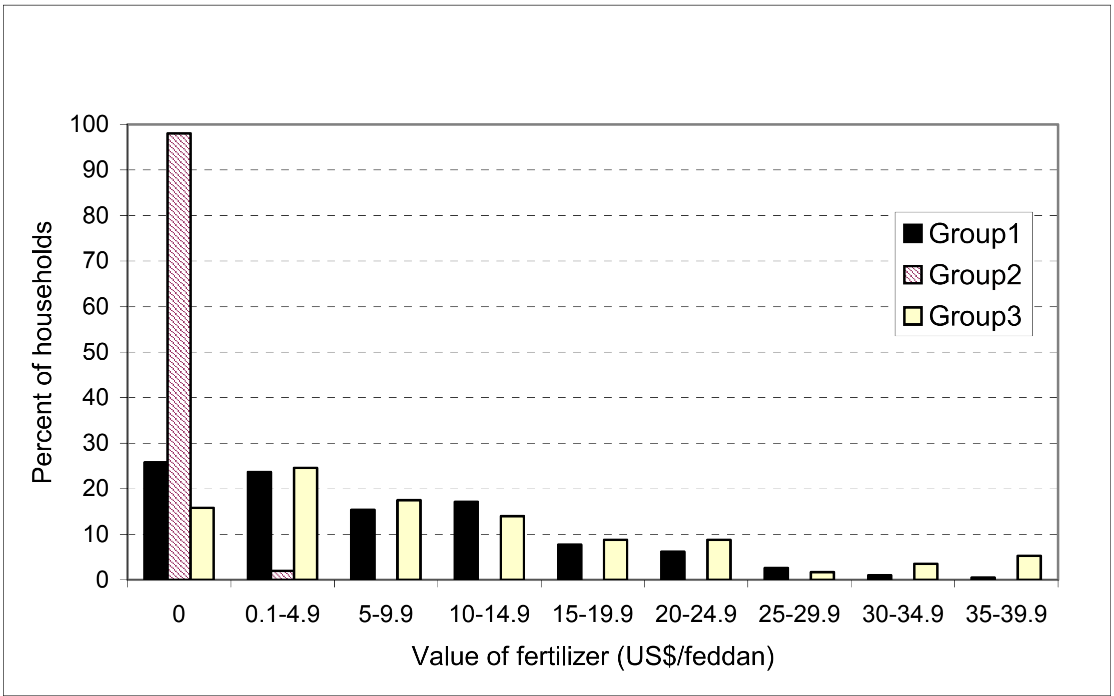
[2] The values computed at local price equivalent

Source: Own survey (2001)

The mechanization level in the study area was high. In particular farmers of *Group 1* and *Group 3* used tractors for seedbed preparation (80% and 98% of the households respectively). Farmers of *Group 2* mainly used draft animals and hoes. Only 25% were using tractors for seedbed preparation.

Despite the comparatively poor soil quality in the area *of Group 2*, only few farmers were using chemical fertilizer. As shown in Fig. 5 most of the farmers did not use chemical fertilizer. Those farmers who applied fertilizer used only small amounts. But the intensity of the use of fertilizer and pesticides was the highest in *Group 3* (Table 7).

Fig. 5. Frequency of households using fertilizer



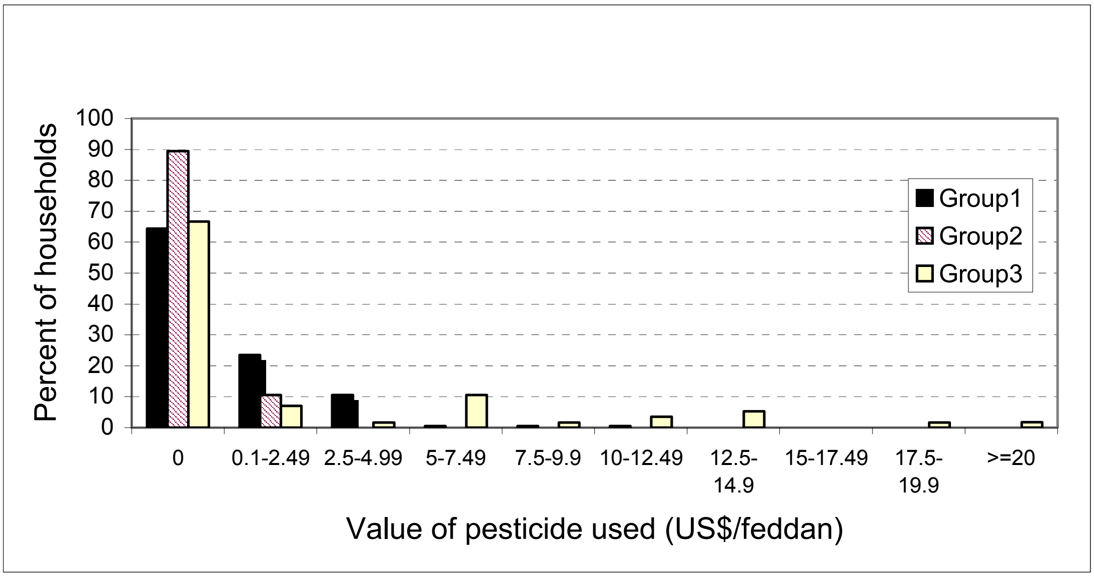
Source: Own survey, 2001

Farmers were asked if the PPD sprayed their farmland against DL and other pests or if locust control was managed by them. In case of the latter, they were asked how much they spent and from which source they received the pesticides. The findings show that most locust control activities were covered by the PPD and/or the local PPSs. In case that the farmers got actively involved, they mainly used pesticides in dust formulation and to a lesser extent also a EC or ULV formulations and spent in average about US$ 3.8 for pesticides against DL and US$ 11.7 for other pests. Apparently less than 24% of all pesticides purchased during the 1998 were used against the DL.

The distribution of farmers that used pesticides in 1998 shows that about 64% of those of *Group 1* and *Group 3* and 90% in *Group 2* did not any pesticide. As shown in Fig. 6, the proportion of farmers who used pesticides more intensity were those of *Group 1* and *Group 2*. At a household level, the farmers of *Group 1* spent in average US$ 15.5

for pesticides for both DL and other pests, whereas those in *Group 3* spent about US$ 14 for pest control other than DL.

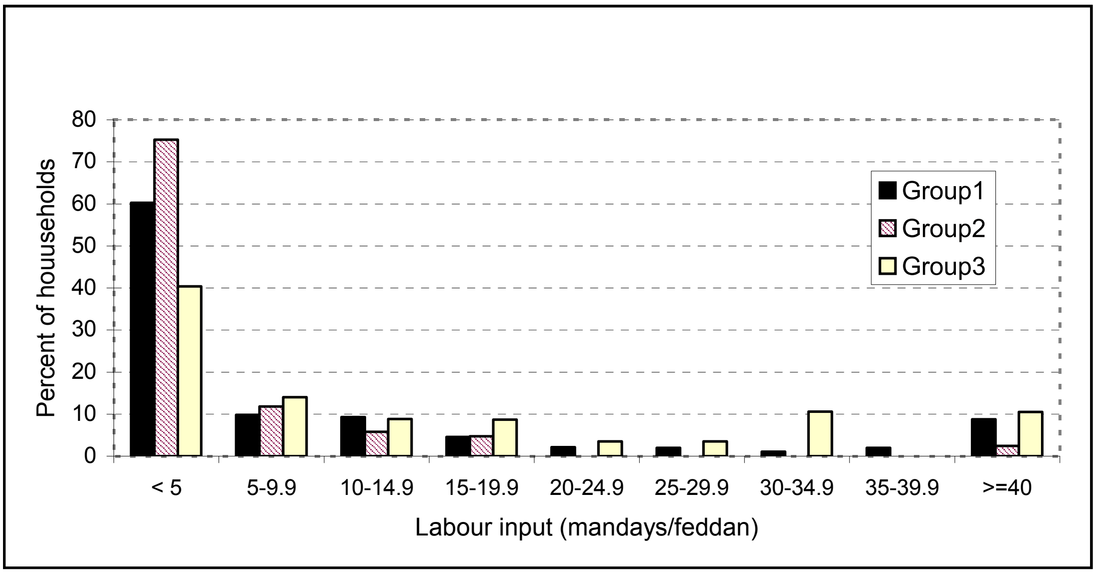
Fig. 6: Frequency of households using pesticides



Source: Own survey, 2001

According to the review made by Joffe (1995, p.11), survey and control costs born by donors ranged between US$ 6-19 per ha in 1986. The cost increased to US$ 15-30 per ha when the costs of the PPD are included. In this study, the cost of pesticides used to control DL in 1998 was computed as follows: The area treated by PPD against DL was 47,000 ha with the pesticide of a value of US$ 436,000. Thus the cost of pesticides applied by the PPD per ha was US$ 9.5 in the area of *Group 1*. On the other hand, average value of pesticides applied by the farmers themselves in the area of *Group 1* was US$ 3 per ha. Thus, the cost of pesticides used was US$ 12.5 per ha. This is equivalent to US$ 5 per Feddan. In the area of *Group 2*, the DL control operation by PPD can be assumed as 50% less than that of *Group 1*. Hence, the cost of the pesticide applied by PPD was about US$ 4.5 per ha. The farmers of *Group 2* were spending only US$ 0.20 per ha for pesticides. As a result, the average cost for pesticide was of US$ 2.0 per Feddan. The intensity of labour was high in the areas of *Group 1* and *Group 3* (Fig.7). The low labour input of *Group 2* could be one of the reasons for the lower productivity of crop production in this study area.

Fig. 7: Frequency of households using different labour intensity



Source: Own survey, 2001

5.4 Livestock

Livestock is an important component of the farming system of smallholder farmers in many developing countries. Integration of livestock in the farming system enables the household to meet different objectives such as income generation, supply with meat and milk, manure for the maintenance of soil fertility, and to manage the risk arising from crop failure. The herds in the study area included small ruminants (sheep and goats) cattle and equine. In cases of food shortage and acute financial needs, the small ruminants were sold and used to reduce the risk of starvation.

As indicated earlier, the highly affected area is endowed with comparatively smallest farm size. This is naturally associated with smaller herds (Table 8) due to the limited grazing area and low fodder production. The slightly affected area and the control group own relatively larger number of animals since grazing land is relatively abundant. The herd size has been converted into tropical livestock unit (TLU) using a standard conversion factor, which takes a cow and an ox as 1 and expresses the other animal categories relative to a cow taking the feed requirement into account.[6] For the total sample, in average a household owns 6 TLU of US$ 725, at local price. In terms of the per capita holding, there is an average of 0.81 TLU per AE with a value of US$ 105. As shown in Table 8, there is not statistically significant difference between the *Group 1* and *Group 2* in terms of average livestock holding. But there is a pronounced difference between the groups in terms of the distribution of livestock ownership: 2 % of the households in *Group1*, 14% in *Group 2*, and 16% in *Group 3* do not own any livestock.

Table 8: Total livestock units and animal value, 1998

Type	*Group 1*	*Group 2*	*Group 3*	Average
Total TLU	4	7*a*	10[a]**	6
Livestock unit per AE	0.68	0.87	1.2[a]	0.81
Animal value at local price (US$)	454	679	1718[a]***	725
Animal value per AE	80	97	205[a]***	105
Households without animals (%)	2	14	16	7

a, *b*, and *c* means figures are significantly different from that of *Group1* at 1%, 5%, and 10% level respectively

*, ** and *** means figures are significantly different from that of the *Group2* area at 1%, 5% and 10% level respectively

Source: Own survey (2001)

5.5 Productivity Analysis

Productivity of the resources used in crop production can be measured in terms of factors employed. In this study, the actual gross margin from crop production per unit of land, per unit of labour input and per unit of operating capital expressed in terms of cost of seeds, chemicals and tractor were used. The gross margin per units of these factors measures the remuneration to the factors employed after covering all the variable costs.

[6] Based on Storck et al. (1991, p.188), the LU of each category of animals is as follows: calf = 0.25, weaned calf = 0.34, heifer = 0.75, cow and ox = 1, horse = 1.1, adult donkey = 0.7, young donkey = 0.35, camel = 1.25, adult sheep and goat = 0.13, young sheep and goat = 0.013 and chicken 0.013.

The results indicate that the productivity per land unit in *Group 1* area was significantly higher than that of *Group 2* and lower than that of *Group 3* (Table 9). It is obvious that the productivity of the invested factors is positively correlated with their intensity.

Table 9. Productivity of variable inputs (US$ per unit)

Gross margin per:	*Group1*	*Group2*	*Group3*
Unit area (Feddan)	259.3	15.3[b]	681[b]***
Unit labour (Man day)	40.0	14.2[b]	46**
A dollar of variable cost	68	48[c]	19**

b, and *c* are significantly different from *Group1* at 5% and 10% level respectively

*, ** Figures are significantly different from that of *Group2* at 1% and 5% level respectively

Source: Own survey (2001)

The analysis of crop production efficiency shows that soil fertility, irrigation and the use of agricultural inputs determine the productivity levels. The extent to which the conventional factors of production and use of pesticides determine productivity is further analysed using non-linear production functions. Usually a production function is specified using Cobb-Douglas function of the following form:

$$Y = AX_i^{\alpha i} \qquad (1)$$

where Y represents the output, A represents the constant term, Xi represents the variable inputs and αi represent the parameters of the model. The partial derivative of the function gives the marginal productivity of the factors of production. That is,

$$MPi = \frac{\partial Y}{\partial Xi} \qquad (2)$$

where MP_i is the marginal productivity of factor i.

In this analysis, Equation (1) was initially estimated to identify the factors that affect the productivity. The actual model includes log-transformed crop income per Feddan, as a dependent variable and log-transformed conventional factors of production (as shown in Table 10), farming experience represented by age of the head of the household, and crop protection factors as explanatory variables. Pests and diseases affect the productivity negatively. Hence, it can be expected that the use of insecticides and other crop protection measures increases crop production by reducing damages.

It is assumed that the federal PPD performs most, if not all, DL control also in the farmers' fields. As indicated above, attempts have been made to get an idea about the extent farmers are involved in locust control. The responses showed that indeed only few farmers actually make use of pesticides to control locusts. The amount of money spent for this purpose is small as compared to the amount spent on other pests (US$ 3.8 vis US$ 11.7). The proportion of cultivable area that was sprayed by PPD during the DL control campaign of 1998 was included as one variable in the model. Moreover, the money spent by the individual farmers per Feddan to spray DL on their own fields was included as an explanatory variable.

Table 10: Determinants of crop productivity: *Cobb-Douglas function*

Variables	All cases				*Group 1*				Marginal value product (US$)	
	B	**t-value**	**Sig.**	**VIF**	**B**	**t-value**	**Sig.**	**VIF**	**All cases**	***Group 1***
Conventional factors:										
*Labour per Feddan**	4.32E-02	0.282	0.780	1.294	0.127	1.00	0.328	1.157	1.04	1.14
*Fertilizer per Feddan**	0.282	**3.85**	0.001	1.572	0.253	**3.66**	0.002	1.631	1.33	1.29
*Traction hours per Feddan**	-0.584	-1.612	0.120	1.895	-0.594	**-2.00**	0.059	1.455	0.56	0.55
Seed value per Feddan	2.79E-04	1.199	0.242	1.708	3.48E-04	0.53	0.602	1.418	1.00	1.00
Crop protection factors:										
Pesticide for other pests per Feddan	1.78E-04	1.154	0.260	1.244	1.84E-04	1.48	0.155	1.210	1.00	1.00
Pesticides for DL per Feddan by farmer	7.22E-06	**3.865**	0.001	1.365	7.41E-06	**4.58**	0.000	1.413	1.00	1.00
Proportion of area sprayed by PPD, DL	2.38E-03	0.502	0.620	1.335	7.92E-03	1.57	0.132	1.671	1.00	1.01
Experience in farming	-7.57E-03	-0.51	0.615	1.367	-2.21E-02	-1.70	0.106	1.414	0.99	0.98
(Constant)	7.641	**10.725**	0.000		7.848	**11.52**	0.000			
R2	0.688				0.832					
Adjusted R2	0.583				0.693					
F-Value	6.6	(Sig. at 0.000)			5.6	(Sig. at 0.001)				
Dependent Variable: Natural log of income per Feddan										

* Natural log transformations of the variables were used.

Source: Own survey (2001)

One of the standard assumptions in applying the ordinary least square (OLS) in regression model estimation is *no multicollinearity* among the explanatory variables. Multicollinearity is a sample phenomenon that shows the degree of linear relationship among some of the explanatory variables of the model. It is suggested that one of the collinear variables is removed in order to get unbiased estimate of the other variable (Gujarati, 1995). Multicollinearity among the variables included in the model was detected using variance inflation factor (*VIF*) test[7]. As shown in Table 10, there is no serious multicollinearity between variables in the model.

The marginal value product of coefficients of the variables show the proportion by which crop productivity increases due to a unit increase in the magnitude of each of the variables. If the population parameter is normally distributed with zero mean, the t-value is calculated as the ratio of the estimated parameter of a variable to its standard deviation (Gujarati, 1995). Comparison of the calculated t-value to the student t-distribution is used to test the significance of the estimated parameter. The result shows that the use of chemical fertilizer has strong and positive influence on the income per Feddan both in *Group 1* and the whole study area. This means, the income from crop production increases by about US$ 1.3 if fertilizer use increases by US$ 1.00.

As expected, the crop protection had positive influence during 1998 on the income per Feddan. Both, the campaign conducted by PPD and the action taken by the farmers against locusts had a positive but marginal effects on the income. The marginal returns of the crop protection appeared to be constant. But it is interesting to note that farmers' investment (expressed in terms of the amount farmers invested per Feddan for DL control) was positive and significant compared to the campaign variables (expressed in terms of the proportion of the cultivated area that was treated by the PPD against the DL). It appears that the individual action taken by the farmers is more targeted and perhaps more timely because the control campaign conducted by the PPD requires more logistics and preparation. As the breeding areas are remote and

[7] Multicollinearity refers to linear relationship among the explanatory variables while collinearity refers to the same relationship between two variables (Gugarati, 1995). *VIF* is the diagonal element of the inverse of correlation matrix, which is $(1-R^2_i)^{-1}$, where R^2_i is the coefficient of determination obtained from regressing the i^{th} independent variable on all other independent variables (Kennedy, 1985, p.153). Therefore, a high *VIF* indicates an R^2_i near unity and hence suggests collinearity. According to Kennedy (1985), *VIF* of more than 10 indicates a harmful collinearity.

vast, the chances to prevent DL outbreaks are small. The result has important policy implication: strengthening the control capacity of individual farmers to control locust could be an effective way to reduce crop damage in case that control operations carried out by PPD fail to stop DL from reaching the cropped areas. The result should, however, be interpreted with caution, since the national campaigns are normally conducted in remote areas and are of indirect benefit to the farmers. Moreover, the national campaign has the chance to hit locusts in the hopper stage, whereas farmers are mainly confronted with adults which are more difficult to control.

Pesticides as *damage control agents* make their contribution to the yield essentially different from other yield increasing inputs such as land, labour and capital (Lichtenberg and Zilberman, 1986). To incorporate the special properties of pesticides into production functions, Lichtenberg and Zilberman (1986, p262) suggest that "*the contribution to production by damage control agents may be understood best if one conceives of actual (realized) output as a combination of two components:* ***potential output*** *and* ***losses caused by damage agents*** *present in the environment*". This means that the *actual yield* obtained is a result of the *potential yield* and the *potential loss* due to pests. Hence, the production function becomes:

$$Y = f(X_i, D(PS_i)) \quad (3)$$

where, X_i represents factors included in Equation (1), and $D(PS_i)$ represents the damage function.

The damage function follows a cumulative probability distribution. It can be expressed in different econometric forms, though the exact form of the probability distribution function is not known. Following Lichtenberg and Zilberman (1986) and Ajayi (2000), either of Exponential, Logistic, Weibull or Pareto stochastic distribution forms can be specified for $D(PS_i)$. According to Ajayi (2000), the Weibull model gives a marginal productivity estimate that is more plausible for economic interpretation and congruent with biological processes.

In this study, the Weibull form of the function was specified. That is,

$$D(PS_i) = 1\text{-}exp(-PS^c) \quad (4)$$

Then, the logarithmic transformed form of the production function will be:

$$\text{Ln}Y = \text{Ln}\,\alpha + \beta_i\,\text{Ln}\,Xi + \text{Ln}\,[1\text{-}exp\,(-PS^c)] \quad (5)$$

where, Ln represents natural logarithm, α, β_i and c are parameters to be estimated. The marginal productivities of the variables included in the model could be estimated as follows:

Marginal product of $X_i = \frac{\partial Y}{\partial X} = \beta i \frac{Y}{X}$ (6)

Marginal product of the pesticide *(PS)* =

$\frac{\partial Y}{\partial PS} = \{Y/[1 - \exp(-PS^c)]\} * [\exp(-PS^c)]*[cPS^{c-1}]$ (7)

where, * represents multiplication.

The Weibul function was estimated using non-linear estimation procedure. The result is given in Table 11.

The results show that the parameters estimated are similar with that of the previous model. Differences existed in terms of the level of significance. In addition, the marginal productivities of the factors are smaller when the Weibull specification of the damage is included in the production function. The crop protection factors, which are the interest of the study, show positive marginal return but are statistically not significant.

Table 11. Production function including the damage function specification: Weibull

Variables	All Cases			Group1		
	Parameters	T-value	Marginal value	Parameters	T-value	Marginal value
Conventional factors:						
Labour per Feddan	0.18040	1.71[c]	0.71	0.09203	1.39	0.39
Fertilizer per Feddan	0.32070	0.73	0.27	0.17253	**5.79**	0.15
Traction hours per Feddan	0.03350	0.18	0	-0.27262	**-1.98** [b]	-7.23
Seed value per Feddan	0.00002	**2.00** [b]	0.00	0.00002	**2.50** [a]	0.00
Crop protection factors:						
Pesticide for other pests per Feddan	0.05947	1.62	0.47	0.01927	0.87	0.42
Pesticides for DL per Feddan by farmer	0.02335	0.29	0.011	0.05092	1.13	0.04
Spraying of DL by PPD	0.01147	0.12	0.008	0.10571	1.35	0.06
Experience in farming	-0.00820	-0.81	-0.79	-0.00356	-0.60	-0.98
(Constant)	9.47410	**14.81**[a]		10.51750	**26.09** [a]	
R-squared	0.26040			0.24814		

[a, b] are sig. at 1% and 5% level respectively. Source: Own survey (2001)

5.6 Household Income

The income of smallholder households is generally based on crop-, livestock production and off-farm activities. The disposable income is computed by adding the values of crops produced, whether sold or consumed, the value of animal products, and income earned by working outside their own farms. This is the return to the household's labour. Table 12 summarizes the income and the production costs. The gross margin represents the net income available to cover all other expenses such as tax, consumption and saving.

There are significant differences between the three groups. The largest income was generated by *Group 3,* followed by those of *Group1*. The farm households of *Group 2* areas made comparatively marginal investments in agricultural production and in return benefited less. During the 1998, the income over the variable cost was only US$ 137 per AE of *Group 2* whereas those in the *Group 1* earned an average of US$ 566 per AE. But, there was no significant difference between the *Group 1* and *Group 3* in terms of the gross margin per AE (Table 12).

Table 12. Mean household income and expenses (US$), 1998

Income and expense category	Farm groups		
	Group1	***Group2***	***Group3***
Gross farm income	4271	899[c]	5108**
Off-farm income	85	89	288[a]**
Animal products	123	46[a]	204[b]***
Gross household income	4479	1034[b]	5600***
Variable cost:			
Seeds	46	18[a]	51***
Fertilizers	99	0[a]	96***
Pesticides	13	0.3[a]	14***
Other inputs	146	56[a]	390
Total variable cost	304	75[a]	552
Gross margin	3966	825[c]	4556**
Gross income per adult equivalent	648	162[b]	834
Gross margin per adult equivalent	566	137[b]	662**

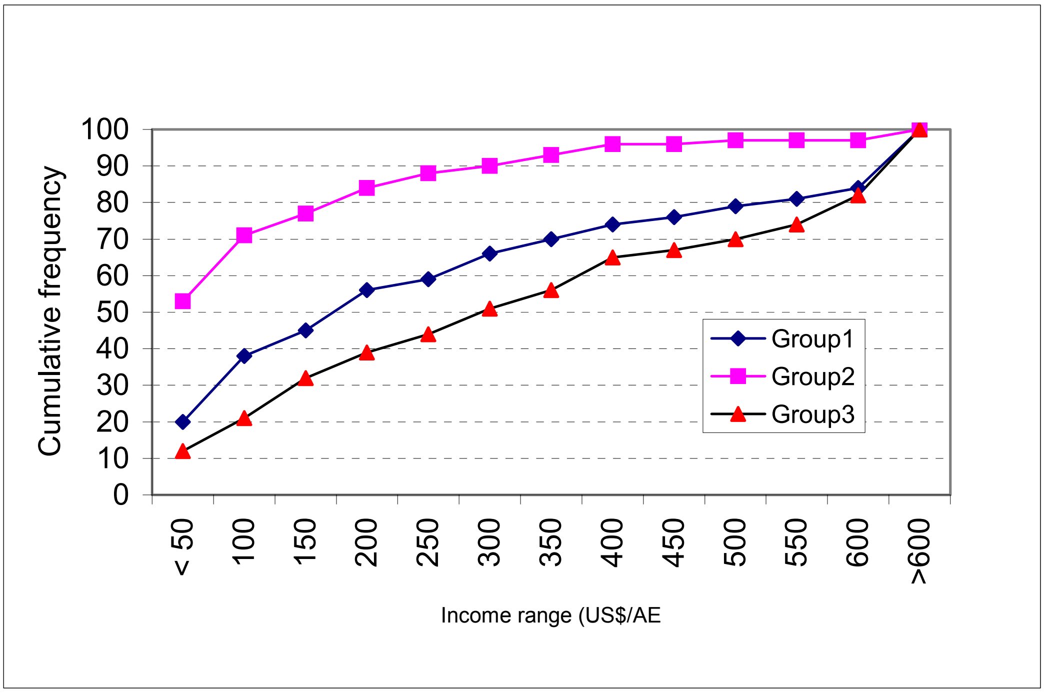
a, b and *c* shows that the means are sig. different from *Group 1* at 1%, 5% and 10% level respectively

*, ** and *** shows that mean of *Group3* is sig. different from that of *Group2* at 1%, 5% and 10% respectively

Source: Own survey (2001)

Farmers of *Group 2* area are relatively more resource poor than those in the other groups and food insecurity and poverty prevail. The average gross margin earned per AE is far below the minimum required for subsistence. According to the World Bank (1986), per capita subsistence requirement, given the parity price of the currency, is one US$ per day. The distribution of income per AE reveals the prevalence of food insecurity in the study area (Fig. 8). About 50% of the households of *Group 2* earned less than US$ 50 during 1998. The result shows the prevalence of poverty in the area due to low productivity of crop production and frequent drought. This result is also consistent with the observations made during the PRA. About 90% of the sample households of *Group 2* earned less than US$ 300 per AE. Compared to this group, the households of *Group 1* earned relatively more as shown by the distribution of the per capita income of this group appearing on the right side of that of *Group 2*. Nonetheless, food shortage is chronic in this area, too. About 20% and 66% of the households in the affected area earned less than US$ 50 and US$ 300 per AE respectively. This means that the survival of the farmers is severely at risk by any loss of grain produced and such a loss cannot be tolerated.

Fig. 8: Distribution of per capita income



Source: Own survey (2001)

5.7 Farmers' Assessment of DL Control

Despite the cost of chemicals for locusts control and the arguments on its effectiveness (Joffe, 1998; Herok and Krall, 1995), the farmers consider the current control practice as the best option in case that locust swarms are invading their fields. Regarding the 1988 and 1998 campaigns in the areas *of Group 1* and *Group 2*, the farmers were asked about the adequate timing of the control operations, their methods, safety measures to protect the animals and the community from being contaminated, protection of the water supply from pollution and training of the community to take precautionary measures against the negative impacts of the pesticides. The farmers were asked to give their opinion regarding the different aspects listed in Table 13.

The main weakness, as mentioned by 29 % of the farmers of *Group 1* and 39 % of those of *Group 2*, is the timing. This is consistent with the result of the PRA, where a delay of one week after the arrival of DL in the vicinity was reported before the control operations started. This might be the consequence of inadequate preparedness of the PPD.

Table 13: Farmers' Assessment of DL control (%)

Parameters	*Group1*			*Group2*		
	Poor	Moderate	Very good	Poor	Moderate	Very good
Timing of the spray	**29.0**	23.7	47.3	**39.0**	14.6	46.3
Place of application	9.1	25.8	**65.1**	19.5	12.2	**68.3**
Method of application	12.4	24.7	**62.9**	17.1	4.9	**78.0**
Care for health when applying	8.1	4.8	**87.1**	14.6	4.9	**80.5**
Care against water pollution	3.8	2.7	**93.5**	9.8	0	**90.2**
Training on plant protection	**52.2**	15.1	32.8	**42.5**	30.0	27.5
Effectiveness of the chemicals	8.6	25.8	**65.6**	17.5	15.0	**67.5**

Source: Own survey (2001)

During the PRA, some farmers indicated that there were warnings to move the animals away from the target areas. Some of the farmers tracked their animals away from the contaminated sites only for a short time. Some other farmers indicated that the pasture was sprayed without their knowledge, which poisoned some of the animals. The impact of the chemicals on the water quality was more difficult to assess and no complaint was observed during the survey.

As it was reported elsewhere (e.g. Joffe, 1995, p.15), the traditional control methods applied by the farmer are not effective, a finding which has also been acknowledged by the interviewed farmers.

In case the Government would reduce DL control operations, the farmers were asked, if they wanted to contribute to the DL control. The alternatives discussed were (i) to be directly involved in DL control operation or (ii) to think of an insurance scheme and to pay an annual premium for compensation of crops damage caused.

The results indicated that 68 % of the sample farmers would be willing to participate in one or the other way in the DL control operations, while only 6 % preferred to adopt a compensation scheme. The remaining 20 % were indifferent to take any of the alternatives (Table 14). Similarly, the largest proportion of the sample farmers in the *Group 2* area preferred to participate in locust control operations rather than requesting for compensation after damage occurred.

It is also worth noting that the concept of insurance scheme was new to the farmers and thus might have had influenced the response of the farmers. The fact that only small number of farmers preferred the compensation scheme may be attributed to lack of experience since the financial insurance markets are not developed in the rural areas of Sudan. There is only one livestock insurance company in Sudan with limited coverage in the vicinity of Khartoum.[8]

Table 14: Proportion of farmers contributing to avoid crop damage (%)

Ways of participation	Desert locust		Other pests		
	Group 1	*Group 2*	*Group 1*	*Group 2*	*Group 3*
Direct DL control	68	75	67	76	67
Damage compensation	6	5	7	4	9
None of the options	26	20	26	20	24

Source: Own survey (2001)

The farmers were also asked how much they might be willing to contribute to the locust control or to damage compensation. In the literature, four possible methods of estimating willingness to pay are provided: *bidding games, closed-end referendum, payment card,* and *open-ended question* (Hanley and Spash, 1993; Hardeweg, 2001).

[8] The only agricultural insurance in Sudan includes livestock insurance policy run by Sheikan Insurance and Reinsurance Co. Ltd. Which is confined to the vicinity of Khartoum. The company is planning to launch Crop Insurance in cotton producing areas of Gazira state (personal communication).

The open-end question approach was used in this study to assess the extent to which the respondents would be willing to contribute to locust control and the premium they would pay for full compensation.

As shown in Table 15, the households of *Group 1* were willing to pay about US$ 11 to protect their crop from DL damage, whereas the ones of *Group 2* would pay only US$ 1.4 per Feddan. Due to the higher productivity in the *Group 1* area, the proposed share constitutes only 4 % of the gross margin per ha, whereas the share could be 9 % for the *Group 2* group. In general, the result is consistent with the previous studies in Sudan and Morocco (Belhaj, 1998) and in Eriteria (Belhaj, 2001). The results indicated that the average contribution to DL control in Sudan, Morocco and Eritrea were US$ 8.2, US$ 17.7 and US$ 3.6 respectively. Although the factors attributing to the differences in the premium between the households within a country and between countries should be further studied, it seems that the extent to which the DL threatens the agricultural production and resource endowment such as fertile land that have impact on agricultural productivity play important role in this regard.

Table 15: Contribution to reduce losses due to locust damage and damage compensation

Payment per Feddan	DL control		For damage compensation	
	Group 1	*Group 2*	*Group 1*	*Group 2*
Cash (US$)	11.0	1.4	11.4	2.1
Percent of yield	11.0	9.0	13.0	11.0

Source: Own survey (2001)

In the literature, crop insurance is assumed to decrease the use of pesticides (Freinerman, et al., 1992) and their negative side effects. The survey result, however, does not show a significant difference between the number of farmers willing to contribute to locust control, and premium for insurance though there is a significant difference between the number of farmers that are willing to participate in DL control and those who prefer an insurance scheme. As indicated above, there is no crop insurance market in Sudan and limited market orientation. Attempts have been made to identify some key factors that determine the farmers' willingness to pay for the DL control. A log-transformed amount, that the farmers would be willing to pay per annum, was used as a dependent variable. The explanatory variables were related to the income (gross margin per unit area, as proxy of productivity indicator), family size, age of head of the household (as a proxy for experience), education of the head of the household, proportion of pests damage, the number of years the farmer experienced DL invasion, vulnerability to DL as indicated by location of *Group 1* area (=1), *Group 2* area (=2) and *Group 3* area (=3).

It is expected that the premium farmers are willing to contribute is positively correlated with the frequency of locust invasion, crop damages, the income, farmers' perception of DL control, household characteristics, and proximity to the affected areas.

The results of the model are in conformity with the hypotheses (Table 16). The variable which determines the premium is the vulnerability to the DL. As the variable switches from *Group 3* to the *Group 2* and then to the *Group 1*, the premium increases significantly. Moreover, the higher the number of DL invasions, the more farmers are willing to contribute. Although it can be argued that DL control is a public good and that DL control in one area will avoid damage in another, the results indicate that the farmers' response to the question of contribution to DL control or compensation schemes depends on the level of the DL threat. Education is found to have positive and significant impact on the willingness to contribute.

Table 16: Determinants of willingness to pay for DL control

Variables	**Parameter**	**t-value**	**Sig.**	**Co linearity Statistics**	
				Tolerance	**VIF**
(Constant)	19.682	**2.97**	0.003		
No. of years the farm is affected by DL	1.321	**2.41**	0.017	0.86	1.162
Type of pests causing damage to crops**	-0.864	**-2.93**	0.004	0.89	1.124
Education level of head of household	1.609	**2.95**	0.003	0.824	1.214
Percent of value of crop damaged	6.70E-03	0.41	0.686	0.686	1.457
GM per Feddan*	2.56E-02	0.09	0.926	0.7	1.428
Family size (AE)	4.97E-02	0.34	0.733	0.806	1.24
Age of the household head*	-5.31	**-3.24**	0.001	0.708	1.413
Vulnerability to DL (1= *Group1*, 2 = *Group2*, 3 = *Group3*)	-2.305	**-8.20**	0.000	0.96	1.042
R^2	0.31				
Adjusted R^2	0.29				
F-value	15.56	(sig. at 0.000)			

Dependent Variable: *LN of premium per Feddan*

* Natural log of the variables were used

** The variable was represented by the number of pest types affecting the farmer's crop

Source: Own survey (2001)

6. Impact Analysis

In this section, the damages caused by the DL and other pests and the economic impacts of DL control, side effects of the use of pesticides on persons and animals are analysed. Before discussing the damage caused by the DL, it is essential to assess the perception of the farmers regarding the threat caused by the DL and other pests.

6.1 How important is the Desert Locust Threat?

Crop damage is caused by a number of pests. The farmers were asked to rank the plant pests in terms of perceived importance. Altogether more than 20 different pest species were mentioned. These include insect pests, birds, and rodents. The DL was considered as the most important crop pest by 77% of the households of *Group1*. For about 22%, other pests were ranked more serious crop damage factor (Table 17).

Table 17: Ranking of pests causing damage and number of respondents

GROUP	Ranking	No. of households		% of households	
		Desert Locust	Other pests	Desert Locust	Other pests
Group 1 (N = 194)	First	150	42	77	22
	Second	26	163	13	84
	Third	15	131	8	68
	Fourth	1	1	.5	.5
Group 2 (N = 85)	First	53	30	62	35
	Second	8	75	9	88
	Third	13	64	15	75
Group 3 (N = 57)	First	2	51	4	89
	Second	1	51	2	89
	Third	1	41	2	72
	Fourth		1	0	2

Source: Own survey (2001)

In *Group 2*, 62% of the farmers perceive the DL as the most dangerous pest. But in most cases these farmers could observe in their fields only solitarious DL, which are not harmful to the crops. The farmers reported that the DL caused damage to their crops in 1993, 1995 and 1998 and added that the damage was more severe during the 1998 than during 1993 to 1995. In the *Group 2* area, the PPD tried to control the DL in the pastures during 1998; however, some swarms escaped and invaded the fields of some of farmers.

The farmers reported that DL destroyed all green parts of the plants and caused serious damage during the seedling and grain filling stages. Yield losses due to defoliation, the most common form of locust damage, depends on at what stage defoliation took place. As put by Joffe (1998, p.10), "In cereals, loss may be complete at the seedling stage, although re-plating may be feasible. Losses become high again if the plant is damaged after the ear emerges. Yield may be unaffected during the intervening vegetative period."

In order to depict the impact of the DL on crop yields, farmers were asked to estimate yield losses of sorghum (the most commonly grown cereal crop) due to DL (Table 18). The highest potential yield per Feddan that could be harvested in case of no pest infestation was 1500 kg and 500 kg in *Group 1* and *Group 2*, respectively. An important observation was that although pest control measures could reduce crop losses, 20-30 % of the potential yield was lost. This proportion of loss is high compared to the proportion of losses reported earlier (Herok and Krall, 1995, for instance). The figure could even be higher in the absence of the control operations and would have deteriorated the food security of the households. The uncertain effectiveness of the control operation can be explained by inadequate preparedness to prevent the DL swarms from entering the cultivated areas. For instance, the farmers recalled that it took the PPD a week after DL appeared in the vicinity to mobilize the resources in the study area during the 1998 upsurge. However, the control operations could safe about 40 % of the potential sorghum yield. At this time the sorghum was in milky stage and was already severely damaged. Matured grain that was not ready for harvest was partly damaged and the quality of the harvest was consequently poor. Farmers indicated that 25-50 % of the crops were already harvested before the DL invasion.

Table 18 shows that the sorghum equivalent crop damage by DL is about US$ 633 per household in *Group 1*. This amounts to 13 % of the value of the crop production. Supposing, 36 % of the cultivated area of *Group 2* was affected by DL, the damage would amount to US$ 516 per household.

Table 18: Impact of DL control on sorghum yield

Particulars	*Group 1*	*Group 2*
Potential yield (kg)	1500	500
Yield if there is DL attack, but no control (kg)	200	50
Yield if there is DL attack, but controlled (kg)	800	250
Modal yield	1050	350
Yield saved due to DL control (kg)	600	200
Yield loss due to DL (kg)	700	250
Proportion of area damaged (%)	57	36
Loss per household (US$)	633	516

Source: Own survey, 2001

A regression model was developed to identify factors that may attribute to the variation of crops damages. The dependent variable is a log-transformed value of crop damaged during 1998. The explanatory variables included in the model were labour supply, number of pest types causing damage, the number of years DL affected the rural households, pest control by the farmer, number of persons involved in off-farm activities and the age and education of the head of the household.

The labour availability at the farm households has naturally direct implications on their capacity to participate in plant protection using chemicals or traditional control methods such as putting on fires at in the field edges and burying the pests in furrows. But it can be expected that the more experienced the farmer is, the better he can manage plant protection, and crop damage could be reduced more effectively.

Education has therefore an inverse relationship on the magnitude of the crop damage. Plant protection measures applied by the farmer himself and the PPD are expected to have a negative impact on crop damage. Accordingly, a dummy variable is defined whereby the variable takes a value (1) in case the farmer applied pesticides against DL and (0) otherwise. The result shows a negative relationship between the application of DL control and crop damage, which is significant at 10% (Table 19). On the other hand, the proportion of farm area sprayed by PPD against DL during 1998 was included in the model as an explanatory variable. The result shows the expected negative relationship between this variable and crop damage, though it is not significant. Even though that there is no doubt of the direction of the influence of control campaigns conduced by PPD, the significance of the impact is subject to arguments from different angles: On the one hand, the insignificant influence is in conformity with the result of Joffe (1998), and Herok and Krall (1995) who state "control campaigns are not sufficiently effective." On the other hand, it can be argued that without the intervention of the PPD, the damage would have been higher and the impact of the farmers' efforts less. It is also worth mentioning that generally the farmers recognized the PPD's intervention as useful if some of the shortcomings are corrected (Table 13).

It is also hypothesised that crop damage depends on the nature of area infested since different locations are not equally vulnerable to DL. Hence, two dummy locations were considered. The first dummy takes a value (1) if the household belongs to the *Group 1* and (0) otherwise, with expectation of a positive sign of the parameter. The 2nd dummy takes a value (1) if the household belongs to *Group 2* and (0) otherwise, with a negative expectation of the sign of the parameter.

Table 19. Determinants of crop damage in Sudan

Variables	Parameter	t-value	Sig.	VIF
(Constant)	6.767	4.121	0.000	
No. of types of pests causing damage to crops	-0.24	-1.289	0.198	1.129
Pesticide dummy, if farmer applied	-1.011	-1.73	0.085	1.132
Location, dummy (*Group1* = 1)	0.717	2.657	0.008	3.276
Location, dummy (*Group2* = 1)	-0.595	-2.531	0.012	3.067
Proportion of area sprayed by PPD, DL	-9.02E-04	-0.195	0.845	1.183
Number of persons involved in off-farm	-0.461	-2.035	0.043	1.136
Age of the family head	-1.65E-02	-0.843	0.400	1.256
Education level of head	-0.291	-0.814	0.416	1.320
No. of years the HH is affected by DL	2.339	6.946	0.000	1.235

R^2 0.216

R^2 adjusted 0.193

F-value 9.8 (Sig. at 1% level)

Dependent Variable: Ln of product damaged

Source: Own survey (2001)

As shown in Table 19 the damage model is significantly explained by the number of years with experience of damage caused by DL, own crop protection decisions, and off-farm activities. The crop damage is high in the highly affected area, and the parameter estimated is positive and significant as proximity to the DL prone area increases. Under these conditions the DL damage increases significantly and is putting the farmers' food supply at a risk.

6.2 Crop Damages and Food Shortage

Attempts were made to assess the changes in the food supply of the household in 1999 compared to that of 1998 and the strategies the farmers adopted to cope with food shortage. The main purpose of raising this question was to observe if the crop damage caused by DL and other pests led to exceptional food shortage in the area.

The results indicate that there was food shortage in all of the three groups both in 1998 and the following year. Insufficient food supply was a rather common phenomenon in the households investigated, and the results show that the DL invasion in 1998 did not contribute to an exceptional food shortage in 1999. In addition, it was observed that the farmers were usually involved in short season off-farm work to top-up the food supply of the households by purchasing supplementary commodities.

Many farmers witnessed food shortage in 1998 and 1999 as a result of poor harvests and low income. It was the landless and the small holders who suffered most. Moreover, poor farmers lacked the capacity to bridge the gap between the basic food requirements and the deficit. Reducing consumption was one of the coping strategies. But, the poor families had to consume their insufficient reserves and hence decreased their already limited capacities for future crop production that could lead in a vicious circle of poverty.

The major coping strategy of the families in the study areas was to keep reserves in granaries. Some of the farmers indicated that the commodities such as cereals could be kept for several years to compensate for crop losses as well as drought. Some farmers indicated that they delayed selling of grain until they expected more promising periods. Most of the farmers had to rely on their reserves while only few had the possibility to buy food. Some others who had no cash or food reserves had to borrow food or money. It should be noted that the farmers of the study areas never received any food aid to compensate for losses due to the DL.

Table 20. Summary of the PRA results

Parameters	*Group 1*	*Group 2*	*Group 3*
Food shortage:	Yes	Yes	Yes
Farmer suffered 1998	20-50 %	40-60 %	10-30 %
Farmer suffered 1999	10-60 %	40-60 %	10-20 %
Reasons for food shortage:			
in 1998	DL, other pests	Drought, other pests	Other pests, flood
in 1999	Flood, other pests	Other pests	Flood, pests
Most suffered farmers	Farmers with small area and tenants; Poor farmers	The poor	Poor farmers
Means of coping with food shortage	Reserve, purchase, credit (30 % in 1998, 7 % in 1999)	Reserve, purchase, credit, aid (year 1982-86)	Reserve, purchase and credit
Migration	Yes	Yes	Yes, but few
Migration due to DL	No	No	--
Reasons for migration	Drought, poverty, looking for job (youth)	Drought, looking for job	Drought, better life in the cities
Price of sorghum in 1999	Decreased (12-16 %)	No change	Decreased
Quantity of sorghum purchased in 1999 compared to 1998	Less	Same	Same
Living condition in 1999	Same as the previous years	Same as the previous years	Same as the previous years
Milk price	Increasing (from 100 SD in 1998 to 150 SD in 2000)	Increasing	Increasing

Source: Own survey (2001)

Due to the comparatively higher standard of living in the main towns of Sudan, farmers are looking for job opportunities in the cities during the slack production periods. In addition, the youth is increasingly leaving the villages mainly for Khartoum. As a result, the city is hosting to-date about one-third of the country's population.

The production level in 1998 was normal. However, the farmers pointed out that the yield would have been higher, if the crops had not been damaged by the DL. This means that relatively good harvest has been obtained despite the losses that occurred (Table 18). This means that the living conditions of the farmers would have been comparatively better if there were no damages. In the context of food security, effective DL control results potentially in better harvests during good rainfall years (which could however also favour DL breeding) and enable farmers to invest for sustainable growth. As drought reduced the resources of the poor farmers in the study area significantly, DL control could be considered as indispensable to avoid crop damage during good rainfall years.

6.3 Externalities

Externalities are defined as the economic and non-economic effects of the behaviour of one stakeholder on the well-being of the other. In the context of the DL, where locust campaigns are considered as a public matter, the farmers derive both positive and negative benefits from the public intervention. Hardeweg (2001, p.72ff) provides four categories of potential and actual cost components of public DL control. These are (1) direct costs for pesticides, survey operations and administrative costs, (2) losses in production due to side effects of the pesticides on crop and livestock productivity including economically important organisms, (3) cost on human health due to contamination and residual effects, and (4) environmental costs including pollution and effects on ecosystem.

Previous economic assessment studies were criticized for having ignored the social and environmental implications of DL control (FAO, 2000), but obtaining reliable data of the social and environmental costs and benefits of DL control is very difficult. Indeed, joint efforts are needed in a multi-disciplinary approach to generate this information.

In this study, attempts were made to estimate the cost linked to the risks of using pesticides on human and animal health. Farmers may get contaminated while using pesticides, working in recently treated fields, or via contaminated water, soil or air. Moreover, consumers may be poisoned by consuming contaminated products.

Cole, et al. (1998) provide a brief review of potential methods to account for impacts on the health including epidemiological and surveillance approaches. Health problems can result in two types of costs: Health-care costs (direct costs) for treatments, and indirect cost of lost outputs or wages due to time for off-farm or reduced productivity (Cole, et al., 1998; Hardeweg, 2001; Ajayi, 2000).

Farmers were asked if they observed cases of a person falling sick or died due to the pesticides use in 1998. The farmers indicated that they could observe symptoms such as headache after control operations. The results of the study revealed that such observations increased with the proximity of the control operations to their farms. In the DL affected areas (both *Group 1* and *Group 2*), the information referred to 1998 but does not necessarily refer to DL control. Among the farmers of *Group 3*, the highest number of sick or even death cases was observed, attributed to the cumulative effect of pesticides used on cotton since 1995.

As shown in Table 21, 20 persons of *Group 1* fell sick after having e.g. inhaled pesticides. This represents a probability of 1.5 % of being affected by pesticides in this area. Due to the use of pesticide for many years, particularly in cotton fields, accidents with pesticides were more frequent (i.e. 2.3 %) in the *Group 3*. It was mentioned that the symptoms lasted from a half-day to 15 days, with an average of 1-3 days. Framers of *Group 2* reported only few case of poisoning.

The health cost per household[9] in the highly affected area was about US$ 2.2, taking into account the average number of persons contaminated, the average number of days off work, a daily wage of US$ 0.4, and the average sum for treatment. This figure is higher in the control group (about US$ 30 excluding death) due to the use of pesticide against cotton pests for several years (Table 21). The negative effect became even more crucial due to careless handling of pesticides by the farmers. During the study it was observed that some farmers hired daily labourers who had neither the necessary skills nor any protective clothing.

Table 21: Impact of pesticides on human health

Parameters	***Group 1***	***Group 2***	***Group 3***	***Total***
No. of households (HH)	194	85	57	336
No. of persons ill	20	8	10	38
No. of households affected	15	7	7	29
Probability that a person falls sick	0.015	0.011	0.023	0.015
No. of persons affected per HH	0.103	0.094	0.175	0.113
Probability that a HH is affected	0.077	0.082	0.123	0.086
Average no. of days a person falls sick	1.8	1.5	3.5	2.18
No. of persons died			1	1
Amount spent for treatment, (US$/HH)	28	24.4	240	37.1
Health cost, US$ per HH[1]	2.2	2	29.5	3.2

[1] See footnote No. 9.

Source: Own survey (2001)

[9] Health cost = (Treatment cost per HH + (average no. of sick persons per HH x average no. of off days x wage per person per day)) x Probability that the household is affected.

Regarding the impact of pesticides on livestock, farmers were asked whether they knew of any case of poisoning. The numbers and values of animals affected were obtained and the cost for treatment estimated. The results showed that the proportion of contaminated or dead animals due to pesticides was 6 % in the *Group 1* but 37 % in *Group 3*.

In order to estimate the impact of the pesticides on animal health in economic terms, the costs for treatment of sick animals and the value of animals died were weighted by the chances that such cases occurred. As a result, a household of *Group 1* lost in average about US$ 1.5, whereas in the *Group 3* the average figure was US$ 69 per household. This value does not include the value of wild animals that might have been poisoned (Table 22).

Table 22: Impact on animal health

Parameters	*Group 1*	*Group 2*	*Group 3*	*Total*
No. of animals ill, TLU	2.17	0	12.8	14.97
No. of HH affected	3	0	2	5
No. of animals died, TLU	17.23	34.08	65.82	117.13
No. of HH affected	9	10	19	38
No. died per HH, valid cases	1.91	3.41	3.46	3.08
Average no. died, all cases	0.09	0.40	1.15	0.35
Probability that a household is affected	0.062	0.118	0.368	0.128
Cost of treating animals (US$ per TLU)	20	0	10	16
Value of animals died (US$/HH)	9.50	42.90	123.56	37.30
Total cost of animal health, US$/HH[1]	1.5	5	69.1	4.80

[1] Total cost of animal health per HH = (value of animals died per household + (average number of animals sick x cost of treating the animal)) x Probability that the household is affected.

Source: Own survey (2001)

7. Conclusions

Previous economic studies show that grain production in Sudan and Morocco during the plague year of 1988 and upsurge of the 1998 were above average compared to the non-plague years (e.g. Joffe, 1995; 1998 and Belhaj, 1998). The comparatively good yields were credited to good rainfall, offering also favourable breeding conditions for the DL at the same time. The effectiveness of DL control has generally been criticized since it failed during the 1986-89 plague to avoided damages to agricultural production at reasonable costs (Joffe, 1995; Herok and Krall, 1995). The average costs exceed the benefit in an order of US$ 10-20 million a year (Joffe, 1998). On the other hand, the reliability of data used for the analysis and the lack of socio-economic and environmental data called for more research in this field (FAO, 2000).

This case study tried to assess the perception of the farm community to DL control, to quantify the economic losses and to assess the impact of DL control on human health and the environment. The study was based on the DL control operations conducted in Sudan in 1998.

The core findings of the study are:

1. Consistent with earlier studies, the results confirmed that the agricultural production during the upsurge year 1998 was not below average despite the damages caused by the DL. The possible reasons were good rainfall and diversification of crop production, which allowed harvesting of some crops prior to the DL invasion or planting/replanting after the infestation.

2. The production function analyses (Cobb-Douglas and Weibull) showed that the conventional factors of crop production such as fertilizer and labour have a higher positive impact on the productivity than locust control. The influence of the PPD interventions on the productivity was small and insignificant. The result of the production function analysis indicated even higher marginal returns of farmers' crop protection measures compared to those carried out by PPD.

3. There is no clear indication that the damage caused by the DL during the upsurge of 1998 had a significant impact on the livelihood of the farm community. This could be due to combined effects of (1) crop diversification, which allowed partial harvesting of crops before the DL invasion, and (2) the control operations by the PPD, which reduced potential damage directly or indirectly, since uncontrolled hopper bands and swarms could have caused further damages to agriculture in neighbouring areas or states.

4. The assessment of the impact of pesticides on the human health showed a probability of 8 % that a farm household in the DL affected area could suffer from the negatives effects of DL control with a cost of about US$ 3. 6 % of the households registered hazardous effects on their animals at a cost of US$

1.5. The impact of pesticides was significantly higher in the control area due to excessive use of pesticides against other crop pests (see Table 21 and 22).

5. The relevance of DL control measures was underscored by the farmers' views. Since poverty is prevalent in the study area, the farmers opted for timelier control. The farmers' response also illustrated the motivation to contribute to locust control to protect their crops. Lack of or limited training chances regarding good plant protection practices was one of the major concerns raised by the farmers.

6. Although the issue of crop damage insurance emerged from the discussions of alternative approaches of DL management (Hardeweg, 2001; Belhaj, 2001), the result of this study revealed that farmers prefered to participate directly in locust control operation rather than to claim for loss compensation after the damage occurred. Depending on how much farmers are at risk by the DL, the analysis of factors affecting the motivation to contribute to DL control showed a spatial difference in the marginal rate. This gives an indication for the level the farm community could potentially be involved in the cost sharing.

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Appendix 1. PRA check list

1. No. of households, and average family size in the village
2. Crops commonly grown in the area; planting time and harvesting time (irrigated, rainfed), problems of production of the crop and their rank.
3. Crop damage: year, causes of damage, proportion of yield damage per unit of area.
4. Yield: crop, minimum, maximum, most commonly harvested yield,
5. Rainfall situation: good, medium, and poor.
6. DL: appearance in 1988 and 1998 (month, frequency and duration of stay), disappearance (month and reasons), nature of appearance (large swarms, medium and small), extent of crop damage among farmers).
7. Opinion of farmers about the spray in terms of: timing, place and method of application, care taken to protect animals and human being, care taken against water pollution, training given to the community and the effectiveness of the chemicals used.
8. Farm size: minimum, maximum and average area per household, fertility, proportion of land less farmers in the area.
9. Problem of food for consumption during 1998 and 1998; means of coping with food shortage
10. Formal credit, source and purpose of credit.
11. Price of crops: during 1998 and 1999, change of price, reasons for change.
12. Pesticides: application by the farmers themselves, source of chemicals, negative effect of using pesticides for other pests and DL (human beings and animal health as well as water pollution), and treatment obtained (distance of treatment centre and cost of treatment).
13. Livestock: type, average number, value of animals, existence of change in number and value, reasons for change, problems of livestock production.
14. Farmers who left the village due to DL damage: Number, places they live now, whether they returned or not.
15. Investment: priorities

Appendix 2: The Survey Questionnaire

The objective of the survey is to acquire true picture of how the farmer/nomad perceives the DL control being implemented by the Plant Protection Directorate and quantify the magnitude of losses and understand the local control mechanisms so that economically, socially and environmentally feasible alternative can be identified. The information you provide us will be kept confidentially and will have no negative consequences. Please answer the questions based on your experiences and expectations.

Name of the Respondent: _________________State: ___________Village: ________
Name of the Interviewer: ___________________________Date: ______________

1. What are the major factors damaging your crops? Rank them:
a) drought ____ b) pests _____ c) flood _______
d) others (specify) ____

1.1 Have pests ever damaged your crops since you started farming? (yes/no)_______
Which pests? ____
Please rank the pests in order of the damage they cause to your crops.
1st __________________2nd ____________________3rd _________________

1.2 If Desert Locust (DL) destroyed your crops, please tell us the years. _________, ________, ________, ________, _____

1.3 In 1998, how long did DL stayed in your field? _________________

1.4 Which crops were damaged by DL? Please tell us the area and the yield lost.*

Year	Crop type	Area (Faddan)	Production (sack)	Crop type	Area (Faddan)	Production (sack)
1988	1.			3.		
	2.			4.		
1995	1.			3.		
	2.			4.		
1996	1.			3.		
	2.			4		
1998	1.			3.		
	2.			4.		

* Please include both perennial and annual crops when applicable

1.5 What was the area allocated to each of the crops during the latest DL invasion year and the year that followed? Please also give the yield you harvested (actual harvest) during these years.

	Summer crop				Winter crop			
Crop	Area (Faddan)		Production (Sack)		Area (Faddan)		Production (Sack)	
	1998	1999	1998	1999	1998	1999	1998	1999
1.								
2.								

Rem: If you cannot easily convert the units of measurement, please indicate that unit

1.6 What was the maximum damage you experienced?

Crop type	Area (Faddan)	Production (sack)	Which year?
1.			
2.			

2. Were your plots sprayed during the DL invasion years? (yes/no) _________

2.1 Who sprayed? ______________________

2.2 Area sprayed during the latest invasion year:

Crop type	PPD	SELF					
	Sprayed area (Faddan)	Area with pesticide		Amount of pesticide		Cost paid for (in Dinar)	
		Sprayed	Dust	Spray (Lt)	Dust (kg)	Spray	Dust
1.							
2.							

2.3 Please tell us your opinion regarding the spray by judging it as *very good (V)*, *moderate (M)*, or *poor (P)*.

- Regarding the timing? ☐
- Regarding the place of application? ☐
- Regarding the method of application? ☐
- Regarding the care taken to protect animals and human being? ☐
- Regarding the care taken against water pollution? ☐
- Training given to the community to protect themselves against the chemicals ☐
- Regarding the effectiveness of the chemicals used? ☐
- Others (*specify*) ____

2.4 Did you use chemicals against other pests? (yes/no) ________________
2.5 If yes, against which pests? ____________________________________
2.6 Which chemicals? ____
2.7 Where did you get them? (Market/ PPD/ others, specify) _____________

2.8 Information on pesticides use against other pests during the last invasion in 1998

Crop type	PPD	SELF					
	Sprayed area (Faddan)	Area with pesticide		Amount of pesticide		Cost paid for (in Dinar)	
		Sprayed	Dust	Spray (Lt)	Dust (kg)	Spray	Dust
1.							
2.							

2.9 Do you know the negative impacts of these chemicals? (Yes/no) ______________
2.10 Did you or your family face any health problem due to pesticide? (yes/no) _____
If yes, tell us the following:

Name of person affected	No. of days he/she was ill	Degree of sickness (severe, moderate, light)	Payment to recover (SD)

2.11 Did any of your animals suffered from the effect of pesticides? (yes/no) _______
If yes, tell us the following:

Type of animal	No. died	Value of the animal	No. ill	Degree of sickness (severe, moderate, light)	Payment for treatment

2.12 Do you know the different pesticides used in your area? (yes/no) ___________
If yes, please name them? ____
____
2.13 Do you have any preference to the DL control chemicals? (yes/no) ___________
If yes, which ones do you prefer and why? ____________________________________
____
2.14 What kind of protection do you use while applying chemicals? ______________
____
2.15 What other DL control tactics exist in your locality? (Traditional techniques)
____
____

2.16 Which of them do you apply? ____
2.17 Which one is the best strategy? ______________________________________
____
2.18 What is the basis for your choice? ____________________________________
____
2.19 From the following strategies of controlling DL, which one is the best? Rank

a) Preventive control: to locate reproduction sites and destroy the eggs before they develop ________
b) Strategic control: to attack the DL before they arrive in the agricultural field__
c) Mechanical control: to kill the DL with fire or abatement. __________
d) Individual control: using chemicals _______________
e) Other strategies: specify them.____

3. If the PPD cannot continue to provide the type of DL control provided so far, what controlling strategy would you use? ____________________________________
____

3.1 Since the damage by DL is eminent, and if the current fund for preventive control is no more available, would you like to contribute to prevention of DL (other pests) or contribute some money for compensation of part or all of your output if damaged? (mark √)

	Regarding DL	Regarding other pests
Preventive control	_________	_________________
Compensation for damage	_________	_________________

3.1.1 If contribution to preventive control is chosen,
How much would you pay to avoid losses of production on 1 Faddan?

	Cash (Dinar)	Grain (Sacks)	% of output
Regarding DL	_________	__________	__________
Other pests	_________	__________	___________

3.1.1 Are you willing to pay this amount each year? (yes/no) ________
If no, what is the minimum you are willing to pay each year to prevent the pests?

	Cash (Dinar)	Grain (Sacks)	% of output
Regarding DL:	_________	__________	__________
Other pests:	________	_________	__________

Who should bear the remaining cost? ______________________________
If yes, are you willing to pay a bit more than the amount given above? Yes/no______________, why? _________________________________

3.2 If compensation for damage is chosen,

How much would you pay to get full compensation of production damaged on 1 Faddan in good year?

	Cash (Dinar)	Grain (Sacks)	% of output
Regarding DL	__________	___________	___________
Other pests	__________	___________	____________

How much would you pay to get half compensation of production damaged on 1 Faddan in good year?

	Cash (Dinar)	Grain (Sacks)	% of output
Regarding DL	__________	___________	___________
Other pests	__________	___________	____________

How do you prefer such a compensation be managed if realized? (mark √)

- The fund should be managed by the village
- The fund should be managed by International Organization
- The fund should be managed by National Organization
- Other institutions (specify) ____________________________________

3.3 If there is fund for investment, please indicate areas of your investment preference. ____

4. RESOURCE

4.1 Consider last invasion year (1998). Please tell us the No. of plots you owned and their allocation.*

Plot	Area (Faddan)	Distance to home (minutes walk)	Crop grown	No. of trees (if perennial)	Fertility**
1					
2					

* Ask all cases even if DL is not important, ** Fertile, medium, poor

4.2 a Quantity of input used and expenses: Summer production of 1998 and 1999

Year	Plot	Crop grown	Area (Faddan)	Labour (days)	Traction (hrs)*	Seed (kg)	Fertilizer (Dinar)	Pesticide (Dinar)	Production (sack/kg)

**Please distinguish animal traction from tractor.*

4.2b Quantity of input used and expenses: Winter production 1998 and 1999

Year	Plot	Crop grown	Area (Faddan)	Labour (days)	Traction (hrs)*	Seed (kg)	Fertilizer (Dinar)	Pesticide (Dinar)	Product (sack/kg)

**Please distinguish animal traction from tractor.*

4.3 If labour was employed, the wage paid for labour (Dinar) ___________ and the number employed ______________

4.4 If animal traction was rented, please tell us the rent ___________ (Dinar per hr)

4.5 Tractor rent ______________(Dinar per hr); __________ hours used.

4.7 Irrigation cost: _____Lt of Diesel @ ______Dinar per Lt = _________Dinar

4.8 What were the prices of the following products?

Output	Price (Dinar per kg		Output	Price (Dinar)	
	1998	1999		1998	1999
Sorghum			Orange (income per tree)		
Millet			Lemon (income per tree)		
Seasam			Cotton (income per tree)		
Onion			Palm (income per tree)		
Cucumber			Milk (Dinar per Lt)		
Molokuya			Water Melon (Dinar per lorry)		
Okra			Fodder (Dinar per lorry)		

4.9 Please tell us the type and number of farm implements you have.

a) Plough _________ (Source: purchased, donated, specify)
b) Hoe ___________ (Source: purchased, donated, specify)
c) Sprayer ________ (Source: purchased, donated, specify)
d) Tractor ___________(Source: purchased, donated, specify)
e) Water pump machine __________(Source: purchased, donated, specify)
f) Others (specify) ____

4.10 Please tell us the amount you paid, if you rented land for ploughing. ________(Dinar) OR ________________sacks of grain (specify)

If you are tenant, please tell us the arrangement ______________________________
____

4.11 What is the best possible yield in a good year, minimum yield if that good year is affected by DL and the most common yield you could harvest (sack per Faddan)? Assume the field operation is well done.

Crop	Good yield year not affected by		Good yield year but affected by ___ & sprayed		Good yield year but affected by ___ & not sprayed		Most common yield level
	DL	Other pest	DL	Other pest	DL	Other pest	
Sorghum (sack)							
Millet (sack)							
Okra (sack)							
Molokuya (kg)							
Onion (sack)							
Cucumber (sack)							
Palm (kg)							
Cotton (kg)							
Orange (sack)							
Lemon (sack)							

5. LIVESTOCK

5.1 Please tell us the number of animals you had in 1998 and 1999 and their approximate values

Animal type	Number during year		Unit price (Dinar)		Reason for keeping
	1998	1999	1998	1999	
Goats: adult					
Goats: kid					
Sheep: adult					
Sheep: young					
Cow: local breed					
Cow: Cross breed					
Heifer					
Calf					
Donkey: adult					
Donkey: young					
Oxen					

5.2 Milk

Animals milked (1998)	No. milked	Milk per day (Lt)	Lactation period (months)
Cow			
Goat			

6. Some actions indicating Coping with food shortage

6.1 Animals bought

Type	1998		1999	
	No.	Value	No.	Value
Sheep				
Goat				
Cattle				
Donkey				
Others:				

6.2 Animals sold

Type	1998		1999	
	No.	Value	No.	Value
Sheep				
Goat				
Cattle				
Donkey				
Others:				

6.3. What measures were taken to feed your family, if your crops were damaged?

	1998	1999
1. Purchase dura (sacks)		
2. Receive credit (Dinar)		
3. Received food aid (sacks)		
4. Migrate to other places (tick)		
5. Others (specify)		

6.4 Credit received and repayment (Dinar)

	1998	1999
Credit received		
Credit paid back		
Source of credit		

6.5 If it is a DL year, do you expect changes in dura price? Yes/no _________; If yes, increase OR decrease? _________; by how much? _______________

If it is a DL year, do you expect DL invasion in your field? Yes/no ______

“ ‘ do you take measures to avoid DL? Yes/no ___________

If yes, which measures?____

7. HOUSEHOLD

7.1 Please tell us the number of members in your family

a) Total number of family member ______________
b) Total with less than 7 years __________________
c) Total with 7 to 15 years _____________________
d) Total men with 16 to 50 years ________________(farm work yes/no) _____
e) Total women with 16 to 5o years ______________ (farm work yes/no) _____
f) Total (men and women) with more than 50 years _________

7.2 What is the age of the family head? _______________

7.3 What is the education level of the head? ____________

7.4 Number of children in school? __________________

7.4 What is the main purpose of your farming?

a) Consumption c) Cash income
b) Livestock feed production d) Others (*specify*) _______________________

7.5 Number of family member who work outside farming? ____________________

Why working outside farm? ____

7.6 Average yearly income of one person in off-farm work? ___________________

When did you start this off-farm work? ____________________________________

If started after 1998, the reason? ____

8. EXPECTATION

8.1 Tell us how you fell about the future of your farming

a) I have a great hope that I can produce and feed my family
b) I am saving some money for future investment
c) Market is getting nearer and I can produce and earn more
d) I am trying to change the hard working environment to produce more
e) I am won by calamities
f) Others (specify)____ __

8.2 Do you expect that DL will appear in the future? (yes/no) _________

How often do you expect? Once in every _______years

8.3 Do you think you can control crop pests effectively? (yes/no) _________

8.4 Do you feel that environmental damage is getting worse? (yes/no) _____

Appendix 3. Production system and changes in production (PRA)

Particulars	*Group 1*	*Group 2*	*Group 3*
Crops	Sorghum, beans, watermelon, vegetables, palm tree	Sorghum, millet, watermelon, seasam	Sorghum, beans, groundnuts, cotton, citrus, vegetables
Major crops damaged by DL	Sorghum	Sorghum and millet	
Livestock	Goat, sheep, cattle, donkey, camel	Goat, sheep, cattle, donkey, camel	Goat, sheep, cattle, donkey, camel
System of production	Mixed farming; flood water supplemented by irrigation; limited production by rain; no intercropping; dependent on tractor, oxen and hand cultivation	Mixed farming; rainfed; intercropping; Oxen and hand cultivation	Mixed farming; rainfed and irrigated; crop rotation compulsory
Trend of production (major reason)	Decreases (drought)	Decreases (drought)	Stable but depends on rain and water availability; pests
Proportion of landless	15-30%	Nil	Few landless but too small for some farmers
Common soil type[1]	Sandy in the rainfed; sandy loam in irrigated field	Sandy	Sandy soil mixed with black soil
Soil fertility (most common)	Irrigated: fertile; rainfed: 40-60% fertile	The majority is not fertile	Medium, if fertilizer is applied, very good harvest is obtainable

[1] The classification is based on physical observation only