AN ECONOMIC ENQUIRY INTO THE IMPACT OF CEMENT-KILN DUST ON AGRICULTURE BASED ON PERCEPTION OF FARMERS

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "An economic enquiry into the impact of cement-kiln dust on agriculture based on perception of farmers" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara,
17 -10-1989.

SEEMA, P.

CERTIFICATE

Certified that this thesis entitled "An economic enquiry into the impact of cement-kiln dust on agriculture based on perception of farmers" is a record of research work done independently by Kum. Seema, P., under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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We, the undersigned, members of the Advisory Committee of Kum. Seema, P., a candidate for the degree of Master of Science in Agriculture with major in Agricultural Economics, agree that the thesis entitled "An economic enquiry into the impact of cement-kiln dust on agriculture based on perception of farmers" may be submitted by Kum. Seema, P., in partial fulfilment of the requirement for the degree.

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Introduction

INTRODUCTION

1.1 The linkage between ecology and economics

Environment with respect to man is often defined as external, physical and natural conditions in totality influencing him and which in turn are influenced by his activities. The economic aspects of environmental quality have been increasingly attracting the attention of economists in recent years. This has resulted in the evolution of what is called environmental economics (environomics) as a distinct field of enquiry. Environmental economics seeks to study the relationship between economic progress on the one hand and environmental quality on the other. Economic progress in the modern world has been accompanied by technological advancement. The common manifestation of technological advancement is in addition of goods of value and wastes of liability to the community. But commodity prices do not truly reflect the neglected consequences of economic progress, even if air and water are no more treated as free goods.

From environmental stand point, any accumulation in the ecosystem of certain substances or life forms consequent to production or consumption activities is pollution. But this alteration to environment is called pollution by economists only when they are undesirable. (Seneca and Taussig, 1979).

If the environmental opportunity cost of utilising the receptive capacity of nature is not to be defined in a static setting, the approach should be preventive or anticipatory. But, for the use of public goods, there exists a free-rider problem when the user may not be willing to contribute to the cost of protection. This market imperfection envisages governmental action (and not market mechanisms) to prevent misallocation of resources, necessitating the pragmatic approach of assessing the benefits and costs of each emission, by independent agencies.

As held by ecologists, threshold effects are typical for environmental damages so that the information on environmental changes may only become apparent after pollutants had had their impact for a longer time. This is especially true for cement dust pollution. Risk factor then should be incorporated in impact assessments.

To minimise uncertainity in such assessments, research providing information on the kinds and extent of impacts is the need of the day.

1.2 Impact of pollution on a micro level economy

To arrive at the shadow price of a better environment, and to trade off the environmental quality against economic goods and services, the physical, biological and social impacts of the external diseconomics should be reflected in money terms. The relatively low resilience of flora to unrealistic environmental management is to be utilised for predicting the threat to other constituents of the biosphere and the resultant stagnation or retardation of economic progress in future. Environmental inventory before and after a project implementation has to be assessed in economic terms to arrive at priority in developmental planning. In order to find the impact on a micro level economy, the damage cost assessment as attempted in this study is necessary.

Economics of environmental degradation has particular signififance in developing countries, both in the short and long term perspectives because of their dependence on natural resources and huge size and growth rate of population. Reversing the annihilation caused to nature becomes impossible considering both the persistence of antimatters produced in retaliation by nature and the inability to allocate resources, bypassing other urgent targets. Bankrupting the environmental quality of future generation leads these countries to cross roads with a weak resource base for economic options. In these countries environmental inequalities are parallelled by economic ones.

Small and marginal farmers in developing countries respond well to any incentive or interference to their profession. Therefore, degradation of farm resources caused directly and indirectly by industrial effluents has an adverse impact on the regional agricultural scenario. Most of the cultivators have a strong antipathy to industrial pollutants resulting in a high negative price for these unwanted inputs.

An improvement of environmental quality at a given technology with full utilisation of the resources is possible only if more resources are used in abatement and the production of commodities is reduced. However, determining the level of production, according to Koopman's efficiency (i.e. producing on the transformation space with given technology and resources avoiding wastage of resources) (Siebert, 1987) may not be feasible in a developing economy supporting huge population. Then the more realistic approach will be defining several sources of emission as a bubble (introduced in 1977 by the air quality policy in the U.S.). A bubble as such has to satisfy the tolerable quantity of emission, so that the optimum weightage is attached with the impact on environmental quality of a bundle of sources rather than with individual stack emission. In a similar context, damage assessment of pollutants in an area becomes more relevant taking the primary, secondary, direct and indirect modes of pollution as a bubble.

1.3 The present study - it's objectives and organisation

The present study on the impact of cement kiln dust on agriculture has been planned with the following objectives. 1. To study the perception of farmers on crop loss due to pollution and 2. To examine the socio economic perspective of air quality in the area.

Literature relevant to the study are reviewed in the next chapter. The third chapter describes the pollution, polluted area and the control. Methods adopted to assess the impact are described in the fourth one. Chapter five presents the results obtained and discussions thereon. In the sixth chapter, the possible conclusions after summarising the results of analysis are consolidated. Details of cement kiln dust and needed back ground informations are furnished in appendices.

1.4 Limitations

The method of interview adopted to assess the impact is constrained by pre-conceptions of farmers in general regarding the changed climate and deteriorated crop performance and also by their lack of awareness on the modes and significance of environmental contamination. Inaccessability of remote areas hinders the complete coverage of pollution affected area by a single person, within a limited time. Lack of monitors like high volume samplers, or ambient air monitors, necessitated the dependence on secondary data which is meagre and inadequate for the particular source of pollutant. Exclusion from the survey of areas coming under the neighbouring state of Tamil Nadu which also are affected by the same source of emission, though for a different period of the year, leads to an under estimation of the actual impact.

Review of Literature

REVIEW OF LITERATURE

In this chapter, an attempt is made to review and relate researches relevant to the concepts of the present study. This has been accomplished in two broad sub-heads viz. Environmental Economics and Crop response to cement kiln dust.

1. Environmental economics

1.1 Externality

Production externalities exist, when the production activities of one firm directly affect the production activities of another firm. In a real world economy, all inputs are not fully converted to output nor are the outputs utterly destroyed in consumption, without leaving material residuals. As environmental rights are not private or in competitive markets, the aforementioned situations create external diseconomies of scale, where Pareto criterion for economic efficiency is not satisfied. Even if internalization of discharge costs is done perfectly, Knight (1924) observed that as far as residuals render disservices, Pareto optimality cannot be guaranteed. But later studies as by Pigou (1932) and Scitovsky (1954) reveal a strong propensity of theoretical literature to view externalities as exceptional and minor. Moreover traditionally, environmental supply demand relationship was such that public consumption goods were attributed a zero price. (Buchanan and Stubblebine, 1962).

Doubts regarding the consideration of individual and social preference ranks as purely exogenous data in economic analysis has been raised by a number of research workers like Boulding (1966), Kapp (1970) and Nijkamp (1974).

Seneca and Taussig (1979) calls forth a needful change in attitude towards the basic consideration, and state that "taking the basic economic magnitude as service (and not good)there exist uncompensated technological external diseconomies".

The classification of externalities by Nijkamp (1977) and Anderson and Hafkamp (1984) based on the (non-) separability, (non-) reciprocity, (infra-) marginality and potential irrelevance, can be utilised in shadow pricing pollutant as also its marginal abatement cost, because the above classes reflect the relative risk factors in the long run consideration of social cost.

Due to population pressure, economic growth, technological complexity of modern pollutants and the high income elasticity of environmental quality, there is a reversal of traditional environmental supply demand relationship seen in Buchanan and Stubblebine (1962). Projecting this scarcity aspect of environmental quality against the utility concept of Siebert (1987) the significance of external diseconomies of production, increasing the discrepancy between marginal social cost and marginal private cost can be adequately magnified.

1.2 Impact assessment and analysis

A. Importance

The argument in favour of impact studies on ecology is basically that the environmental repercussions are but warnings for future humanity. Boulding (1966) has pessimistically derived the reckless spending of environmental capital in pursuit of a wrong headed goal of maximising current output. It was pointed out by Krutilla (1967) that the demand for natural sites increases over the shrinking supply opportunities creating a steady rise in the implicit social price of nature, foreclosing many future economic options. This is in tune with the antigrowth argument based on Turvey (1963) and Scitovsky (1976) for the sake of reducing scarcity, sustaining the assimilative capacity of environment, allowing the survival of other species than man and preventing the natural environment from being an apparent luxury. This approach does not match the political traditions of society, especially in the underdeveloped nations, though they are in the midst of a geometrically enlarging population. Therefore many researchers probed into reliable methods of assessing the impact of economic activities, intending to facilitate the comparison of alternatives available.

B. Methods

Wolozin (1966) had observed an empirically convenient inclination towards partial equilibrium analysis, permitting the external damage and control cost functions to be defined for particular cases without reference to broader inter relationships and adjustments in the economy.

The environmental cost as per Dales (1968) is the total waste disposal cost obtained as the sum of environmental damage cost and environmental management cost.

As criticised by Ayres and Kneese (1969), the partial equilibrium view accrues to the manner of accounting for production and consumption process at variance with the fundamental law of conservation of mass. They have concluded that the direct or indirect participation of each member of a society pave the base for an existing environmental problem and in order to highlight the significance of microscale environomic analysis, the macro economic impact of the competitive use of environment should be analysed. The materials balance model putforward by Ayres and Kneese (1969) envisaged description of flows and stocks of energy and materials. Though the model is useful in economic environmental modelling, it has limitations such as negligence of release, dispersion and interaction of pollutants.

The operational model of the input-output approach putforward by Leontief (1970) is not applicable in the context of this study because of non-availability of data on matrices of constituent pollutants in the emission and on abatement sector.

Barrett and Waddell (1970) realised the problem to assess the opportunity cost in the absence of free competition, regarding the assumption in price effects, although the damage to agricultural production can be gauged in principle based on laboratory studies.

The widely discussed benefit cost analysis (Mishan (1971), Dasgupta and Pearce (1972), Coomber and Biswas (1972)) for project evaluation of environmental concerns, even if satisfies the condition of inter-dependance and social opportunity cost, to restore Pareto market equilibrium, is not an easy application due to situations necessitating stochastic or sensitivity analysis, omission of equity evaluation, lack of uniformity on preference, determination of discount rate and intangible effects.

The economic structure per se as cited by Jain et al. (1971) is an environmental factor in impact assessment as is air or water. Then the external diseconomy of production had to cover the socio-economic, recreational, agricultural and occupational ramifications in order to arrive at the true social cost curve giving the real overproduction of ecologically harmful products.

Odum (1971) and Daly (1973) utilised the entropy concept as a technological linkage system between economic activities.

To assess the socio-economic reflections, a saroad format as given by Stern (1971) can be utilised, with suitable modifications; but assessing the damage cost functions by a survey based on injuries has doubtful applications to judgemental decisions as per Heggstad and Hech (1971). Hence damages to vegetation have to be adopted from histological, physiological and soil impact studies in concerned fields.

According to Ray (1972) alternatives to the project, the relationship between short term uses of human surroundings, management of long term productivity and any irretrievable commitments of resources ought to be discussed.

The pioneering work by Nordhaus and Tobin (1972) disclosed that the allocation effects of the incomplete appreciation of opportunity cost of environmental impact and exclusion of environmental nuisance from prices of goods leads to an overstaed NNP, by the amount of welfare cost of pollution i.e. the social cost of realising that level of NNP is not reflected. In accordance with their findings, rather than a resource depletion for the production sector, the depletion of non-appreciable goods is more serious because of the non-existence of a circular flow of materials in the system, unlike the money flow in an economy where substitution in price mechanism can alter the resource combinations.

Most often the major (but less noticed) impact is secondary or tertiary which is much more difficult to be assessed due to dearth of predictive techniques available. Perhaps a projection of future residuals according to the materials balance model given by Ayres and Kneese (1969) and a time sequential analysis of economic impact as by Edmunds and Leyty (1973) and Antonini _et al_. (1974) added to an optimal allocation of risks based on ex-post perceptions (Social risks cannot be shifted) may be able to solve the problem.

If the impact assessment of a project involves economic analysis, succeeding the environmental impact statement, the recommendations of Environmental Protection Agency are relevant. Accordingly Leung _et al_. (1978) rightly argue for a full disclosure law regarding negative and positive ramifications; and the associated primary and secondary impacts.

The cost of environmental protection calculated by the Organisation of Economic Co-operation and Development in 1978 includes resource cost, target losses for economic policy, environmental policies, leading to higher price levels, retarded productivity, and worsened balance of payment situation. But they did not associate equal importance to the stimulating effect of pollution abatement technology and higher levels of employment.

Seneca and Taussig (1979) rightly point out that even if the net social gain from partial or full substitution from farming to another industry is not greater than zero, the external diseconomy of the firm is to be measured by farmer's net income loss.

The significance of informed communication between biologist and economist in pollution research is highlighted by Ronald Reagan's Executive Order 12291 in 1981 explicitly requiring the application of benefit cost procedure according to Adams and Crocker (1982).
The constraints in the application of environomic models including materials balance model Ayres and Kneese, 1969),

the input - output matrix (Leontief, 1972), a quadratic criterion function (Nijikamp and Somermayer, 1971), the functional approach (Hueting, 1974) and the multilayer models (Anderson and Hafkamp, 1984) proclaim the theoretical gap in the field of systems analysis regarding complex reactions in the ecosystem and the long term aspects of pollutant and abatement (Adams et al. 1984).

The finding of Siebert (1987) regarding the need for ex-ante information based on the progressive increase in the quantity of pollutants with increasing output, can be supported by empirical data. The interaction of increases in income and output levels with a growing population has to be inculcated, together with the risk factor, already considered by Siebert in order to arrive at the long-run effects of pollution. However, this has implications of linking shadow cost of pollution to sectoral decisions. Shadow pricing pollution is a multi objective optimization problem based on a trade off between marginal income and marginal pollution.

1.3 Environmental policy

Collective environmental action calls forth the policy maker to maximize expected utility of environmental quality subject to constraints. Of all theoretical mechanisms like zoning ordinances (Mishan, 1969), industrial regulations, taxes, subsidies and effluent charges, taxes represent an objectively flexible tool, while effluent charges rely on the profit maximising behaviour of firms. Fiscal measure as suggested by Kneese (1971) and Ackerman (1973) reward pollution source by offering to purchase the implicit environmental property rights.

Dorfman and Snow (1975) point out that, the distributional effects of effluent charges in the Society's mode of resource allocation cannot be neutral to equity. The poor are under represented in areas where the air quality is met, and over represented where it is violated. The equity efficiency trade off problem in environmental policy becomes even more complex, when we extend the equity concept to include the welfare of future generations relative to the current generation.

Studies by Seneca and Taussig (1979) on the alternative policies, indicate that though the allocational efficiency effects are equivalent for both effluent charge solution and market solution, there is great difference in the distributional effects. They have brought to lime light the fact that inspite of considerable scientific evidence demonstrating the relationship between poor air quality, and deteriorating agricultural performance, it is not that easy to establish this legally. Private utilities responsible for environmental decay readily find expert witness to testify that many factors could have caused the foliage to yellow, the crop to fail or the cattle to sicken. Thus, whatever optimality is obtained in systems analysis by equalising marginal damage cost and marginal management cost, the recovery is rendered a frustrating experience on account of the current structure of property rights and laws, rather than a true questioning of the causal relationship between a pollutant and crop damage. These observations assume relevance where facilities lack in monitoring, warning and quick legal actions. The bubble concept innovated in 1977 by the air quality policy of the U.S.(Seibert, 1987) of maintaining the environmental standards in an area as a whole can be adopted by decision makers of developing countries.

2. Crop response to cement kiln dust

2.1 Cement kiln dust

The poor utilisation factor of electro static precipitator was disclosed by Sinha (1973), measuring the average air borne dust concentrations as 250 ppm of which 55 per cent of particles measuring less than 2.83 μ, 25 per cent between 40 and 53 μ and 9.3 per cent measuring 10 μ. He went on to argue that potassium and calcium in the solid effluents were neither in true state nor as chemical compounds in favour of plant growth. The small quantity of nitrogen and sulphur in the gaseous effluent is converted to acids which also damage vegetation. Pawar et al. (1982) has proved the superior phytotoxicity of cement kiln dust compared to fly ash and coal. Details of cement-kiln dust are furnished in appendix one.

2.2 Climate and impact of pollution

Many have emphasised the role of meteorological factors in pollutant dispersal, intensity of accumulation and their related crop response. Equally important is the impact of pollutants on the micro climate of the area. Saponification of cuticle and disintegration of tissues due to cement kiln dust in presence of moisture raising the pH to 10-12 was reported by Czaja (1962). Pollutants, the injury caused by them to nature in reaction with the climate and soil of the area appear in studies by Heggestad and Hech (1971), Canter (1977), Adams *et al*. (1984) and Cowling (1985). Considering the characteristic size and nature of cement kiln dust particles, wind direction, wind velocity, rainfall and humidity are the most important natural elements. The view of Ferrara and Cagneti (1980) on persisting wind direction related to maximum time integrated concentration of discharge, supports the observations.

2.3 Effect on soil properties

Sreerangaswami and Jambulingam (1973) estimated a deposition of 170 kg dust per acre of land per 75 days forming one to 2.5 cm thick crust on unploughed soil. Parthasarathy *et al*. (1978) has reported 1.7 tonnes/ha/ 30 days of cement kiln dust on soil and consequent reduction in pore space accompanied by increase in thermal conductivity and specific gravity. A low water holding capacity of such soils was reported by Sheikh *et al*. (1976) and Parthasarathy *et al*. (1978). Kubikova (1981) observed accelerated soil erosion, distintegration of soil profile, increased calcium cations and a reduction of many elements. Studies by Singh (1981) showed a decline in soil of accumulated nitrogen and phosphorus whereas an enhanced amount of potassium and calcium.

Discussing the variations in soil reaction, Vanhaunt and Stratman (1970) stated that the pH turned unfavourable to yield except for grasses tolerating high pH. Puri et al. (1982) had reported an increased pH of 7.4 to 8 in polluted area from 5.7 in control area together with an increasing trend in sulphur content. Kœ pka and Smiech (1983) had denied any change in soil reaction, except for a considerable reduction in acidification, and an increase in content of exchangeable calcium, magnesium and potassium. Khosla and Puri (1984) found a marked increase in amylase activity and reduced invertase activity in affected soils.

Oblisami et al. (1978), Khosla and Puri (1984), and Rethinam et al. (1987) found an increase in calcium, magnesium, zinc, manganese and copper of affected soil together with a micro nutrient toxicity (30 to 40 ppm in polluted soil and one ppm in control). As recognised by Guderians (1986) the culprits in phytotoxic solid effluents were calcium particulates, water soluble cement, tricalcium silicate, dicalcium silicate, tricalcium aluminate and tetracalcium aluminium ferrite.

2.4 Effect on plant population

Sreerangaswamy et al. (1973) reported that the proximity to the kiln had most of its vegetation constituted by small leaved plants except for medium foliated ones. Weed flora like Euphorbia hirta and Heliotropium scabbum tolerate the pollutant. Brandt and Rhodes (1973) and Kubikova (1981) and Sreerangaswamy et al. (1973) also report disappearance of some and dominance of other plant species in areas polluted by cement factory effluent.

2.5 Effect on crop pests

Darley (1966) attributed an increased aphid menace in polluted alfalfa to probable destruction of natural enemies. Manning (1971) demonstrated an increased incidence of foliar diseases in cement kiln dust affected plant - Cercospora sp in sugarbeet and Gleosporium sp in grapes. Rai and Pathak (1981) pointed out that the numbers and not kinds of pathogen increased on the polluted flora.

2.6 Direct effects on crops

Efforts to predict crop response from pollutant dose should be evaluated based on their contribution to improve the economic efficiency of environmental policy decisions. For the cement-kiln dust deposit, crop responses are of varying nature.

Parish (1909), Pierce (1910) and Anderson (1914) studied the injurious effects of cement kiln dust on citrus; orange and cherry respectively. Parish stressed on impaired light reception, and starch formation. Pierce and Anderson noted the prevention of pollen germination. Retarded growth in poplar and alfalfa was observed by Bohne (1963) and Darley (1966). According to Vanhaunt and Stratman (1970) plants were dusted at a rate of one to 49 gm per m^2 per day near a cement factory.

Investigation into the impact of cement kiln dust on maize, by Sreérangaswami and Jambulingam (1973) revealed that the reduced seed set was caused by drying up of silk and interference with the transversal of stigmatic surface. Parthasarathy et al.(1978) has reported the physical parameters like plant height, internode, number and size of cobs adversely affected by cement kiln dust. Anda (1986) had cited increase in evapotranspiration on maize crop polluted by cement dust.

Sheikh et al. (1976) observed that the shading effect of dust deposit and low water holding capacity of soil together reduced crop growth by 50 to 55.6 per cent and resulted in shorter and smaller fruits in olive.

Studies of Oblisami et al. (1978) revealed adverse impact of cement-kiln dust on plant height, girth of stem, number of leaves, and number of bolls in cotton, along with reduced ginning percentage of affected fibres.

In 1977 Hanus and Toth could attribute a lower rate of photosynthesis and higher rate of dark respiration in polluted bean plants. Taniyama et al. (1979) found a reduced rate of photosynthesis and grain yield of rice due to one, two or five gm cement dust per m^2.

Yunus et al. (1979) could correlate ideoblast frequency with the pollutant and Rao (1985) could arrive at a linear relationship between pollutant dose and plant response which caused 54.70 per cent reduction in chlorophyll and 61.60 per cent reduction in biomass at 100 m away from the factory relative to plots 400 m away.

Rajachidambaram and Krishnamurthy (1979) have observed abnormal stomata in affected coconut, turmeric, sugar cane and tamarind.

Varshney and Gang (1980) and Singh and Rao (1980) have recorded considerable reduction in leaf area, leaf bio mass, total biomass and chlorophyll content. Plants having pilose or pubescent leaf surface were reportedly more expressive of the above symptoms, compared to plants with glabrescent leaf surface. As reported by Singh and Rao (1980) there are qualitative and quantitative degradation in affected wheat grains.

Lal and Ambasht (1982) studying the impact of cement kiln dust on guava, observed considerable reduction in yield and energy content. Studies of Anda (1986) proved an increased radiation intake of polluted maize plants leading to a 16.20 per cent yield reduction. Sai _et al_. (1987) obtained the reduced crop yield in affected fruit trees strongly correlated with biometric observations.

2.7 Managing the polluted environment

The opinion of Parthasarathy _et al_. (1978) that soil amendments based on red soil do more good than those based on black soil should be based on the favourable change in pH in red soil. Investigation on amending the polluted soil with straw, farm yard manure and pig manure reveals improvement in soil physical properties of pollution affected soils (TNAU, 1979). Genetic studies by Feder (1978) suggests evolution of cultivars displaying a range of tolerance to gaseous and particulate atmospheric pollutants. Mitigating the pollutant's quantitative and qualitative effects in wheat grains using foliar urea spray was reported by Singh (1981). Observations on tolerance difference among different plant genera by Sreerangaswamy et al. (1973), Kubikova (1981) and Oblisami (1988) can also be utilised in pollution management, using such plants as pollution sink.

From this theoretical orientation, it was perceived that the micro level impact of the external diseconomy of an industrial establishment, remains very much an open question.

Location of the Study

LOCATION OF THE STUDY

The present study on the impact of cement-kiln dust on agriculture, pertains to the environs of the Malabar Cements Limited situated in Palghat district of Kerala. The district headquarters- Palghat lies at the north latitude of 10° 46' and east longitude of 76° 39' at 97 meters above mean sea level. The cement plant is located at Walayar 24 km north east of Palghat. A brief profile of the study area is given in this chapter. This would give an idea about the setting.

1. Pollution and its source

Malabar cements is the first portland cement manufacturing plant in the state, commissioned in February 1984, to utilise the minable reserves of Pandarathu Hills north of Palghat with a rated capacity of 1,200 tonnes of clinker a day. According to factory sources, about 30,000 tonnes of cement is being produced per month by the dry process - a four stage suspension pre-heater system-with control equipments like electrostati precipitator, gas conditioning towers, cyclonic and bag filters established at different stages of manufacture. According to Stern (1971) for a dry process plant of 1000 tonnes per day capacity, the dust loss can be of the order of 0.70 tonnes per day from the kiln alone. In the raw mill drying and grinding section, the loss can be as high as 1.52 tonnes per day for a plant of the same capacity. Dust loss from clinker grinding goes upto 0.05 tonnes a day. These values are arrived at after making use of dust collection equipments such as electrostatic precipitator. Thus dust particulate matter is the foremost pollutant of atmosphere in the vicinity. Norms for dust emission as per Central Pollution Control Board of India for cement plants with more than 200 tonnes per day capacity are 150 mg/Nm^3 for protected area and 250 mg/Nm^3 for other areas. The U.S. national air quality standards for particulate matter for an average time of 24 hours are 260 micro grams per m^3 (primary), 150 micro grams per m^3 (secondary) and 80-100 micrograms per m^3 (hazardous to human beings).

Cement kiln dusts are not exclusively cement dust, and are mostly suspended particulate matter of diameter 0.1 - 10 μ and particulates of more than 10 μ diameter.

Norms for emission of individual pollutants in cement-kiln dust are provided in appendix two.

2. Polluted area

The study was conducted in the environs of the cement factory, located in Walayar about 24 km north east of Palghat town, in the border area of the states of Tamil Nadu and Kerala (Area map given in page 30) Sahya ranges encircle the factory by far on the north and north eastern sides. The Palghat gap in the Western ghats brings and spreads the easterlies towards the south west direction during the months of November to March (Table 3:1 and Figure 3.2). The velocity and direction of easterlies contribute to the extent and intensity of cement kiln dust pollution the geographical coverage of which in Kerala includes two panchayats: Pudussery and Marutharoad. The almost denuded valleys of the nearby ranges house the limestone mines, a vast area of dry land shrubs and few inhabitants. Most of the inhabitants switched over helplessly to farming as the once dense forest (1196 ha as per the revised working plan for 1975-76 to 1984-85 of Palghat Forest division) ceased to be a source of livelihood. Now a strip of reserve forest extends scarcely upto three km towards the

FIG. 3.1 MAP OF PALGHAT DISTRICT.

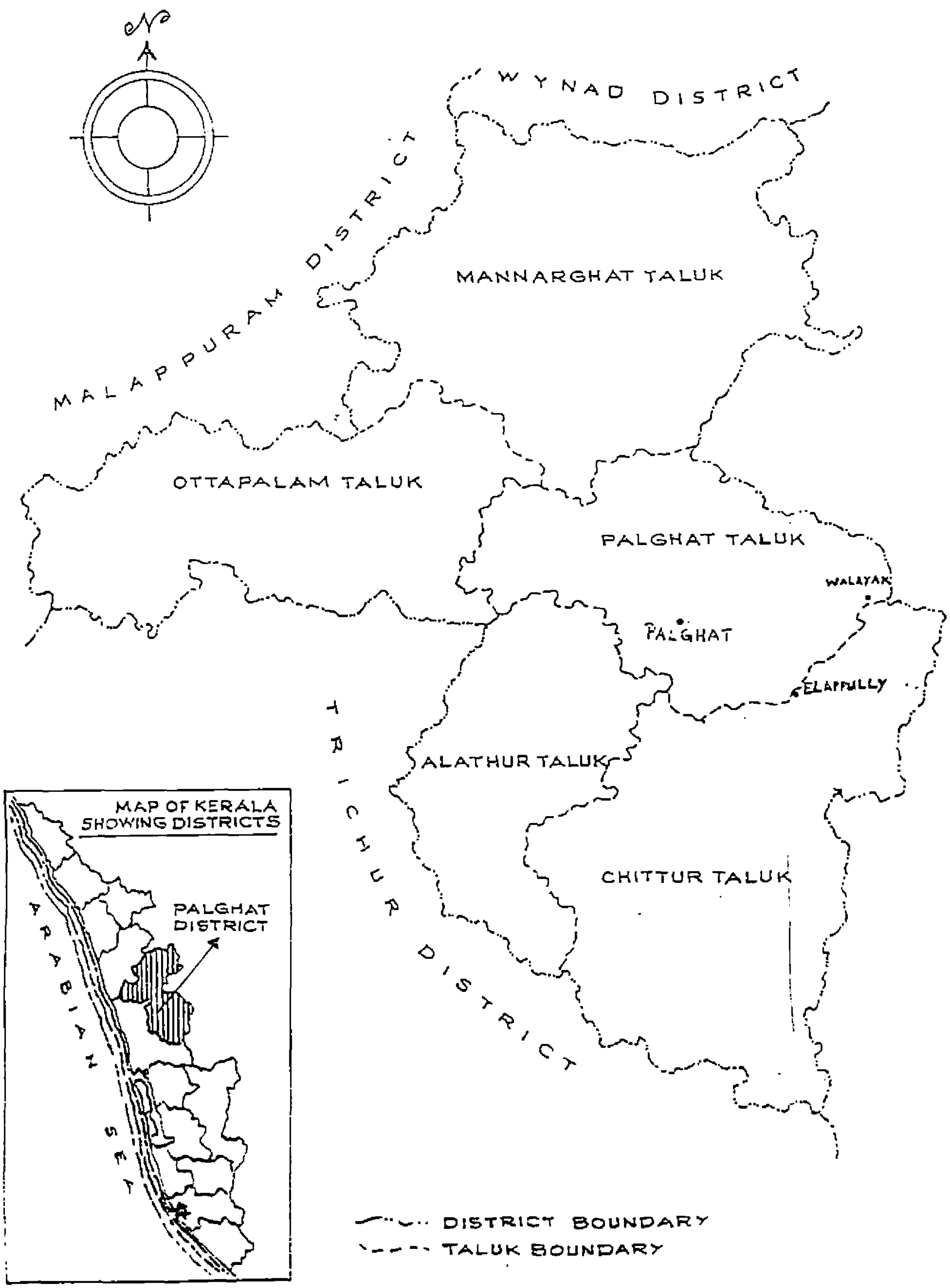
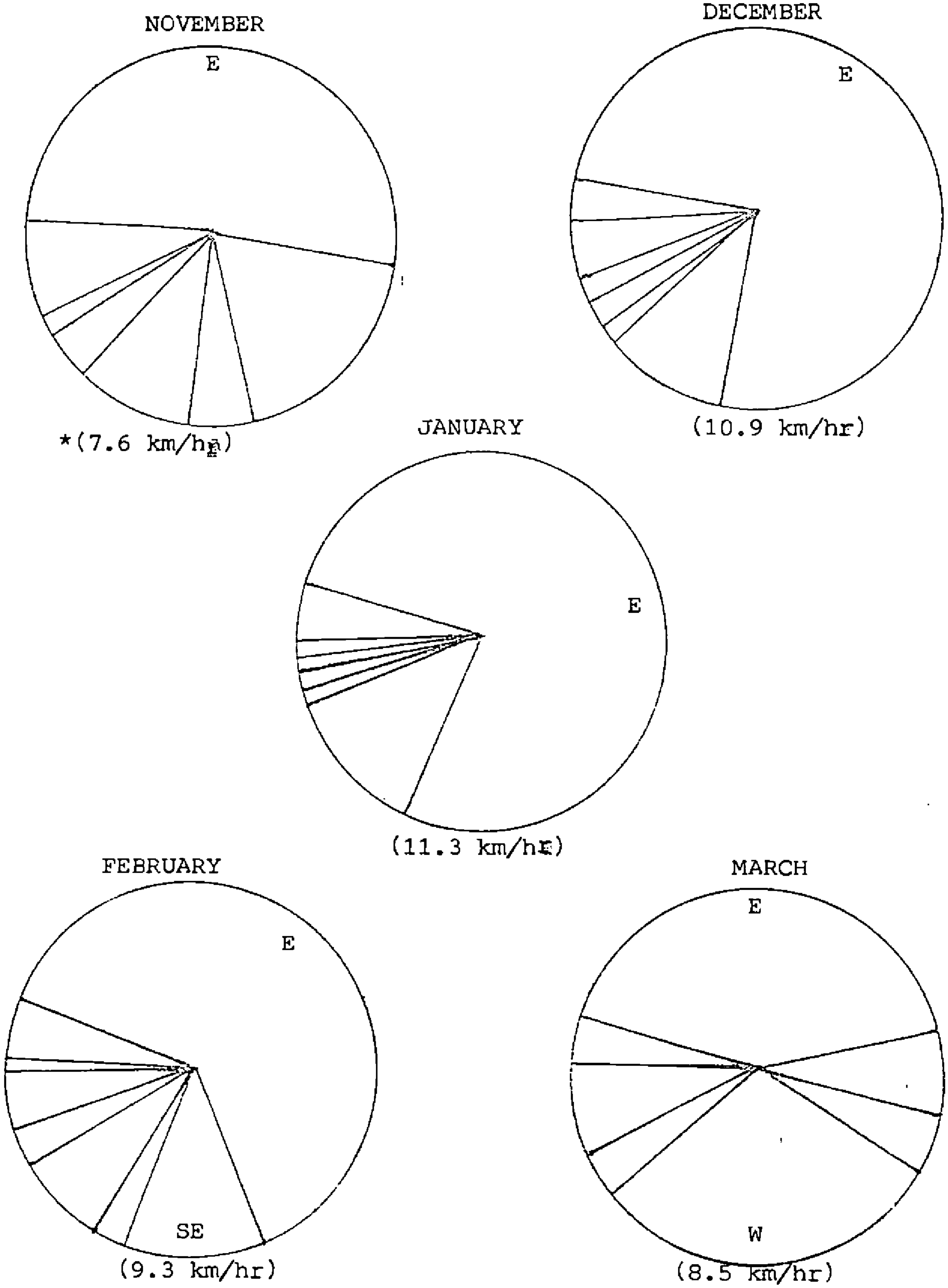


Fig.3.2 WIND DIRECTION DURING THE POLLUTED SEASON
(% No.of days wind from)



* Figures in parenthesis are mean wind speeds for the months

Table 3.1 Wind direction - Zone I (% No.of days of wind from)

	N	NE	E	SE	S	SW	W	NW	Calm
January	0	0	85	13	0	0	0	0	2
	0	9	72	11	0	1	3	2	2
February	0	2	70	14	0	1	6	0	7
	1	8	56	11	0	3	13	4	4
March	0	2	49	8	0	3	22	1	15
	0	6	36	6	0	7	37	6	2
April	0	1	14	4	0	9	55	4	13
	0	1	7	2	0	12	65	11	1
May	0	0	3	0	0	9	77	5	6
	0	0	0	0	0	18	71	10	1
June	0	0	0	0	0	16	77	6	1
	0	0	0	0	0	23	70	7	0
July	0	0	0	0	0	27	69	3	1
	0	0	0	0	0	28	67	5	0
August	0	0	0	0	0	29	69	1	1
	0	0	0	0	0	26	60	5	0
September	0	0	2	0	0	22	71	3	2
	0	0	0	0	0	28	67	5	0
October	0	1	18	6	0	8	48	7	12
	0	1	6	2	0	19	55	14	3
November	0	1	65	12	0	1	9	2	10
	0	3	39	8	0	6	29	9	6
December	0	0	83	13	0	0	0	0	4
	0	6	71	10	0	2	5	2	4

Source: IMD, Pune

west; thereafter farms and villages follow. Even large farm holders have a poor standard of living. Many of the villages are not yet electrified, nor are they connected with roads. The whole of Pudussery panchayat and parts of Marutharoad panchayat comprised the study area. Affected areas in Tamil Nadu are not subjected to study now, since the season of pollutant dispersal there does not coincide with that in areas coming under Kerala.

3. Control area

Para (Elappully) a village with almost similar cropping pattern, climate and soil as that of polluted area was selected to be the control. This area is free from pollution by cement kiln dust, due to its location which helps to escape the dust carrying winds. Tables 3.2, 3.3 and 3.4 furnish the basic informations, soil properties, and cropping pattern in both the polluted and control areas.

4. Climate and land use pattern

Meteorological factors as discussed in chapter two are important determinants of the impact of any

Table 3.2 Basic data on zones one and two

Sl. No.			Zone I		Zone II
			Pudussery	Marutharoad	Elappully
1	Total geographical area	(ha)	11548.66	856.00	4907.00
2	Total cropped area	(ha)	2890.40	838.80	4189.50
3	Area under forests	(ha)	1196.00	-	-
4	Irrigated area	(ha)	1540.20	622.40	793.00
5	Unirrigated area	(ha)	2027.80	202.40	1420.00
6	Sources of irrigation		Walayar dam, Eari	Walayar dam, Malampuzha dam	Walayar dam
7	Cultivable waste land	(ha)	364.00	10.40	N.A.
8	Uncultivable waste land	(ha)	280.00	4.80	N.A.
9	No.of effective farm families		1815.00	2354.00	7997.00

N.A. = Not available

Source: Offices of the Dept. of Agriculture, Kerala at Pudussery, Marutharoad and Elappully

Table 3.3 Soil properties in zones one and two

Sl. No.		Zone I		Zone II
		Pudussery	Marutharoad	Elappully
1	Soil pH (Mean)	6.65	5.50	6.35
2	Soil type	Laterite	Laterite	Laterite and black cotton
3	Total soluble salts (Electrical conductivity m mhos/cm)	0.33	0.10	0.23
4	Organic carbon (%)	0.45	0.93	0.48
5	Phosphorus (kg/ha)	29.57	60.40	62.28
6	Potassium (kg/ha)	270.85	137.00	242.70

Source: Offices of the Dept. of Agriculture, Kerala at Pudussery, Marutharoad and Elappully.

environmental contamination. The climatological tables (Table 3.5 and 3.6) present the prevailing values for various factors. Figure 3.3 giving nine-year time series data on rainfall suggests that, the decline in the annual precipitation was more consistent in the affected areas. As is evident from the Table 3.2, the proportion of area under crops and number of effective farm families were relatively low in Padussery Panchayat, which lies nearest to the source of emission. Groundnut, vegetables, maize, coconut, paddy, cotton and sugarcane were the main cultivated crops. The cropping pattern, soil characteristics and other basic data are provided in Tables 3.2 - 3.4. Farming in the area was mostly rainfed and dryland, except for some pockets where water was available for irrigation. Walayar dam, a major source of irrigation in the area, does not cater to the needs of even nearby fields for the past five to six years as reported by the informants. Orchards of Mango, cashew and tamarind also were sources of income. Millets like ragi, maize and jowar formed part of the cropping pattern, raised mostly for domestic consumption. Notable difference was absent in the varieties grown in zone I and zone II.

Fig. 3.3 RAINFALL PATTERN

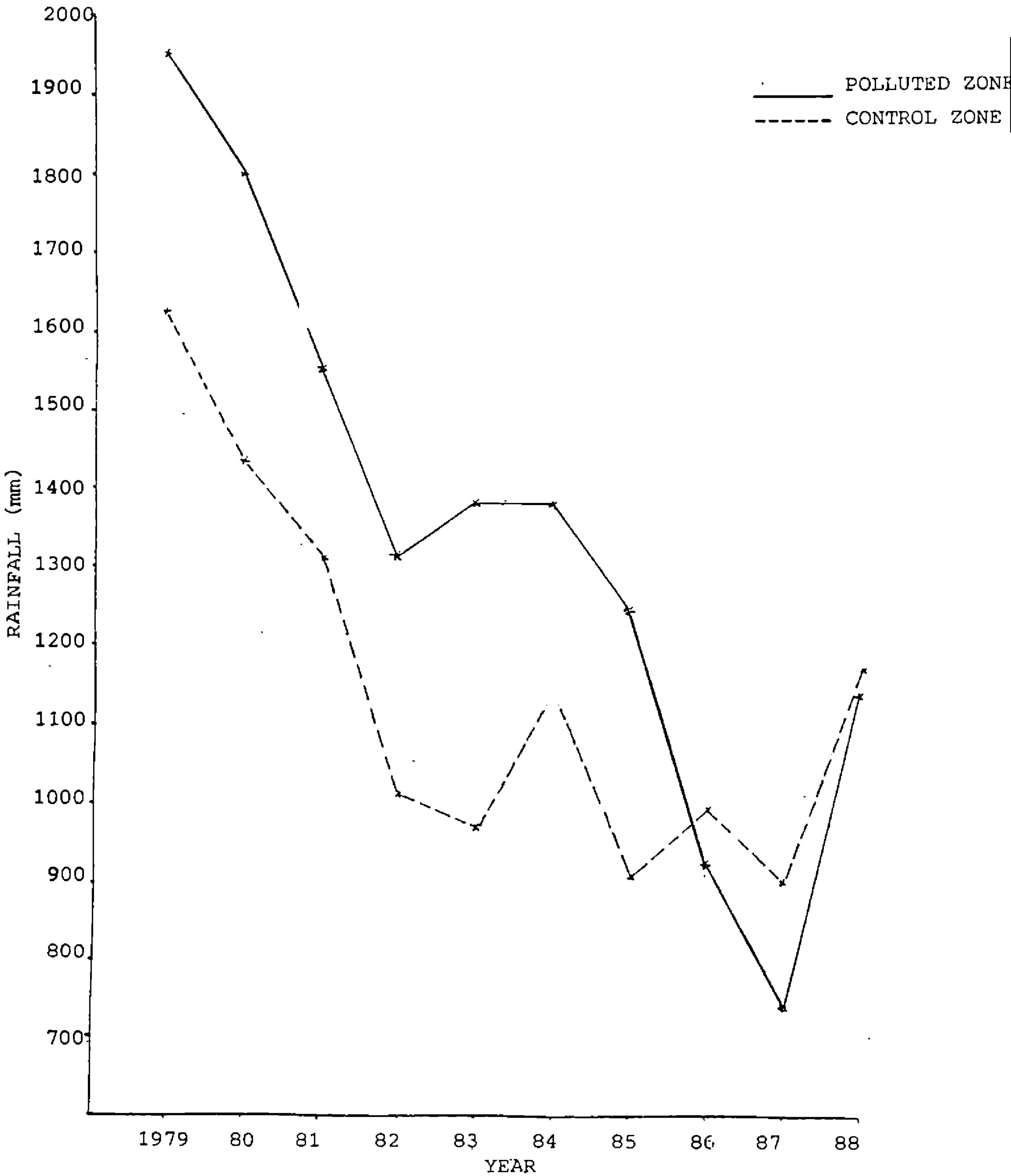


Fig. 3.3 RAINFALL PATTERN

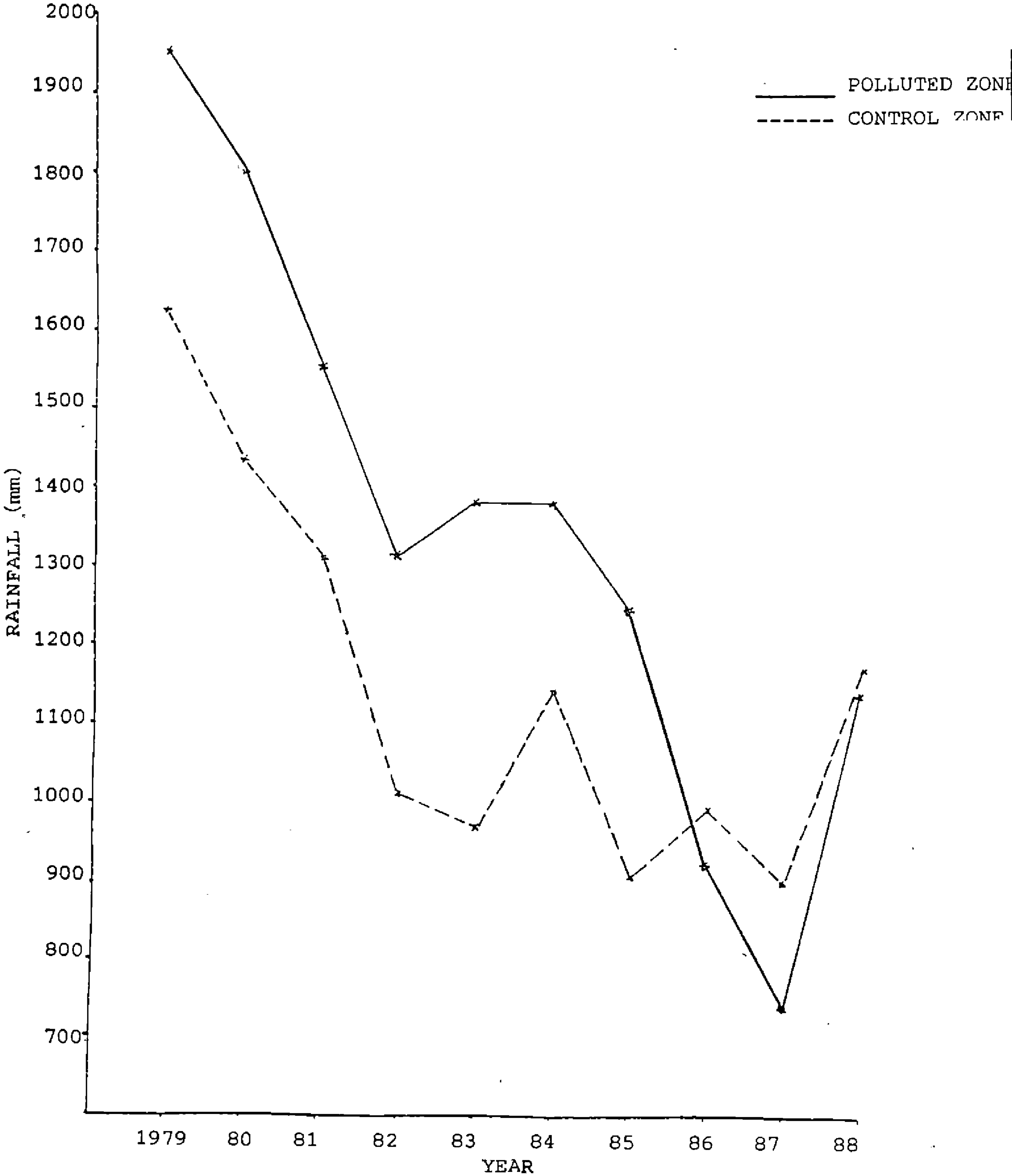


Table 3.4 Cropping pattern in zone one and zone two

Sl. No.		Zone I		Zone II
		Pudussery	Marutharoad	Elappully
1	Total cropped area (ha)	2390.40	888.80	4189.50
2	Area under major crops (ha)			
	Paddy (virippu)	1468.00	714.00	1422.00
	Double cropped paddy lands	1238.00	622.40	300.00
	Groundnut (April sown)	286.00	Nil	560.00
	Groundnut (November sown)	313.20	Nil	730.00
	Coconut	126.80	75.60	500.00
	Sugarcane	78.00	1.50	156.00
	Pulses	63.60	7.20	800.00
	Vegetables	16.80	30.50	2.50
	Cotton	18.00	Nil	8.00
	Others	20.10	9.20	11.00

Source: Offices of the Dept. of Agriculture, Kerala at Pudussery, Marutharoad and Elappully.

Table 3.5 Climatological table for zone II

Month	Maximum temperature (°C)	Minimum temperature (°C)	Evaporation (mm)	Wind velocity (km/)	Rainfall (mm)
January	40	19	8-12	8	Nil
February	36	18	8-16	12	10.0
March	39	21	16-26	12	3.0
April	40	23	18-44	20	17.0
May	38	23	0-26	12	50.0
June	36	20	Nil	15	254.7
July	33	21	Nil	15	244.3
August	33	20	Nil	17	277.5
September	33	21	-	10	20.0
October	35	21	4-8	10	41.3
November	32	18	13	8	58.1
December	33	15	11-14	12	21.0

Source: ISD Farm, Eruthempathy

Methodology

METHODOLOGY

This study on the economic impact of cement kiln dust is based mainly on a sample survey of farmers from the polluted area and from a control area. This chapter is devoted to the explanation of the sampling procedure, nature of data collection and the methods adopted for analysis.

1. Sampling

The stretch of land upto 20 km from Walayar towards Palghat with one to two km width was divided into seven regions - first five of two kilometers each and the last two of five kilometers each. This was done to have more number of observations from the initial 10 kms, because as per other impact studies on cement kiln dust, the environmental contamination due to cement kiln dust was expected to be intensive upto a maximum of 10 km from the source of emission.

The list of cultivators for each of these regions obtained from the offices of the Department of

Agriculture, Government of Kerala located in Pudussery, Marutharoad and Elappully was used as the sampling frame. One to seven regions constitute the first zone, while the second zone (Eighth region) stands for the control. Fifteen farmers from each of these seven regions and twenty farmers from the control area were selected by simple random sampling, avoiding those who had undertaken any transfer of property in the period from 1983-84 to 1986-87.

2. Data collection

Selected farms in the polluted and control regions were surveyed during 1987-89, using a well structured and pre-tested interview schedule. The schedule (Appendix 3) was prepared after referring to pollution injury chart and Saroad format used in National Crop loss Assessment Net work Statement of United States Environmental Protection Agency (Stern, 1971), and several socio economic questionnaires. While evaluating the symptoms of effect of pollution on crops, any identifiable and measurable response of a plant to pollution is termed injury. Damage refers to identifiable and measurable adverse effects upon the desired or intended use of plant or it's produce.

3. Quantifying the foliar deposit

The quantum of particulate pollutant deposited on different crops was determined with the view to assess the extent of pollution in the wind-ward side of the plant and to include the pollutant load as an explanatory variable in regression analysis. This was done on the basis of estimates of foliar deposit on a representative sample of plants.

The selected and marked representative number of plants in the farmer's field were initially washed off the dust. A rain-free period of ten days was given before collection of leaves. Leaves or leaflets were collected at random with minimum disturbance, from the selected plants from major crops at different distances from the factory. The sampling plots were located in areas away from roads to avoid dust arising from traffic. The samples were transported in clean polythene bags to the lab, where the pollutant was washed off into dry, clean and weighed silica crucibles using a small brush with minimum distilled water. The washed samples were kept in hot air oven at 105°C until moisture-free,cooled and recorded the weight of the dust. The area of leaves were calculated using graph paper and the dust deposit per unit area was arrived at.

4. Economic and statistical tools of analysis

From the models discussed in chapter two, a classified treatment of environmental externalities was found to be a realistic application of analysing how external effects originate from economic behaviour, and influence economic behaviour in their turn through the environment.

Confining to the case of crop enterprises, the impact of pollution, if any, could be assessed from a spatial and temporal analysis of variations in cultivated area and crop yield/ha in both the polluted and control zones. It could be reasonably assumed that crop production in the region had no adverse impact on the environment. Temporal comparison was made between the year of commencement of cement production (1983-84) in the plant and the year previous to the study (1986-87). Farm incomes for the above mentioned years were compared at constant price level. Spatial differences in cropping intensity, crop yield and farm income were tested with analysis of variance and compared with the control area. Variations in the above parameters should be explained by different causitive factors including pollution. Linear production functions of the form $Y = f(X_1, X_2 \ldots . X_n)$ were fitted with X_1 to X_{n-1} standing for the imputs needed and X_n standing as a proxy for pollution. X_n was not relevant in the control zone. The foliar deposit of cement kiln dust could not be included in regression analysis, as a mechanically weighable quantum of deposit could not be obtained after six km SW of the factory.

Linear multiple regression equations were fitted, with the following variables.

A) Y = Yield per hectare (kg/ha or Nos./ha)

X_1 = Input of seed (kg/ha)

X_2 = Labour (Mandays/ha)

X_3 = Fertilizer consumption (Rs./ha)

X_4 = Irrigation (Rs./ha)

X_5 = Plant protection (Rs./ha)

X_6 = Distance from the factory (km)

B) Y = Farm income/ha for 1986-87 (Rs. '000)

X_1 = Cropping intensity

X_2 = % of gross cropped area under paddy

X_3 = % of G.C.A. under-ground nut

X_4 = % of G.C.A. under vegetables

X_5 = % of G.C.A. under other seasonals

X_6 = % of G.C.A. under coconut

X_7 = No.of trees/ha of other perennial crops (Cashew, tamarind, mango).

X_8 = Distance from the plant (km)

After obtaining the best fit between the dependent and explanatory variables, step-wise analysis was attempted to arrive at the best subset of variables and their relative effects, eliminating the unimportant ones (Draper and Smith, 1966). Multiple regression and stepwise regression analysis were carried out taking the observations for the first and second zones as separate sets of data.

An estimate of crop loss due to cement-kiln dust if any can be obtained from the mean loss in yield compared to the control area and the area affected under the concerned crop.

Results & Discussion

RESULTS AND DISCUSSION

The data collected by interviewing the selected sample farmers in their farms were consolidated and tabulated. The tabulated data were analysed using the tools discussed in chapter three, in order to understand the socio-economic environment in the study area and the repercussions of cement kiln dust on agriculture in comparison with the control. Accordingly, the results are grouped into four sections. The socio-economic situation is taken up in the first. The next two sections deal with the impact of cement kiln dust on agriculture, which are followed by a brief section on suggestions for future research in the field. All along the discussion, one to seven regions constitute the first zone (polluted) while the eighth-region stands for the second zone (control).

1. The socio-economic environment

1.1 Family size

Distribution of the respondent families on the basis of number of members (Table 5.1) showed a maximum frequency in the size group five to seven for both the polluted and control zones, coming upto

Table 5.1 Distribution of respondent families on the basis of size

Family size (No.of members)	Zone I		Zone II		Total	
	No.	Per cent	No.	Per cent	No.	Per cent
2 - 4	33	31.43	4	21.74	37	29.60
5 - 7	62	59.05	13	65.22	75	60.00
8 - 10	9	8.57	3	13.04	12	9.60
Above 10	1	0.95	-	-	1	0.80
Total	105	100	20	100	125	100
Average family size	5		6		5.5	

59.05 per cent and 65.22 per cent respectively. The next highest frequency was obtained for the size group two to four in both the polluted (31.43 per cent) and control (21.74 per cent) zones. The minimum frequency in both the zones accrued to the family size above ten. The average family size for the polluted zone was five. For the control area, it was six.

1.2 Age

Age group classification of respondent farmers (Table 5.2) revealed that a majority of the respondents belonged to the group of 31 to 41 years, in both the zones. The least of the frequencies corresponded to the age group 21 - 31 in zone one and above 60 in zone two. For the polluted zone average age of informants was obtained as 45 years and for the second zone it was 42 years.

1.3 Education

Distribution of family members of respondents on the basis of education (Table 5.3) indicated that 9.85 per cent in the polluted zone and 12.88 per cent in the control were illiterate. Maximum frequency accrued

Table 5.2 Age-group classification of respondents

Age in years as on Dec. 30, 1988	Zone I		Zone II		Total	
	No.	Per cent	No.	Per cent	No.	Per cent
21 - 31	2	1.90	3	13.04	5	4.00
31 - 41	43	40.95	7	34.79	50	40.00
41 - 51	27	25.71	6	30.43	33	26.40
51 - 60	23	21.90	3	13.04	26	20.80
Above 60	10	9.54	1	8.70	11	8.80
Total	105	100	20	100	125	100
Average age	45		42		42.5	

Table 5.3 Distribution of family members of respondents on the basis of education

Educational status	Zone I		Zone II		Total	
	No.	Per cent	No.	Per cent	No.	Perccent
0-5 age group	35	7.66	20	15.15	55	9.34
Illiterate	45	9.85	17	12.88	62	10.53
Primary School	140	30.63	37	28.03	177	30.04
Middle School	130	28.45	37	28.03	167	28.35
High School	95	20.78	17	12.88	112	19.02
Under graduate	10	2.19	3	2.27	13	2.21
Graduate	2	0.44	1	0.76	3	0.51
Total	457	100	132	100	589	100

to those educated upto primary school level in both the zones: 30.63 and 28.03 per cent in zone one and two respectively. Graduates were only 0.44 per cent in the first zone and 0.76 per cent in the second.

1.4 Occupation

Table 5.4 presents the occupational classification of respondents. More than 57 per cent of the respondents in the polluted area and 39 per cent in the control were engaged in agriculture alone. The comparatively lesser importance of service and business sectors in the polluted zone reflects the apparently low absorption of indigenously available labour to the industries located here. The first zone houses 22 small scale and four large scale industrial establishments

1.5 Holding size

Marginal land holders were 31.42 per cent and 47.84 per cent in the first and second zones respectively. Small farmers constituted 33.34 per cent in zone one and 26.08 per cent in zone two. Nearly 24 per cent of the informants in the first zone and 15 per cent in the second zone owned holdings of size two to three hectares.

Table 5.4 Occupation-wise distribution of the respondents

Occupation	Zone I		Zone II		Total	
	No.	Per cent	No.	Per cent	No.	Per cent
Agriculture alone	60	57.14	8	39	68	53.97
Agriculture + Service	35	33.33	7	35	42	34.30
Agriculture + Business	10	9.53	4	22	14	11.72
Agriculture + Business + Service	-	-	1	4	1	0.01
Total	105	100	20	100	125	100

Holders of more than three hectares of land came upto 11.43 per cent in zone one and 10 per cent in zone two (Table 5.5). This has to be considered against the average holding size for the state: 0.43 ha.

1.6 Value of assets

Tables 5.6 and 5.7 furnish the values of assets per farm and per hectare in the study area. The value (in Rs. '000) of assets possessed per farm ranged from 186.13 (region one) to 603.96 (region seven) averaging to 325.04. In the control area it averaged to 300.00. In all assets, except livestock and farm implements, the seventh region averaged to the highest value, while the lowest value accrued to the first region. The value of assets per hectare (in Rs.'000) ranged between 109.78 (region one) and 288.05 (region seven) averaging to 177.17. Control region had an average value of assets per hectare of 175.70 (Rs.'000). Here too except for the livestock and farm implements, the highest value could be attributed to the seventh region and lowest to the first one. About 72 per cent of the value of assets in the first three regions of the polluted zone was constituted by agricultural assets.

Table 5.5 Distribution of respondents on the basis of holding size

Holding size (Ha)	Zone I		Zone II		Total	
	No.	Per cent	No.	Per cent	No.	Per cent
Below 0.5	5	4.80	4	20.00	9	7.82
0.5 - 1	28	26.62	6	30.00	34	26.56
1 - 1.5	15	14.29	2	10.00	17	14.06
1.5 - 2	20	19.05	3	15.00	23	17.97
2 - 2.5	15	14.29	2	10.00	17	13.28
2.5 - 3	10	9.52	1	5.00	11	8.59
More than 3	12	11.43	2	10.00	14	11.72
Total	105	100	20	100	125	100

Table 5.6 Value of assets per farm (Rs. '000) in different regions

Assets	I	II	III	IV	V	VI	VII	VIII
Land	133.36	133.80	195.23	189.80	351.93	238.60	493.40	229.07
Building	40.80	42.67	55.43	64.80	61.81	60.53	80.87	54.65
Irrigation structures	2.72	3.56	3.63	4.77	5.41	3.31	7.77	3.90
Livestock	2.42	2.14	3.97	2.74	4.81	1.69	4.28	6.37
Farm implements	0.86	2.61	0.63	3.58	0.63	0.42	2.34	0.55
Household articles	3.97	5.76	6.32	3.83	7.68	5.56	15.30	5.56
Total	186.13	200.54	265.21	269.52	432.27	310.11	603.96	300.10

Table 5.7 Value of assets per hectare (Rs. '000) in different regions

Assets	I	II	III	IV	V	VI	VII	VIII
Land	80.26	80.60	107.80	105.40	158.53	204.30	239.68	134.11
Building	23.81	25.70	30.12	36.00	27.84	33.29	36.00	32.00
Irrigation structures	1.59	2.14	1.97	2.65	2.44	2.42	3.46	2.28
Livestock	1.41	1.29	0.34	1.52	2.17	1.37	1.78	3.73
Farm implements	0.39	0.37	0.34	0.52	0.28	0.34	0.32	0.32
Household articles	2.32	3.47	3.43	6.80	3.46	4.53	6.81	3.26
Total	109.78	113.57	144.00	152.78	194.72	246.55	288.05	175.70

The same was 49 per cent in the control zone. Evidently the assets in the polluted zone were characterized by low value and relative illiquidity.

1.7 Family income

Distribution of respondent farmers on the basis of family income is presented in Table 5.8. In the polluted zone, 42.86 per cent of the sample farmers were having an annual family income between Rs. 5000 and Rs. 15,000/= and 39.13 per cent of the farmers in the control zone also were having the same range of income. The lowest frequency was observed to be for the income group upto Rs. 5000 amounting to 13.34 per cent and 17.39 per cent in the first and second zones respectively.

Mean annual income (Rs.'000) per animal of livestock ranged between 1.99 (region one) to 5.22 (control). Health care cost varied from Rs.46.67 (fifth region) to Rs.84.33 (third region) as given in Table 5.9. Sreerangaswami and Padmanabhan (1981) have reported abdominal disorders among cattle fed by fodders dusted with cement kiln dust. In the study area 22 per cent of the livestock owners complained about a cough spreading among the stock in the polluted

Table 5.8 Distribution of respondents on the basis of family income

Family income Rs./annum	Zone I		Zone II		Total	
	No.	Per cent	No.	Per cent	No.	Per cent
Upto 5000	14	13.34	3	17.39	17	14.27
5000 - 15000	45	42.86	8	39.13	53	42.40
15000 - 25000	23	21.90	3	17.39	26	20.08
More than 25000	23	21.90	6	26.09	29	23.25
Total	105	100	20	100	125	100

Table 5.9 Income from livestock in different regions

	I	II	III	IV	V	VI	VII	VIII
Mean annual income/ animal (Rs.000)	1.99	1.84	3.19	3.82	5.01	3.14	4.37	5.22
Health care cost/ annum per animal (Rs.)	65.00	60.20	84.33	70.00	46.67	55.00	55.60	58.90

zone and reluctance among their cattle to consume dusted fodder. Some of them have already evaccuated the severely polluted regions with their livestock, leaving the farm lands in the polluted area.

1.8 Liability

Per farm liability showed a mixed trend along the regions one to seven though it decreased consistently in five to seven regions. Liability per farm was a maximum in the control and a minimum in the seventh region. However, liability per hectare was a maximum in the third region and a minimum in the seventh region. Reading from Table (5.10), which gives the liability situation in different regions, there was a mixed trend, upto the fifth region, and the regions five to seven had shown a consistent decline. Liability (Rs.'000/ha) averaged to 1.86 and 2.15 in the first and second zones respectively. Nearly 68.70 per cent and 49.75 per cent of the liability in the polluted and control zones respectively were comprising of overdues. Out of the total liability, 55.19 per cent was from co-operatives in the first zone, while the control area had a contribution of 70.5 per cent, from the co-operatives. The role of commercial banks came to an extent of 17.65 per cent

Table 5.10 Liability (Rs.'000) in different regions

	I	II	III	IV	V	VI	VII	VIII
Liability per farm	2.81	2.54	4.63	3.99	5.27	2.80	1.05	6.12
Liability per ha	1.64	1.53	2.53	2.22	2.39	2.28	0.46	2.15
Percentage of total liability from								
1. Co-operatives	48.88	35.75	74.26	26.30	79.52	60.60	61.00	70.50
2. Commercial banks	33.21	20.59	18.37	22.72	2.05	16.38	10.00	10.00
3. Other sources	17.91	43.66	7.37	50.98	18.43	23.02	28.00	19.50

in the polluted zone and 10 per cent in the control. Credit forwarded from other sources came upto 27.05 per cent in the first zone and 19.50 per cent in the control. The backwardness of the second and fourth regions in the polluted zone is indicated by the over dependence on non-institutional credit sources.

The poor worth of the relatively illiquid assets possessed, and heavy liability largely comprising of overdues disclose the relatively larger number of economically weaker population in the polluted zone. This is in line with the argument by Dorfman and Snow (1975).

1.9 Cropping intensity and foliar deposits of cement kiln dust

Taking into consideration the results of studies by Sreerangaswamy *et al*. (1973) and Kubikova (1981), the particulate deposits of cement kiln effluents were expected to influence the eco types of local flora and hence the cropping intensity too. An attempt is made here to relate farm income to pollution through cropping intensity. Quantification of the pollutant was done as per the method described in section three of chapter four. Table 5.11 furnishes the foliar deposits of cement kiln dust at different distances in the wind-ward side of the plant. Referring to figure 5.1 and Table 5.11, a conclusion cannot be drawn in this regard, because in general cropping intensity decreased with distance. It was higher where affected coconut areas formed considerable part of cropping pattern which did not contribute to farm income. The deposit on foliage (0.17 to 4.4 mg/cm^2/10 days) was not quantifiable after six kilometers. The collection period (January-February, 1988) coincided with paddy harvest, and the representative number of plants required could not be achieved in paddy. In a given area, the foliar dust deposit varied among plant species according to phyllotaxy and nature of leaf surface. Therefore this cannot be taken as representative of pollution in the area. Since air quality monitors were not available, distance had to be taken as proxy for pollutant load, based on observations of Sreerangaswami and Padmanabhan (1981) and Rethinam et al. (1987) regarding increased deposits nearer to the source of emission.

1.10 Irrigation

As mentioned in the description of the location, the sources of irrigation included two major irrigation

Table 5.11 Foliar deposit of cement kiln dust ($mg/cm^2/10$ days)

Distance (km) from the plant (South West)	Banana	Brinjal	Cashew	Coconut	Cotton	Green gram	Ground nut	Guava	Mango	Teak	Tomato
1.50	4.40	2.85	0.25	0.86	1.35	1.59	0.17	2.65	0.75	-	1.92
3.00	1.76	-	0.28	0.75	-	1.43	0.17	4.20	-	1.96	1.94
4.50	1.14	0.71	0.25	0.72	1.11	1.02	0.18	-	0.70	0.36	1.05
6.00	0.74	-	-	0.72	-	-	-	0.72	-	-	-

projects. However, the first two regions in zone one met their requirement of irrigation through minor sources. Water scarcity was closer to drought for a longer time of the year in region three, four and eight. Reading from Table 5.12, 49.07 per cent of the total area in zone one and 34.04 per cent in zone two were irrigated by various sources.

2. Impact of cement kiln dust on agriculture

For each of the important crops in the locality, variations in cultivated area over the years since the inception of contamination by cement kiln emissions, are assessed first. If the area under a crop in a given region is determined by market, consumption pattern, price, climate and crop yield, and if the first four had uniformity of variation in both the control and the polluted zones, the major contribution had to be derived from yield fluctuations. Analysing the factors, based on which yield variations occurred, influence of cement kiln dust on cultivated crops, if any, can be confirmed. Price level taken on a uniform base - year and other things remaining the same, yield fluctuations explained the behaviour of agricultural income from unit area of cropped land.

FIG.5.1 CROPPING INTENSITY AND FARM INCOME IN THE POLLUTED ZONE

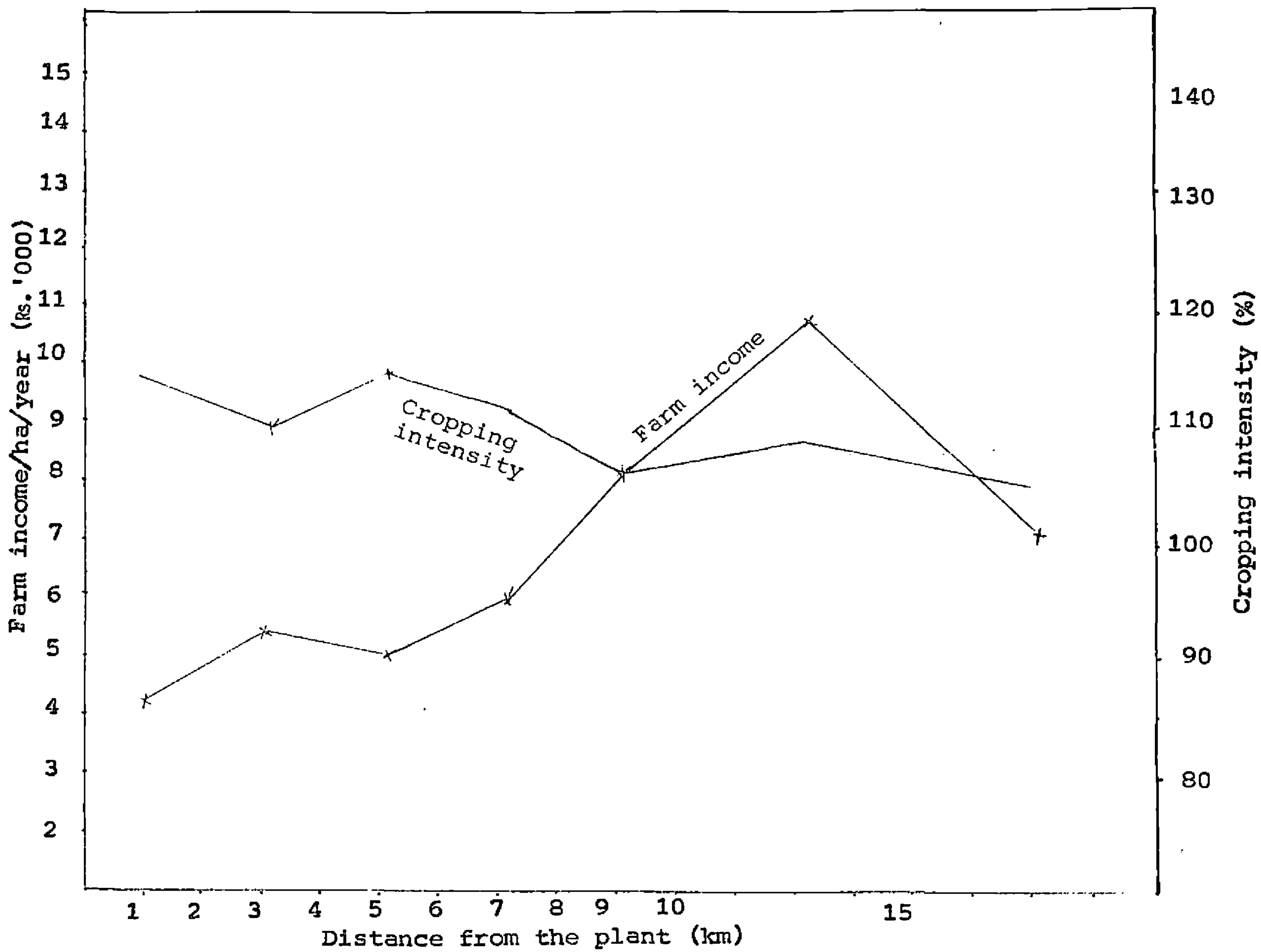


Table 5.12 Irrigated and unirrigated area in the sample holdings (Ha)

Status of irrigation	Area in ha: Zones I	Area in ha: Zones II	Area in ha: Total	Percentage to the total area: Zones I	Percentage to the total area: Zones II	Percentage to the total area: Total
Irrigated	93.57	13.36	106.93	49.07	34.04	46.51
Unirrigated	97.10	25.89	122.99	50.93	65.96	53.49
Total	190.67	39.25	229.92	100	100	100

2.1 Paddy

2.1.A Area

Table 5.13 and 5.14 present the area under and yield of paddy for different regions. Studying the temporal (1983-84 to 1986-87) variations regarding area under paddy, it became apparent that, the percentage to gross cropped area of double cropped paddy lands declined by 35.31 per cent and 4.90 per cent in the polluted and control zones respectively. The polluted season coincided with the second crop of paddy. The profound change in second crop paddy area emerged from comparison of the above with the fact that there was only a 10.55 per cent decline and 2.81 per.cent increase in the area under first crop of paddy for the above two zones. The first crop is called virippu and the second crop mundakan in local parlance. The maximum and minimum average area of paddy per holding corresponded respectively to the seventh and second regions, for both the crops. The highest temporal decline in percentage of paddy (first crop) to the gross cropped area was 14.71 pertaining to region one, while the lowest of 1.12 was for the seventh region (Table 5.13). As indicated by Table 5.14, percentage of paddy (second crop) lands to gross cropped area had the deepest decline in the third region (38.39 per cent) and the least decline (3 per cent) in the seventh, of the first zone.

In accordance with the above, changes were found to be unfavourable towards the polluted season and regions. However, minor variations contrary to the general behaviour among the regions could also be noted. This can be linked with accessability to irrigation through minor sources in the initial regions and a branch canal of Malampuzha project in the last two regions of the first zone.

2.1.B Yield

Mean yield of paddy in tonnes/ha showed a decline of 11.73 per cent and 15.51 per cent (over the period 1983-84 to 1986-87) for the first and second crops in the polluted zone. The same were 18.97 per cent and 8.06 per cent for the control. It can be inferred thereon that there was a divergence in yield variation of the second crop in the polluted zone, both with respect to the control and to the first crop. If the control had an yield 2.51 per cent lower to that of the polluted zone for the first crop, for the second crop it had a 19.56 per cent higher yield level than the first zone indicating that the crop yield was at disadvantage in the polluted season (second crop) when studied against the control.

Analysis of variance of paddy yield for both the crops suggested significance but it could be perceived from a higher F value (Table 5.15 and 5.16) that it was more conspicuous for second crop. The first three regions were significantly different from the rest of them. For nearly 600 ha of affected paddy lands in these regions, a loss of 19.56 per cent was estimated, accounting for a loss of 268 tonnes of paddy. Taniyama _et_ _al_. (1979) has reported loss in paddy yield ranging from 0.06 to 25.22 per cent due to cement kiln dust deposit of one to five grams per plant.

It is apparent from Tables 5.13, 5.14 and Figure 5.2 that although the decrease in yield for the second crop with respect to the first one was a generality among regions in the polluted area, it was more pronounced in regions nearer to the source of emission. However, freedom from severe dust deposits and sufficient facilities for irrigation enjoyed by the last two regions of the polluted zone, made their yield performance even better than the control.

Fig.5.2 PRODUCTIVITY OF PADDY - FIRST AND SECOND CROPS - IN THE POLLUTED ZONE

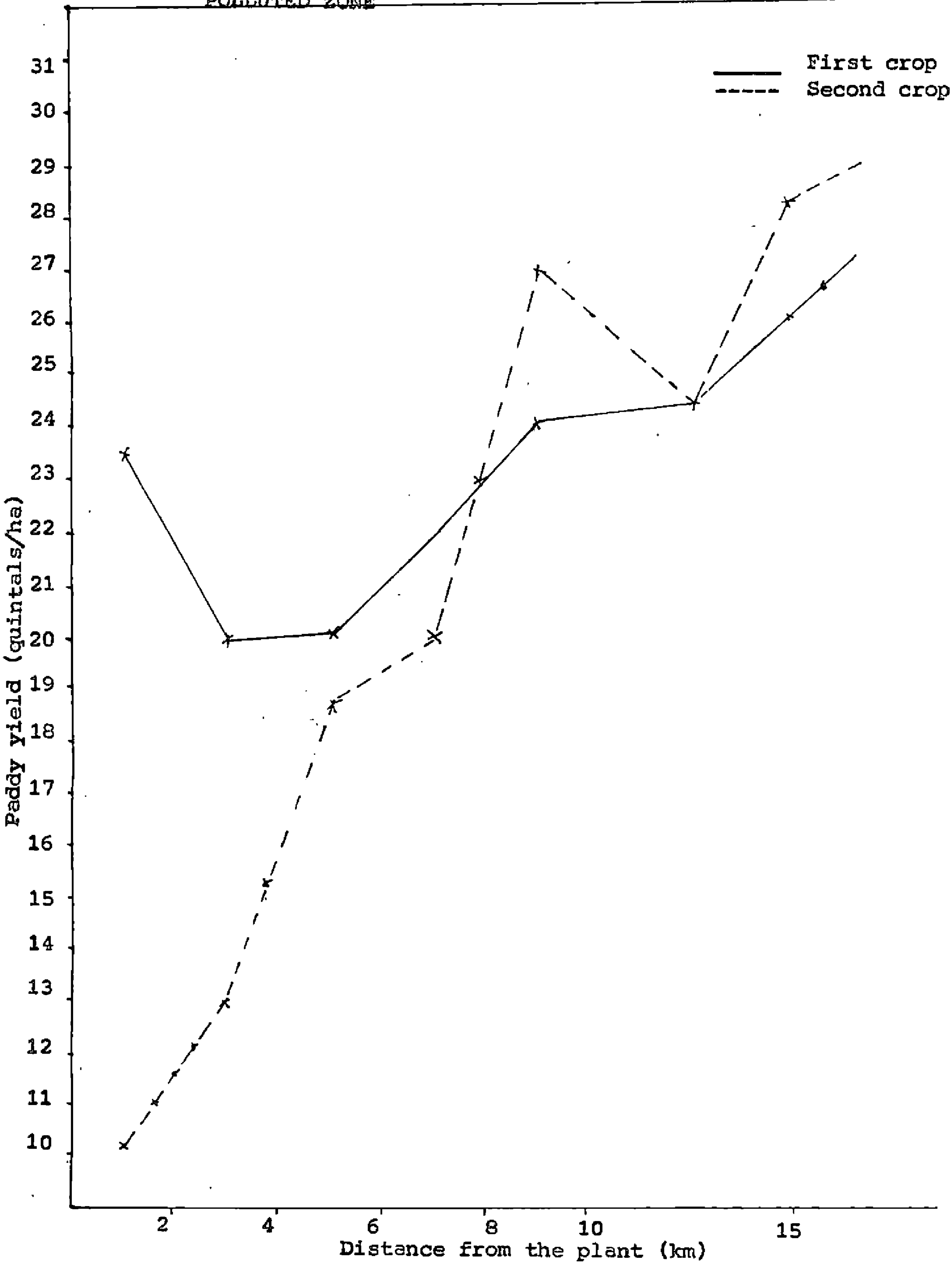


Table 5.13 Cultivated area and productivity of paddy - Virippu in different regions

	I		II		III		IV	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Average area per holding (ha)	1.45	0.64	0.67	0.33	1.75	1.37	1.68	1.25
Per cent to the G.C.A.	36.50	21.79	32.58	21.28	62.60	58.94	66.69	55.49
Mean yield in tonnes/ha	2.80	2.35	2.25	2.00	2.70	2.01	2.63	2.20

	V		VI		VII		VIII	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Average area per holding (ha)	1.72	1.55	1.25	1.05	2.87	2.75	1.04	1.09
Per cent to G.C.A.	61.75	59.36	69.26	65.43	89.90	88.78	59.45	61.12
Mean yield in tonnes/ha	2.60	2.40	2.40	2.40	3.50	3.30	2.90	2.35

Table 5.14 Cultivated area and productivity of paddy (mundakan) in different regions

	I		II		III		IV	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Average size per holding (ha)	0.59	0.29	0.20	0.08	0.68	0.36	0.61	0.35
Per cent to G.C.A.	27.93	17.12	29.15	16.09	53.99	15.60	32.20	27.90
Mean yield in tonnes/ha	2.00	1.02	1.80	1.30	2.52	1.81	2.20	2.00

	V		VI		VII		VIII	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Average size per holding (ha)	0.44	0.34	0.49	0.33	0.84	0.84	0.17	0.15
Per cent to G.C.A.	35.46	23.42	39.48	32.29	33.24	30.24	14.28	13.58
Mean yield in tonnes/ha	2.80	2.75	2.41	2.42	3.17	3.40	2.48	2.28

Table 5.15 Analysis of variance - Paddy yield (Mundakan)

Source	D.F.	S.S.	M.S.S.	F.
Between regions	7	36.56	5.22	29.28**
Within regions	99	17.66	0.18	
Total	106	54.22		

** Significant at one per cent level of probability.

Table 5.16 Analysis of variance - Paddy yield (Virippu)

Source	D.F.	S.S.	M.S.S.	F.
Between regions	7	7.58	1.08	4.82**
Within regions	72	16.22	0.23	
Total	79	23.80		

** Significant at one per cent level of probability.

The variables selected for multivariate analysis were

y = yield (quintals/ha)

x_1 = Input of seeds (kg/ha)

x_2 = Mandays/ha

x_3 = Fertilizers (Rs./ha)

X_4 = Irrigation (Rs./ha)

X_5 = Plant protection (Rs./ha)

x_6 = Distance from the source (km) of pollution.

It is candid from Table 5.17 that out of the six independent variables selected, only the distance from the factory was significant in explaining variance in paddy yield in the first zone. When the six variables together accounted for 78.55 per cent of response variation, the distance factor alone could explain 77 per cent of it as per the result of a step wise regression (equation: 5.1).

$$y = 15.60 + 1.10\, x_6 \quad (R^2 = 0.77): 5.1$$
$$*(0.063)$$

The regression coefficient b_6 (1.103) depicts a more than one unit increase in yield for a unit increase in distance from the cement plant.

*Figures in parenthesis are standard errors of regression coefficients of corresponding variables.

Table 5.17 Results of multiple regression of paddy yield on (Zone I) selected independent variables

Independent variable	Regression coefficient (b)	Standard Error	T value
	Intercept = 11.896		
X_1 = Seeds	b_1 = 0.065	0.048	1.371
X_2 = Mandays	b_2 = -0.014	0.113	-0.124
X_3 = Fertilizers	b_3 = 0.002	0.003	0.690
X_4 = Irrigation	b_4 = -0.045	0.052	-0.871
X_5 = Plant protection	b_5 = -0.012	0.019	-0.650
X_6 = Distance from the source of emission	b_6 = 1.121	0.123	9.132**

F = 50.66** R^2 = 0.786

** Significant at 1 per cent probability

Regression of yield on variables excluding X_6, resulted in R^2 value of 0.57 where fertilizer emerged as significant contributor (Table 5.18). Step wise regression gave the best subset (equation 5.2) comprising of seeds, fertilizers and plant protection, explaining 56.09 per cent, out of the total 57 per cent variation.

$$y = 44.10 - \underset{(0.060)}{0.930\, x_1} + \underset{(0.004)}{0.008\, x_3} - \underset{(0.015)}{0.048\, x_5} \quad : 5.2$$

$$R^2 = 0.561$$

When the data on control region was pooled with the data on polluted zone (excluding distance), the analysis gave the following results. The five explanatory variables in the best fit explain 61.76 per cent of response variation (Table 5.19), where fertilizer and irrigation were the significant inputs. The final step of the step wise regression procedure (equation 5.3) reveals the conspicuous

$$y = 31.150 + \underset{(0.004)}{0.010\, x_3} + \underset{(0.004)}{0.110\, x_4} - \underset{(0.015)}{0.13\, x_5} \quad : 5.3$$

$$R^2 = 0.603$$

Table 5.18 Result of multiple regression of paddy yield (for Zone I) on selected independent variables (without X_6)

Independent variable	Regression coefficient (b)	Standard Error	T value
	Intercept = 40.637		
X_1 = Seeds	b_1 = -0.791	0.063	-1.253
X_2 = Mandays	b_2 = -0.024	0.159	-0.151
X_3 = Fertilizers	b_3 = 0.008	0.004	1.975*
X_4 = Irrigation	b_4 = 0.090	0.070	1.272
X_5 = Plant protection	b_5 = -0.133	0.019	-7.006

F = 22.260** R^2 = 0.570

* Significant at 5 per cent probability
** Significant at 1 per cent probability

Table 5.19 Results of multiple regression of paddy yield (Zone one and two) on selected independent variables

Independent variable	Regression coefficient	Standard Error	T value
	Intercept = 39.582		
X_1 = Seeds	-0.784	0.056	-1.403
X_2 = Mandays	-0.178	0.145	-0.123
X_3 = Fertilizers	0.007	0.009	1.948*
X_4 = Irrigation	0.099	0.056	1.773*
X_5 = Plant protection	-0.126	0.150	-8.544

F = 31.33** R^2 = 0.618

* Significant at 5 per cent probability
** Significant at 1 per cent probability

contribution of 60.30 per cent in response variation (out of the total 61.76 per cent explained by the five selected variables) by the three factors - fertilizer, irrigation and plant protection.

From the above results, it could be interpreted that irrigation gained importance in explaning yield fluctuations as the environment became free of cement kiln dust. Since there existed a significant positive correlation between distance and paddy yield (0.881) and negative correlation between distance and plant protection (-.793), there had to be fairly high pest incidence in the polluted regions. This finding is in line with the observed resource use pattern (Table 5.20) which reveals a higher plant protection cost (and a lower net return per hectare) in areas adjacent to the plant. It can be concluded that distance from the source of pollution, taken here as a proxy for the environmental damage character influenced the crop yield of mundakan significantly.

Studying the cost of cultivation, it was found that, in terms of net return per hectare (Tables 5.20 and 5.21) the first crop was better earning and for the

Table 5.20 Cost of cultivation of paddy (mundakan) in different regions

Per cent of input cost for	Regions							
	I	II	III	IV	V	VI	VII	VIII
Labour (total)	47.40	45.30	42.10	41.53	42.01	46.32	43.81	45.21
Land preparation	5.13	5.26	5.18	6.20	6.80	6.66	6.50	5.80
Sowing/planting	6.10	8.10	6.20	8.28	6.90	7.87	7.24	7.50
F.Y.M.	1.32	1.18	0.52	2.80	1.44	0.90	1.10	0.80
Chemical fertilizers	30.55	31.55	32.18	33.85	35.05	33.81	34.80	34.10
Irrigation	2.00	2.03	2.01	2.02	2.10	1.02	2.89	2.33
Plant protection	6.70	6.78	9.10	2.52	5.70	3.42	2.90	2.95
Others	0.80	2.80	2.71	2.80	-	-	0.76	1.31
Mean cost of cultivation per ha (Rs.)	4315	4750	4380	4105	4205	3980	4223	4495
Per cent of family labour to total labour	43.20	27.85	23.41	33.50	38.30	38.54	36.21	35.35
Net return per ha (Rs.)	-485	402	-27	455	895	1560	2167	1275

Table 5.21 Cost of cultivation of paddy (virippu) in different regions

Per cent of input cost for	Regions							
	I	II	III	IV	V	VI	VII	VIII
Labour (total)	48.65	48.93	44.30	47.23	47.50	46.40	47.20	47.50
Land preparation	5.13	5.08	4.90	4.08	6.20	6.40	6.50	8.03
Planting/sowing	6.10	6.42	5.10	8.10	6.20	6.90	6.90	5.30
F.Y.M.	3.40	2.14	2.52	2.25	2.30	1.20	1.10	1.80
Chemical fertilizers	30.55	28.14	30.10	33.60	33.30	34.30	35.02	33.04
Irrigation	1.10	1.07	1.08	1.02	0.95	0.96	0.65	1.01
Plant protection	4.60	6.27	10.00	1.82	3.50	3.49	2.45	1.67
Others	0.47	1.95	2.00	1.90	0.05	0.35	0.18	1.65
Mean cost of cultivation per ha (Rs.)	4205	4675	4154	3950	4423	3542	3950	4128
Per cent of family labour to total labour	42.27	21.31	19.20	32.32	35.20	38.72	36.75	37.47
Net return per ha (Rs.)	1069	125	655	620	1081	1532	3050	2262

second crop, six to eight regions of first zone gained more than the rest. These three regions when studied against the first three regions of zone one, had relatively lesser proportion of plant protection and more of chemical fertilizers in the total cost. Even as the mean cost of cultivation and varietal distribution did not show much variation between the two zones, net return per hectare was very low for the initial regions of zone one, pointing to the probable low yield levels (Price was taken constant) in these regions.

More than 43 per cent of the area under the second crop paddy in the first four regions showed foliar yellowing and drying. This could be due to considerable reduction in chlorophyll content in the cement dusted plants as observed by Singh and Rao (1981) in wheat. Out of the interviewed farmers 36 per cent complained about an increased incidence of pests, 14.60 per cent on reduced tillering, 14 per cent on higher chaff content and 12.30 per cent on delayed emergence of panicle, over the last few years. Findings of past researches on impaired fertilization in other crops cited in chapter two may be helpful in explaining the yield reduction in paddy also.

2.2 Chilli

For area under vegetables in general, the mean percentage to gross cropped area had shown an increase to the tune of 105.40 per cent in the polluted zone, while a decline rather tenuous, of 1.75 per cent was observed for the control (Table 5.22). Vegetables raised in the polluted season envisaged heavy input of management often including washing off the foliar deposit. Even such washings cannot remove the dusts as per Sreerangaswami et al. (1973). The vegetable mostly grown in the polluted season was chilli. Analysis of variance suggested a significant variation in chilli yield between regions one to three and the rest of them in zone one. Table 5.23 furnishes the results of analysis of variance. Considering the chilli yield, temporal decline was 14.71 per cent in the polluted zone, while no change could be observed in the control. For the 1983-84 crop, with respect to the control zone, chilli yield was 3.50 per cent higher in the first zone, which later in the 1986-87 crop season was 13.15 per cent lower than the control. Temporal variation was the maximum for region one coming upto a reduction of 2.70 t/ha. Spatial decline of 5.50 t/ha between the first and fifth region was a

Table 5.22 Cultivated area under vegetables (Chilli, Bhindi, Brinjal and Tomato) in different regions

	I		II		III		IV	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Average area per holding (ha)	0.03	0.19	0.08	0.16	0.05	0.13	0.08	0.09
Per cent to the G.C.A.	1.34	14.72	4.37	10.38	1.91	5.74	3.17	4.43

	V		VI		VII		VIII	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Average area per holding (ha)	0.07	0.05	0.09	0.12	0.06	0.01	0.04	0.04
Per cent to the G.C.A.	4.04	1.84	5.17	7.48	1.92	0.43	2.28	2.24

Table 5.23 Analysis of variance table for chilli yield/ha

Source	d.f.	Sum of squares	Mean sum of squares	F
Between regions	7	174.778	24.968	17.395**
Within regions	69	99.040	1.435	
Total	76	273.818		

** Significant at 1 per cent probability

maximum in 1986-87 while the difference of 3.30 t/ha for regions six and seven was the highest in 1983-84. Figure 5.3 depicts the trend in chilli yield over the regions, which indicates lower yield levels nearer to the source of emission.

Cement kiln dust deposits on crops was found to be maximum in the season November to February owing to the easterlies carrying the pollutant. Vegetables could be cultivated avoiding the polluted season. Relatively remunerative prices, nearness to market, and deteriorating performance of perennial crops also have their contribution in the increasing preference for vegetables.

A multiple regression of chilli yield on four independent variables as indicated below was worked out.

<u>Variables</u>

Y = Yield (kg/ha)

X_1 = Man days/ha

X_2 = Fertilizer used (Rs./ha)

X_3 = Plant protection (Rs./ha)

X_4 = Distance from the source of emission (km).

Distance from the source of emission (X_4) was the most significant variable explaining response variation in the polluted area, as shown by the results of regression

(Table 5.24). Results of step wise regression revealed that X_4 together with X_2 and X_1 formed the best subset which could explain 89.42 per cent of variability in yield.

$$Y = 3278.291 + \underset{(17.828)}{46.289\, x_1} - \underset{(2.338)}{4.978\, x_2} + \underset{(50.87)}{643.926\, X_4} \quad : 5.4 \qquad R^2 = 0.894$$

The positive and significant contribution of labour in zone one mainly accrued to the benefit of washing off the dust deposit. Following step wise regression for the two zones together, x_3 figured as the only significant cause of variation, explaining about 12.5 per cent of the response variation (equation 5.5), out of the total 20 per cent (Table 5.25) explained by all the selected variables.

$$Y = -1045.62 + \underset{(18.89)}{43.46\, x_3} \qquad :5.5)$$

$R^2 = 0.125$

Nearly 53 per cent of the chilli cultivators attributed the severe flower shedding and consequent yield reduction to cement kiln dust which also caused poor germination percentage and leaf crinkling. Sreerangaswamy _et_ _al_. (1973) had reported only 57.12 per cent germination of chilli seeds in an environment polluted by cement kiln dust.

Table 5.24 Results of regression analysis of chilli yield with selected independent variables (zone one)

Independent variable		Regression coefficient	Standard Error	T value
		Intercept = 2149		
X_1	= Man days	45.565	17.968	2.536**
X_2	= Fertilizer	-4.553	2.406	-1.892
X_3	= Plant protection	6.379	7.454	0.856
X_4	= Distance from the source of emission	630.965	53.406	11.815**

F = 41.896** R^2 = 0.898

** Significant at 1 per cent probability
* Significant at 5 per cent probability

Table 5.25 Result of regression analysis of chilli yield with the selected independent variables (Zones one and two)

Independent variable			Regression coefficient	Standard Error	T value
			Intercept = ¯4871		
X_1	=	Mandays	-51.235	40.847	-1.254
X_2	=	Fertilizer	8.198	5.659	1.449
X_3	=	Plant protection	48.169	18.751	2.569*

F = 2.916* R^2 = 0.200

* Significant at 5% probability

Fig.5.3 PRODUCTIVITY OF CHILLI AND COTTON IN THE POLLUTED ZONE

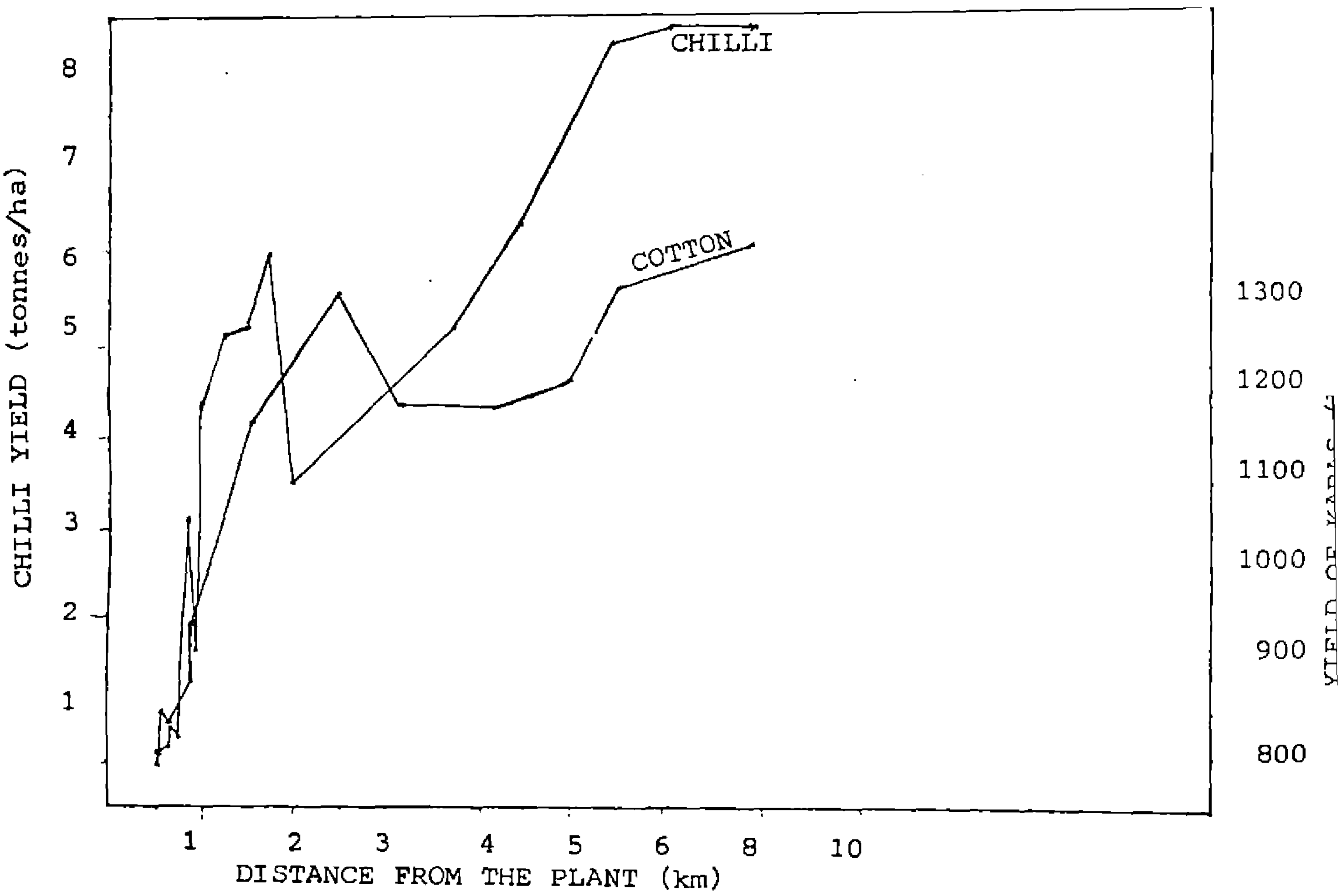
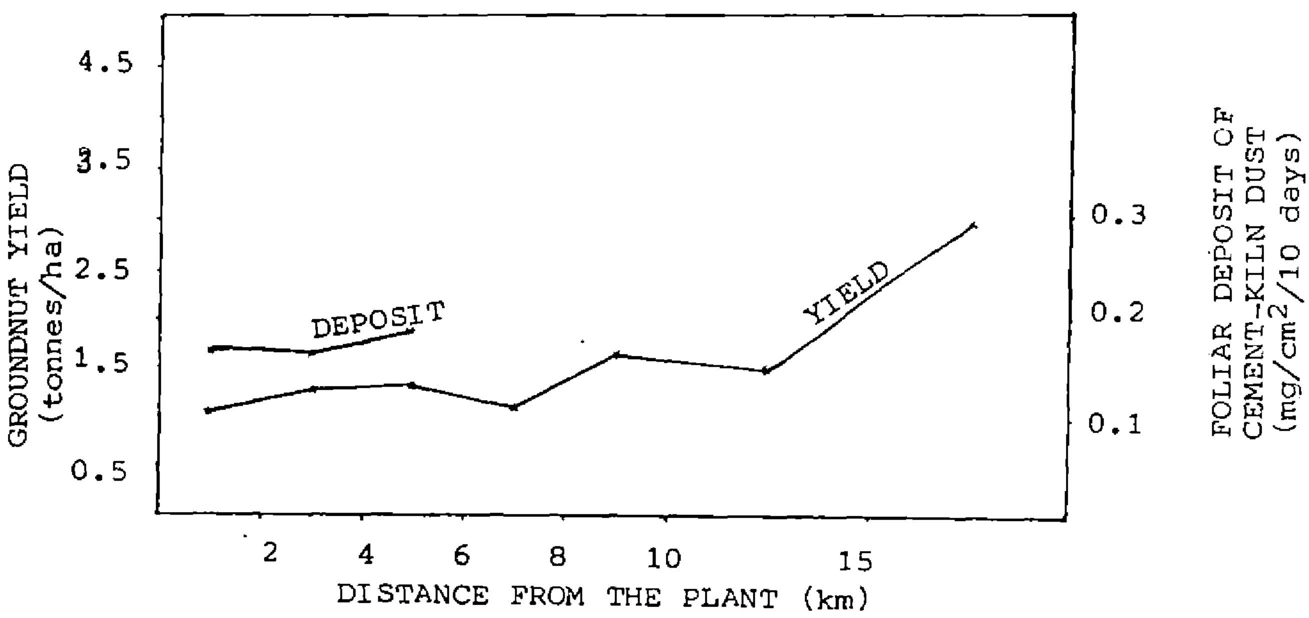


Fig.5.4 Productivity of groundnut and foliar deposit of cement-kiln dust



2.3 Ground nut

Referring to Table 5.26, the changes in area under ground nut and yield per hectare can be interpreted as follows. The proportion of area under ground nut to total cropped area increased by 73.07 per cent and 51.25 per cent in the polluted and control zones respectively. Meanwhile, the yield/ha was reduced by 18.24 per cent in zone one and remained the same in zone two. The yield/ha of ground nut (November sown) in the polluted zone was lower by 34.27 per cent compared to control. Therefore for the 313 ha of groundnut crop sown in November (Table 3.6) an yield loss of 169 tonnes of pods could be estimated. The maximum temporal decline over the four years was for the first region while the maximum spatial variation existed between the first and seventh regions.

Ground nut as a relatively stress tolerant crop was popularly chosen for cultivation, especially for the November to March season. The April and August sown crops of ground nut could escape the cement kiln dust contamination.

Table 5.26 Cultivated area and yield of ground nut in different regions

	I		II		III		IV	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Average area per holding (ha)	0.33	0.42	0.21	0.52	0.19	0.29	0.33	0.35
Per cent to G.C.A.	13.17	24.51	11.66	33.70	6.79	12.57	11.78	8.29
Mean yield in tonnes/ha	2.10	1.05	1.58	1.30	1.57	1.32	1.25	1.10

	V		VI		VII		VIII	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Average area per holding (ha)	0.16	0.16	0.07	0.09	-	0.03	0.11	0.17
Per cent to G.C.A.	6.34	7.50	4.14	5.82	-	0.86	6.38	9.65
Mean yield in tonnes/ha	1.68	1.68	1.50	1.50	-	3.00	2.10	2.10

Table 5.27 reveals a significant variation in groudnut yield between different regions. Results of regression of yield (y) on variables x_1 to x_6 are presented in Table 5.28.

Variables

Y	=	Yield (kg/ha)
x_1	=	Seeds used (kg/ha)
x_2	=	Man days/ha
x_3	=	Fertilizers used (Rs./ha)
x_4	=	Irrigation (Rs./ha)
x_5	=	Plant protection (Rs./ha)
x_6	=	Distance from the source of emission (km)

According to Table 5.28 for the first zone, distance was the only significant factor. All the explanatory variables turned insignificant for the pooled data. Figure 5.4 relates the pollutant load and ground nut yield. Final equation as a result of stepwise regression analysis is given below.

$$Y = 823.225 + \underset{(26.781)}{97.082}\, x_6 \qquad R^2 = 0.374 \qquad : 5.6$$

$$Y = 918.815 + \underset{(0.348)}{0.913}\, x_3 \qquad R^2 = 0.157 \qquad : 5.7$$

Equations 5.6 and 5.7 represent the best subset for zone one and pooled data respectively.

Table 5.27 Analysis of variance table for ground nut yield

Source	D.F.	Sum of squares	Mean sum of squares	F
Between regions	7	308.159	44.023	12.791**
Within regions	73	251.234	3.442	
Total	80	559.394		

** Significant at 1 per cent probability

Table 5.28 Results of regression of ground nut yield on selected independent variables (Zone one)

Independent variable	Regression coefficient	Standard Error	T value
	Intercept = 1486		
X_1 = Seed	0.081	10.178	0.008
X_2 = Mandays	-10.354	20.444	-0.506
X_3 = Fertilizers	- 0.102	0.690	0.147
X_4 = Irrigation	-0.946	46.668	-0.020
X_5 = Plant protection	-0.038	1.875	-0.020
X_6 = Distance from the source	118.969	45.496	2.615**

$F = 1.738$ $R^2 = 0.380$

** Significant at 5 per cent probability

The distance variable x_6 was the only significant explanatory factor in the polluted zone, accounting for 37.40 per cent of response variation out of the total 38.32 per cent. When the two zones were pooled together, x_3 figured as the only significant contributor to variation with $R^2 = 0.157$. Table 5.29 reveals 16.72 per cent yield response to five factors for the pooled data. This does not take into account the distance factor as it is not relevant in the second zone.

Mean cost of cultivation per hectare was Rs.2168/= in the polluted zone, while the control area averaged to Rs.2800.68. Out of the total cost 68-75 per cent was for labour in the polluted zone, where family labour contribution was 89 per cent. In the control area, out of the total labour cost (70.90 per cent of total cost) 80 per cent was for the farmer's family labour. Maximum net return/ha accrued to the fifth region (Table 5.30).

The major symptom observed in ground nut as a result of cement kiln dust deposit was stunting and it was reported by 48.56 per cent of the respondent farmers. Out of the cultivators interviewed, 37 per cent

Table 5.29 Result of regression of groundnut yield on selected independent variables (Zone ene and two)

Independent variable			Regression coefficient	Standard Error	T value
			Intercept = 616		
X_1	=	Seeds	-8.231	6.843	-1.203
X_2	=	Mandays	20.309	14.872	1.366
X_3	=	Fertilizers	0.753	0.520	1.449
X_4	=	Irrigation	-24.623	20.373	-1.209
X_5	=	Plant protection	- 0.608	1.327	-0.458

F = 1.325 R^2 = 0.167

Table 5.30 Cost of cultivation of ground nut in different regions

Percentage of input cost for	Regions							
	I	II	III	IV	V	VI	VII	VIII
Labour (total)	73.22	75.12	69.20	69.01	69.40	68.31	68.65	70.91
Land preparation	9.60	8.89	10.90	10.64	11.60	11.70	11.20	6.90
Planting/sowing	10.91	10.78	10.75	10.90	10.90	12.50	12.30	10.20
F.Y.M.	-	-	0.85	0.50	0.50	1.02	1.04	2.00
Chemical fertilizers	2.84	2.58	3.80	3.95	2.85	2.95	2.95	3.51
Irrigation	1.14	1.12	1.10	1.15	1.90	0.90	0.88	3.09
Plant protection	-	-	0.80	1.80	0.80	1.02	1.08	2.34
Others	2.29	1.51	2.60	2.05	2.05	1.60	1.90	1.05
Mean cost of cultivation/ ha (Rs.)	2108	1950	1750	2205	2342	2425	2395	2800
Per cent of family labour to total labour	94.50	93.81	94.30	92.85	87.80	85.00	84.50	80.12
Net return per ha (Rs.)	1500	1820	1100	1320	3230	2015	2650	2415

complained about smaller kernels, while 18 per cent reported an increased incidence of aphids (attributed probably to destruction of natural enemies by cement kiln dust as observed by Darley (1966) in alfalfa. Oblisami (1988) had reported 60 per cent yield reduction in groundnut, caused by adversely affected peg formation and lesser number of root nodules.

2.4 Cotton

As per Table 5.31 the temporal decline in area under cotton was noted to be the maximum in the third region, while the spatial variation between the second and control was the highest (Figure 5.3). As per the analysis of variance (Table 5.32), the variation in yield/ha was significant among different regions (Table 5.32). The decline in proportion of area under cotton to the gross cropped area, and mean yield were 68.97 per cent and 59.68 per cent respectively, for the first zone. For the corresponding period, in the control there was a 6.41 per cent reduction in the percentage of area under cotton to gross cropped area, inspite of a 56.15 per cent gain in mean yield. In other words, yield of cotton in the control zone compared to the polluted zone was 127.24 per cent higher. From this, for the 18 ha of

Table 5.31 Cultivated area and yield of cotton in different regions

	I		II		III		IV	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Average area per holding (ha)	0.31	0.03	0.45	0.05	0.16	0.03	0.16	0.08
Per cent to G.C.A.	10.48	1.56	24.78	3.46	5.74	1.15	4.23	3.79
Mean yield per ha (tonnes)	2.02	1.20	1.10	0.67	4.30	0.68	1.84	1.02

	V		VI		VII		VIII	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Average area per holding (ha)	0.04	-	0.03	-	-	-	0.20	0.19
Per cent to G.C.A.	1.44	-	1.48	-	-	-	11.39	10.66
Mean yield per ha (tonnes)	1.03	-	3.00	-	-	-	1.30	2.03

Table 5.32 Analysis of variance in cotton yield

Source	D.F.	S.S.	M.S.S.	F.
Between regions	6	328552.81	54758.80	7.469**
With regions	15	109969.16	7331.28	
Total	21	438521.97		

** Significant at 1 per cent probability

cotton in zone one, 20.50 tonnes of loss could be estimated. A regression equation of the following type was fitted to study the yield variations in cotton.

Variables selected for regression

Y = Yield (kg/ha)

x_1 = Input of seed (kg/ha)

x_2 = Man days/ha

x_3 = Fertilizers used (Rs./ha)

x_4 = Irrigation (Rs./ha)

x_5 = Plant protection (Rs./ha)

x_6 = Distance (km)

From Tables 5.33 and 5.34 results indicate significance of irrigation and distance for zone one (with $R^2 = 0.749$) and plant protection alone in the pooled set ($R^2 = 0.822$), where distance is not a factor.

Explanatory variables could explain the response variation significantly only for the polluted zone when step wise regression was carried out, as shown below.

$$Y = 290.918 + \underset{(18.916)}{42.817\, x_4} + \underset{(14.433)}{94.098\, x_6} \quad : 5.8$$

$$R^2 = 0.696$$

Table 5.33 Result of regression analysis of cotton yield with selected independent variables (Zone I)

Independent variable			Regression coefficient	Standard Error	T value
			Intercept = 617		
X_1	=	Seeds	16.510	22.656	0.729
X_2	=	Mandays	-13.754	8.894	-1.546
X_3	=	Fertilizers	-0.669	1.377	-0.486
X_4	=	Irrigation	49.941	20.427	*2.445
X_5	=	Plant protection	1.426	2.327	0.613
X_6	=	Distance	89.052	16.223	**5.489

F = 7.469** R^2 = 0.749

* Significant at 5 per cent probability
** Significant at 1 per cent probability

Table 5.34 Result of regression analysis of cotton yield with selected independent variables (Zone one and two)

Independent variables			Regression coefficient	Standard Error	T value
			Intercept = 646		
X_1	=	Seeds	97.965	85.994	1.139
X_2	=	Mandays	-18.573	30.918	-0.601
X_3	=	Fertilizers	-4.933	4.637	-1.064
X_4	=	Irrigation	50.598	71.671	0.706
X_5	=	Plant protection	5.847	2.952	*1.980

R^2 = 0.217 F = 1.548

* Significant at 5 per cent probability

X_6 was entered first, followed by x_4, which together explained about 69.58 per cent of the variation.

Severely dusted cotton plants yielded low quality kapas. Among the cotton growers in the first three regions, 68 per cent attributed the unmarketably poor quality kapas to cement kiln dust. Discolouration and brittleness could be observed in affected fibres. Similar impacts were reported by Oblisami (1988) who had also detected an increase in percentage of bad kapas, reduced ginning percentage and qualitative deterioration of kapas leading to bad quality lint.

2.5 Coconut

Table 5.35 furnishes the cultivated area and yield of coconut in different regions. Temporal comparison between 1983-84 and 1986-87 revealed decreasing average area under coconut. However, the contribution of coconut crop to gross cropped area increased by 18.30 per cent over the four year period in the polluted zone, while a reduction in yield of 31.69 per cent could be observed. There were reciprocal trends in average area under coconut and its contribution to gross cropped area Ground nut, coconut, banana and some vegetables had a

Table 5.35 Cultivated area and yield of coconut in different regions

	I		II		III		IV	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Average size per holding (ha)	0.15	0.15	0.13	0.13	0.13	0.21	0.21	0.21
Per cent to G.C.A.	5.91	8.50	7.29	8.65	4.78	9.18	8.46	10.13
Mean yield per ha (nuts)	3475	1200	2300	550	1200	450	1285	980

	V		VI		VII		VIII	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Average size per holding (ha)	0.45	0.42	0.12	0.12	0.23	0.24	0.07	0.09
Per cent to G.C.A.	16.15	15.40	6.65	7.48	7.20	7.52	3.99	5.05
Mean yield per ha (nuts)	1580	1691	2885	2892	1600	2020	3578	3575

gain in acreage which could not parellel the decline in cultivated area of paddy, certain vegetables, cotton, and sugarcane. Therefore, gross cropped area evidently had a decline between the years 1984 and 1987. For the control zone, 26.57 per cent gain was there in proportion of coconut in gross cropped area accompanied by 0.084 per cent yield reduction.

Significant variance in coconut yield was obtained between the first four regions and regions six to eight, after analysis of variance (Table 5.36) and Figure 5.5. The mean yield of coconut per annum per tree in the control area was 155 per cent greater than that in the first zone. Then for the 80 ha of bearing coconut palms in the affected area, an annual loss of 139328 nuts could be estimated. Table 5.36 given the mean area and yield of coconut in different regions.

Quantifiable foliar deposits could be obtained upto the fourth region, within which the major symptom of impact of cement kiln dust interference was foliage yellowing and drying, observed in 43 per cent of the palms. Palms had already stopped yielding in 8 per cent of them. The damages could be directly related to thick deposit on leaflets, axils, spikelets and soil in the light of studies

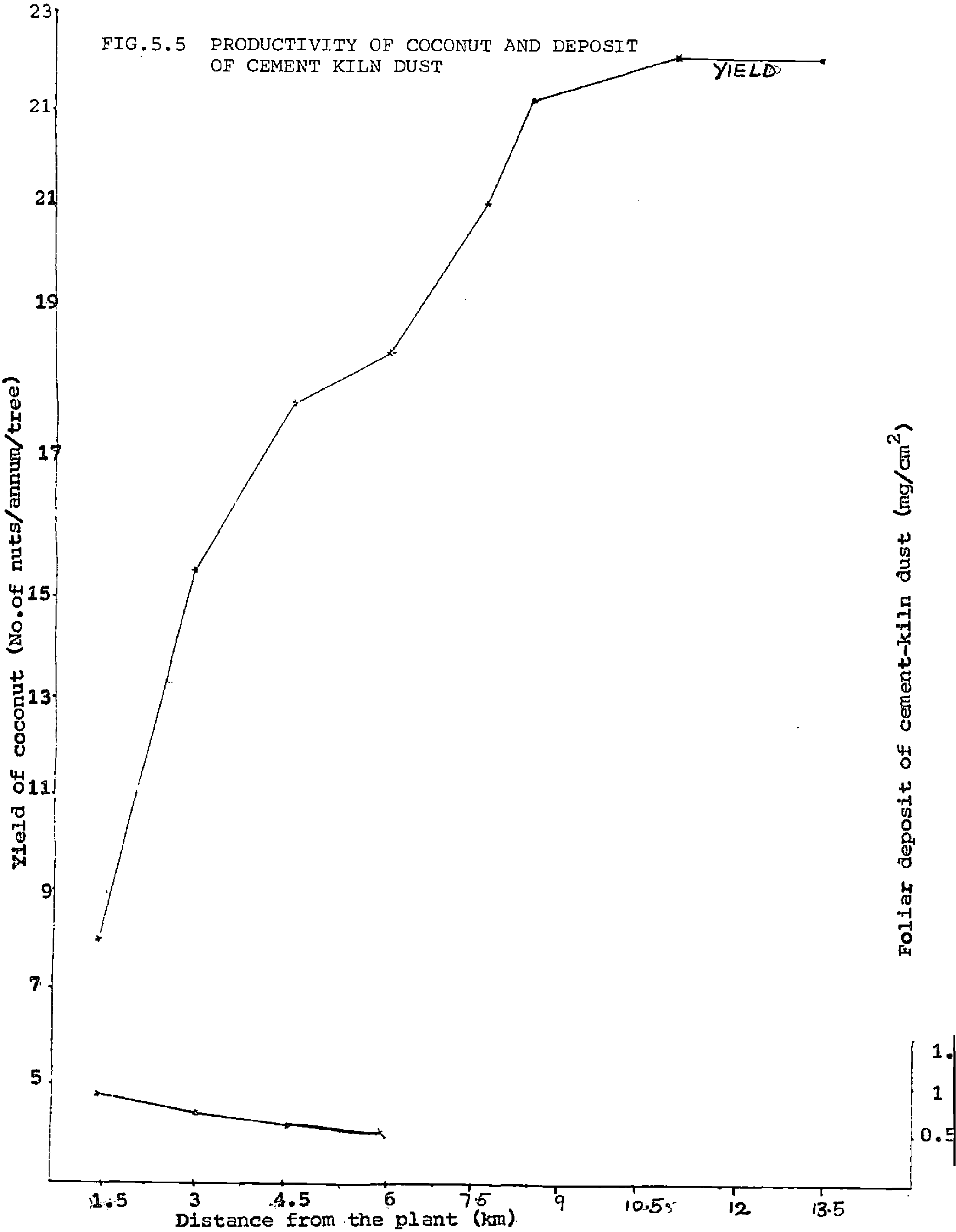


FIG.5.5 PRODUCTIVITY OF COCONUT AND DEPOSIT OF CEMENT KILN DUST
YIELD
Yield of coconut (No.of nuts/annum/tree)
Foliar deposit of cement-kiln dust (mg/cm2)
Distance from the plant (km)
23
21
21
19
17
15
13
11
9
7
5
1.5
3
4.5
6
7.5
9
10.5
12
13.5
1
0.5

Table 5.36 Analysis of variance table for coconut yield

Source	D.F.	Sum of squares	Mean sum of squares	F
Between regions	7	1850.172	264.310	**41.01
Within regions	80	510.727	6.384	
Total	87	2360.899		

** Significant at 1 per cent probability

by Rajachidambaram and Krishnamurthy (1979) and Rethinam *et al*. (1981).

2.6 Other crops

The other crops grown in the area are sugarcane, banana, maize and pulses. Perennials like mango, cashew, tamarind and guava are also sources of income for many. Sugarcane in the polluted areas showed retarded growth and reduced number of nodes with smaller internodes. Area and productivity of sugarcane are furnished in Table 5.37. The histological anomalies reported by Rajachidambaram and Krishnamurthy (1979) like stomatal clogging, loss of guard cells and destruction of stomatal apparatus in coconut, sugar cane, and tamarind have to be the basic causes of yield reduction. In the polluted zone, over the period in discussion, there was a 19.45 per cent reduction in its contribution to gross cropped area and a 5.84 per cent decline in yield per hectare. The first zone had an yield/unit area lower than the control by 6.07 per cent. This accrued to a loss of 195.85 tonnes of sugarcane, in an year.

For banana, over the four year period, the proportion to gross cropped area increased by 38.82 per cent

Table 5.37 Cultivated area and yield of sugarcane in different regions

	I		II		III		IV	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Average area per holding (ha)	0.05	-	0.15	0.08	0.19	0.19	0.03	0.03
Per cent to G.C.A.	2.15	1.55	8.01	5.19	6.69	8.03	1.06	1.06
Mean yield per ha (tonnes)	70.00	61.00	73.80	65.10	71.00	62.40	68.00	68.00

	V		VI		VII		VIII	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Average area per holding (ha)	0.14	0.14	0.08	0.08	0.03	-	0.26	0.16
Per cent to G.C.A.	5.05	3.36	4.43	4.98	0.84	-	14.81	8.98
Mean yield per ha (tonnes)	65.00	63.00	68.00	68.00	64.30	-	69.00	68.50

in the polluted zone and decreased by 2.68 per cent in the control. While the control area recorded no substantial change in banana yield, there was a 4.13 per cent reduction in yield for the first zone, between the two years considered. Thus, compared to control, there was a 32.04 per cent yield reduction pertaining to the polluted zone. In polluted areas banana bunches were with small fingers. The poor yield in affected areas become apparent in Table 5.38 and Figure 5.6.

Average yield of maize was low in the first region compared to the control - the difference ranging between 18 to 23 per cent. Maize and grams gained acreage in the dryland farming practised in the area but they were by and large not market oriented, especially maize, which was cultivated more or less exclusively as fodder (except for lean seasons). Pulses like green gram, black gram and red gram also had their yield potential affected by pollution. Tuber crops which fetch a fairly high farm gate price and relatively tolerant to an environment contaminated by cement kiln dust was not that popular, mainly due to the dry land ecology.

FIG. 5.6 PRODUCTIVITY OF BANANA AND FOLIAR DEPOSIT OF CEMENT KILN DUST

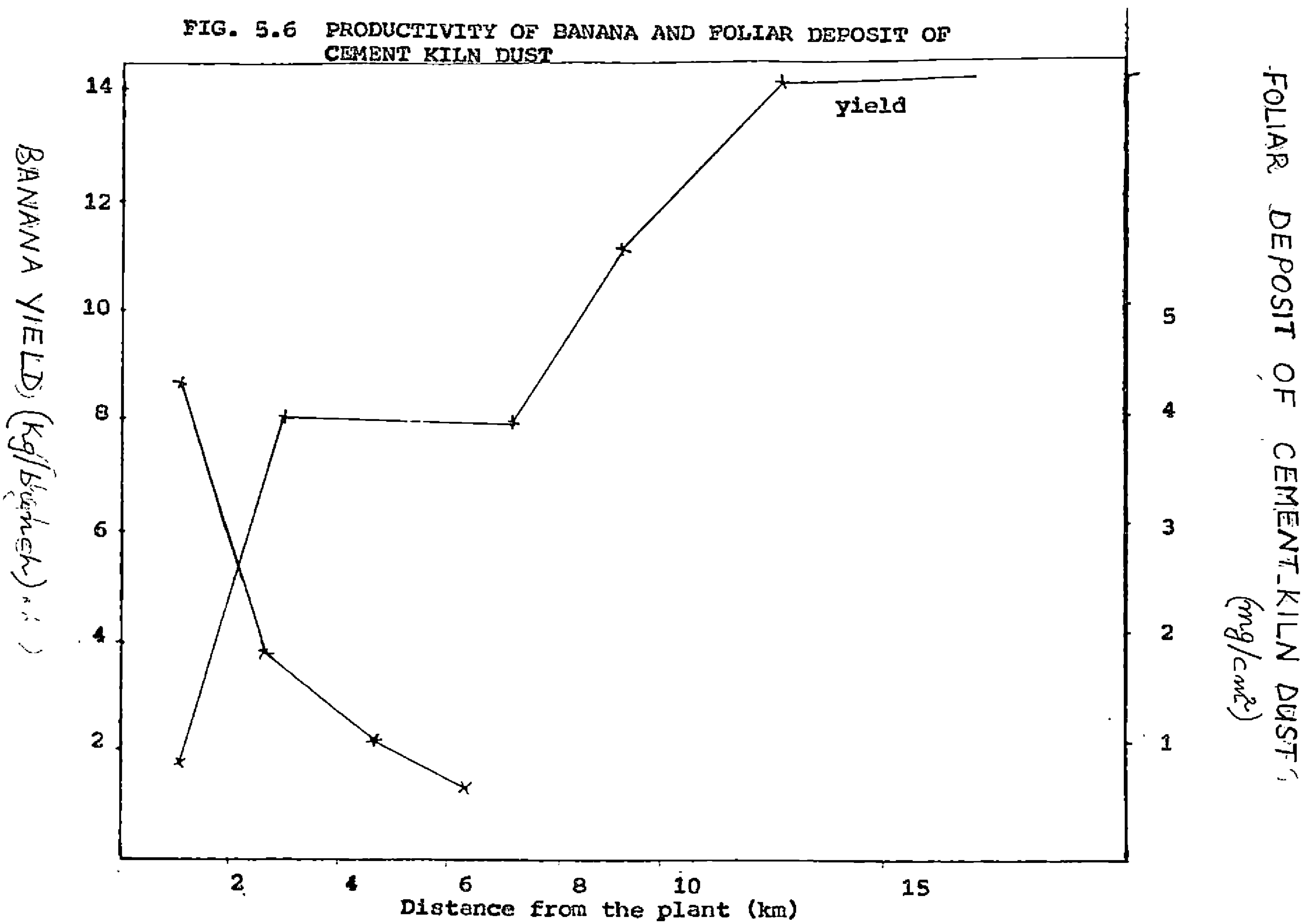


Table 5.38 Cultivated area and yield of banana(varieties excluding Nendran)in different regions

	I		II		III		IV	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Average area per holding (ha)	0.03	0.08	0.05	0.05	-	-	-	0.03
Per cent to G.C.A.	1.08	4.65	1.31	3.46	-	-	-	1.27
Mean yield (kg/bunch)	9.50	4.80	13.00	9.52	12.00	9.30	-	10.00

	V		VI		VII		VIII	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Average area per holding (ha)	0.96	0.96	0.08	0.06	-	-	0.04	0.04
Per cent to G.C.A.	0.96	0.95	4.43	3.32	-	-	1.12	1.09
Mean yield (kg/bunch)	8.80	15.00	12.00	15.00	-	-	14.00	14.02

Fruit crops viz., mango, cashew and guava were sources of agricultural income for many in the region. The yield of such fruit crops was poor when their flowering period coincided with cement kiln dust in the atmosphere. The yield difference with the control ranged from 55 to 98 kg for mango, 16 to 29 kg for cashew, and 8.50 to 9.30 kg for guava. Studies of Lal and Ambasht (1982) and Sai et al. (1987) have reported adverse effect of cement kiln dust on fruit yield.

It can be summarised from the above discussions on the impact of cement kiln effluents on crop yield that there was considerable reduction in crop yield per hectare for the first three regions (upto six kms south west of the plant) when compared to the last region of the polluted zone and also the control. Net return derived from unit area of paddy (for both the crops in the polluted zone, though the second crop was evidently less rewarding) and ground nut were showing a similarity to the above behaviour in crop yield. The extent of such a decline varied in different crops. The area response in each crop to the pollutant was influenced by accessability to sources of irrigation.

3. Agricultural income

Table 5.39 furnishes the details on agricultural income for different regions. Apprising the annual agricultural income per hectare (at constant price) over the regions it could be understood that temporal decline was the rule (Table 5.39) except for regions four, seven and eight. The maximum decline was for region one: Rs. 1462/ha. The annual farm income per hectare had an increasing tendency from the first (with the minimum value of annual agricultural income) to the seventh region (Figure 5.7). The highest value accrued to the sixth region. Similar to the conclusion of yield analysis, here too the last two regions of the polluted zone performed much better than the control. The initial three regions had highest difference from the control.

Income from crop enterprises per hectare of land at 1983-84 prices, declined by 8.44 per cent in the polluted zone, since the inception of cement kiln dust contamination. Meanwhile there was an increase of 6.16 per cent in the control. Consequently, the agricultural income which was 9.49 per cent lower in the control zone (for 1983-84) became 4.94 per cent higher than the polluted zone by 1986-87.

Table 5.39 Agricultural incomes in different regions

	I		II		III		IV	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Mean returns (Rs.'000/year) a) Per farm	11.96	7.40	9.12	8.35	10.89	11.85	11.12	10.79
b) Per ha	4.82	3.37	4.99	4.35	4.90	4.09	4.41	4.87

	V		VI		VII		VIII	
	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87	1983-84	1986-87
Mean returns (Rs.'000/year) a) Per farm	16.22	18.50	12.14	13.13	14.25	16.28	11.13	12.44
b) Per ha	7.31	6.78	9.92	8.80	6.34	6.83	5.52	5.86

(Incomes for 1986-87 are given at 1983-84 prices)

Analysis of variance (Table 5.40) of annual agricultural income per hectare indicated the absence of significant variation among the regions despite low net returns realised from unit area of crops in the polluted zone. Taking into account the significant relationship obtained between different crop yields on the one hand and distance from the factory on the other, it was expected that the prevailing cropping pattern could explain the variations in agricultural income. Therefore, a multivariate analysis using the following variables was conducted.

Y = Farm income/ha (Rs. '000) for 1986-87

X_1 = Cropping intensity

X_2 = Percentage of gross cropped area under paddy.

X_3 = Percentage of gross cropped area under groundnut.

X_4 = Percentage of gross cropped area under vegetables.

X_5 = Percentage of gross cropped area under other seasonals.

X_6 = Percentage of gross cropped area under coconut.

X_7 = No.of trees/ha of other perennials (cashew, tamarined and mango)

X_8 = Distance from the plant (km)

Regression analysis (Table 5.41) revealed that none of the selected variables could significantly

Table 5.40 Analysis of variance table for Agricultural income/annum (1986-87)

Source	D.F.	S.S.	M.S.S.	F.
Between regions	7	209.216	29.888	1.506
Within regions	112	2223.420	19.852	
Total	119	2432.636		

Table 5.41 Result of regression analysis of farm income/annum with the selected independent variables

Independent variable	Regression coefficient	Standard Error	T value
	b = 9.998		
X_1 = Cropping intensity	-0.023	0.026	-0.898
X_2 = Per cent of G.C.A., under paddy	-0.055	0.044	-1.243
X_3 = Per cent of G.C.A. under ground nut	-0.002	0.127	-0.017
X_4 = Per cent of G.C.A. under vegetables	-0.035	0.211	-0.168
X_5 = Per cent of G.C.A. under other seasonals	-0.265	0.456	-0.580
X_6 = Per cent of G.C.A. under coconut	0.133	0.204	0.651
X_7 = Number of trees/ha of other perennials	-0.068	0.156	-0.433
X_8 = Distance from the factory	0.236	0.184	1.279

R^2 = 0.077 F = 0.994

account for variation in agricultural income. Out of the 7.65 per cent variation explained by the eight selected factors, distance alone (which was retained after step wise regression) could cause 4.54 per cent.

$$Y = 4.799 + 0.187\, x_8. \qquad R^2 = 0.045 \quad : 5.9$$
$$\quad (0.845)$$

$$Y = 0.199 + 0.115\, x_3 + 0.693\, x_8 \qquad R^2 = 0.097 \quad : 5.10$$
$$\quad (0.066) \quad (0.263)$$

Thus the area responses (considered in 2.1.A, 2.3 and 2.5) found favourable for vegetables, ground nut, and coconut and against second crop of paddy, could not contribute to farm income from unit area, after the third region in zone one. This pointed to the fact that distance from the factory was more influencing than the type of crop grown. Alternatively for a given region, no crop could be preferred to an other, if pollution was a problem except for the first six km SW of the source, where area under ground nut could marginally contribute to farm income.

Table 5.42 presents the results of regression analysis of farm income/ha/annum with selected independent variables for the first three regions of zone one. Here distance emerged as a significant explanatory factor. The best subset obtained after a step-wise regression, includes distance and the percentage to gross stopped area under ground nut which accounted for 9.7 per cent of the total variation (12.64 per cent) explained by the eight selected variables.

Distance and area under paddy were highly correlated positively (0.787) and area under ground nut, vegetables and other seasonals were highly correlated negatively (-.788, -731 and -.706 respectively) with distance.

The main reason for the failure of cropping intensity as an explanatory factor is that, wherever a high cropping intensity existed in the severely polluted area, it was accounted for by perennial crops - mainly coconut. It is clear from Table 5.35 that its' yield performance was poor under polluted conditions. Therefore the higher cropping intensity failed to contribute to farm income. Although the first three regions of the polluted zone as a whole had nearly 33 per cent lower agricultural income per year compared to control (Table 5.39) the agricultural income per annum from unit area in severely polluted regions was observed to be on par with that of distant regions. Within the first zone, crop diversification

Table 5.42 Result of regression analysis of farm income/annum with the selected independent variables for the first three regions of zone one

Independent variable			Regression coefficient	Standard Error	T value
			b = -2.660		
X_1	=	Cropping intensity	-0.012	0.023	-0.513
X_2	=	Per cent of gross cropped area under paddy	0.030	0.058	0.517
X_3	=	Per cent of G.C.A. under ground nut	0.199	0.131	1.523
X_4	=	Per cent of G.C.A. under vegetables	0.191	0.206	0.924
X_5	=	Per cent of G.C.A. under other seasonals	-0.232	0.349	-0.664
X_6	=	Per cent of G.C.A. under coconut	-0.009	0.197	-0.048
X_7	=	No. of trees/ha of other perennials	-0.015	0.127	-0.115
X_8	=	Distance from the factory	-0.947	0.395	**2.398

R^2 = 0.126 F = 1.194

** Significant at 1 per cent probability

cropping intensity, and gross cropped area were comparatively higher in the severely polluted regions (although the temporal trend of the above, in these regions was of declining nature). Inspite of this, these regions failed to get better returns from agriculture, because of the deteriorated crop condition. Compared to the control, these regions derived lesser net return from unit area of paddy and groundnut as stated earlier. Regarding the distant regions of the first zone, the income per hectare of land holding was not upto the expectation in a pollution free situation and relatively better crop performance. This is attributable to low cropping intensity and lack of crop diversification. Cultivation was more or less concentrated towards paddy in the last region of zone one.

Thus, the uniformity in farm income/ha of land holding between the polluted and non polluted fegions accrued to the reciprocal variations in cropping intensity and crop yield. Yield fluctuations were found to be in accordance with intensity of pollution, other factors remaining the same. But cropping intensity varied based on occupation of informants, other than agriculture and access to irrigation.

The variations in cultivated area, crop yield and agricultural income/annum for the polluted zone in comparison with the control are summarised in Table 5.43. The more affected areas were inhabited by full time cultivators, while the farm income for the land owners of distant regions was only supplementary to income from service or business. So if not for the constraint of contamination by cement kiln dust, their income from agriculture could have been improved over the years, as was the experience in the control and in the last region of the first zone. They could have utilised the present fallow periods for cultivation of market oriented crops and could have harvested better crop yields in all the seasons (Table 5.43). Thus a negative externality for the cement plant in the regional economy of Walayar through its impact on agriculture become distinct.

4. Policy implications and suggestions

The polluted environment in the study area - especially upto six kilometers south west of the plant gets depleted of its value in consumptive, locative and and supply uses. For the cement manufacturing establishment in the locality, it is obligatory to arrest the effluents efficiently and to extract resources without

turning the eco-system fragile. A co-ordinated effort with the participation of the polluter, enforcer, ecologist, economist and affected public should be realised to arrive at the true long run negative externality of such an industry.
If appropriate weights are applied to the low income recepients of both primary and secondary pollutants, the picture on socio-economic impact would be more realistic, because their problem is aggravated by lack of resources for abatement or avoidance.

Sensitive indicator plants should be grown at different distances and directions with respect to the source of emission to assess the impact systematically and take precautions whenever necessary. The minimal values for irreversible damages should be stated in the environmental impact statement. Maintaining tree belts on the farm borders on sides from which direction the pollutant carrying winds blow, will be beneficial. The suitability of locally available perennial tree species to be used as such pollutant sink should be probed into. The following cropping pattern was found most suited to the prevailing conditions. This contains

Table 5.43 Impact of cement kiln dust on cultivated crops and agricultural income

	Polluted zone (1-7 regions) 1983-84	Polluted zone (1-7 regions) 1986-87	Per cent difference of (2) from (1)	Control zone (8th region) 1983-84	Control zone (8th region) 1986-87	Per cent difference of (5) from (4)	Per cent difference of (4) from (1)	Per cent difference of (5) from (2)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
I								
1. Paddy Virippu Mean per cent to G.C.A.	59.897	53.581	-10.545	59.450	61.120	2.809	-0.030	12.330
Mean yield (tonnes/ha)	2.729	2.409	-11.726	2.900	2.350	-18.966	5.897	-2.511
2. Paddy Mundakan Mean per cent to G.C.A. of double cropped land	35.921	23.237	-35.311	14.280	13.580	- 4.902	-60.246	-41.559
Mean yield (tonnes/ha)	2.257	1.907	-15.507	2.480	2.280	-8.060	9.880	19.560
3. Vegetables Mean per cent to G.C.A.	3.131	6.431	105.398	2.280	2.240	-1.754	-27.180	-65.160
4. Chilli Mean yield (tonnes/ha)	10.568	9.013	-14.714	10.198	10.198	0	-3.501	13.148
5. Ground nut	7.697	13.321	73.067	6.380	9.650	51.254	-17.111	-27.558
Mean per cent to G.C.A. Mean yield (tonnes/ha)	1.913	1.564	-18.246	2.100	2.100	0	9.775	34.271
6. Cotton Mean per cent G.C.A.	8.025	2.490	-68.972	11.390	10.660	-6.409	41.930	328.112
7. Mean yield (tonnes/ha)	2.215	0.893	-59.684	1.300	2.030	56.154	-41.301	127.236
7. Coconut: Per cent to G.C.A.	8.074	9.551	18.300	3.990	5.050	26.566	-50.582	-47.126
Yield nuts/ha/annum	2046	1398	-31.692	3578	3575	-0.084	74.878	155.722
8. Sugarcane: Per cent to G.C.A.	4.033	3.249	-19.450	14.810	8.980	-39.365	267.220	176.393
Yield/ha (tonnes)	68.586	64.583	-5.836	69.00	68.50	-0.725	0.604	6.065
9. Banana: Per cent to GCA	1.945	2.700	38.817	1.12	1.09	-2.679	-42.416	59.630
Yield (kg/bunch)	11.060	10.603	-4.129	14.00	14.00	0	26.582	32.038
II. Agrl. income: Rs.'000/annum per hectare at 1983-84 prices	6.099	5.684	-8.439	5.520	5.860	6.159	-9.493	4.943

fallow period coinciding with the severly polluted season followed by crops, the vegetative phase of which will be over only by the time easterlies become less prevalent.

Paddy and/or groundnut (May-June to July-August)	Ground nut and/or vegetables (August-September to November-December)	Fallow (December-January)	Maize and/or cotton and/or grams (January-Feb. to April-May)

It is imperative to use soil amendments like red soil and organic manure in land preparation. The practice of washing off the dust deposit from the plants requires heavy labour and water input and cannot completely prevent or counter damages caused by cement kiln dust. The real cost of pollution borne by the farm sector comprises of higher net return forgone from the present day occupation (by a lower cost of production, higher yield per unit area and better quality of produce attainable in a pollution free situation), indirect effects on ecosystem in the long run and the forgone income from other possible and more profitable enterprises. The last two aspects are yet to be investigated.

Summary

SUMMARY

Many researchers like Ayres and Kneese (1969), Nijkamp (1974), Canter (1977) and Siebert (1987) have ascertained the present day significance of environmental externalities originating from different paths of economic growth. There are environomic models operational at regional level. For instance, the input-output model by Leontief (1972) and the two layer projection by Anderson and Hafkamp (1984). In impact assessments, the need for micro level investigations into the repercussions of pollution on the major occupation of affected people cannot be over emphasised. Many have pointed out deformations in flora dusted with cement factory effluents (Darley et al. (1966), Oblisami et al. (1978) and Kubikova (1981)) and consequent reduction in crop yield.

An economic enquiry into the impact of cement kiln dust on agriculture was carried out based on farmers' perception, during 1987-89. The objectives were to study the socio-economic situation in the polluted area and to arrive at the impact of cement kiln dust on agriculture. Easterlies prevailing in November to March season determined the intensity and dispersal of cement kiln dust

from the source of emission. Simple random sample of 105 cultivators having farms located at different distances from the plant upto 20 km. south-west and 20 farmers from the control zone were selected as informants.

The average family size of respondents in the polluted zone (zone one) was five. In the control zone (zone two) it was six. For the polluted and control zones, the average age was 45 and 42 years respectively. Most of the family members of interviewed farmers were educated upto primary school level forming 30.63 per cent and 28.03 per cent in the first and second zones.

More than 57 per cent of the respondents in the first zone and 39 per cent in the control were deriving their livelihood from farm sector alone. The maximum frequency class of holding size was between one and two hectares in the polluted zone (33.34 per cent) and less than one hectare in the control (47.84 per cent). The relatively illiquid assets (71.99 per cent of the total value was for agricultural assets in the polluted zone while it was 49 per cent in the control) possessed by farmers in the polluted area were also characterised by low value (109.78 in Rs. '000) in the first region and 175.70 in the control). As suggested also by liabilities largely comprising of overdues (68.70 per cent in the polluted zone and 49.75 per cent in the control), there was an over representation of economically weaker population in the polluted area.

Foliar deposit of cement kiln emissions (0.17 to 4.4 mg/cm^2/10 days for 6 kms south west of the plant) depended on climate, phylloplane characters and phyllotaxy. Cropping intensity in general, declined with distance in accordance with the non agricultural occupations of the informants and seasonal supply of water for irrigation.

Area response of crops since the inception of the plant (from 1983-84 to 1986-87) indicated a decline in proportion to gross cropped area of paddy (35.31 per cent), cotton (68.97 per cent) and sugarcane (19.45 per cent). For the control zone these were 4.90 per cent, 6.41 per cent and 39 per cent. For vegetables, ground nut, coconut and banana, the percentage to gross cropped area increased by 105.40 per cent, 73.07 per cent, 18.30 per cent and 38.82 per cent in the polluted zone. Percentage to gross cropped area of vegetables and banana in the control zone decreased by 1.75 per cent and 2.68 per cent respectively. Regarding ground nut and coconut, control zone also had an increase over the period under consideration by 51.25 per cent and 26.57 per cent respectively. Area response was influenced also by access to irrigation. Substitution of second crop paddy with vegetables and groundnut was evident.

Yield response of crops to pollution by cement kiln dust implied an adverse effect for all crops, significant upto six kms south west of the plant. The mean yield/ha of paddy (second crop) in the control zone was 19.56 per cent higher than the polluted zone, accounting for a loss of 268 tonnes of paddy/annum in the polluted zone. Yield/ha of groundnut, cotton and coconut in the control compared to the first zone were higher by 34.27 per cent, 127.24 per cent and 155.72 per cent respectively. The estimated annual loss was of 169 tonnes of ground nut pods, 20.50 tonnes of cotton kapas and 139328 coconut in the polluted zone.

Distance from the plant caused 77 per cent of yield response in second crop paddy over the regions in the first zone. Irrigation as an explanatory factor assumed importance in determining paddy yield, as the environment became free of cement kiln dust. Chilli yield in the polluted zone was 13.15 per cent lower than the control. Distance emerged the most significant variable which along with fertilizer and labour input explained 89.42 per cent of yield response in chilli. Labour incurred in washing off the dust having a positive influence on yield, however was economically disadvantageous.

Out of the total variation over the regions away from the plant, the distance factor alone could explain 37.40 per cent, in groundnut yield. In the case of cotton, distance together with irrigation explained 69.85 per cent of yield response.

Retarded growth in groundnut, discoloured cotton fibres, foliar yellowing in paddy and coconut, and eventual drying of coconut foliage were observed along with declining yield levels in areas affected by the pollutant during November to March. Farmers perceived that the increased pest incidence, high chaff content, reduced tillering and delayed emergence of panicle in paddy; leaf crinkling, severe flower shedding and poor seed germination in chilli; stunting, smaller kernels and increased pest incidence in ground nut as due to cement kiln dust. Reduction in yield was evident in banana, maize, pulses, sugarcane, cashew and mango.

Net return from unit area of paddy and ground nut in the first three regions of zone one were considerably lower to that in the control zone. Income from crop enterprises per hectare of land at 1983-84 prices declined in the polluted zone by 8.44 per cent between 1983-84 and 1986-87, while the control area had shown a gain of 6.16 per cent. Annual income from agriculture per hectare of land in different regions of the polluted zone were on par, because of the reciprocal variation in cropping intensity (due to non-agricultural occupations and seasonal supply of water for irrigation) and crop yield (due to cement kiln dust in the environment) While the relative land use pattern and cropping intensity failed to explain significantly any variations in farm income/ha, out of the 7.65 per cent of explained variation, 4.54 per cent was accruing to the distance factor, for the first zone as a whole. Upto six km south west of the source of pollution, significant variation in annual income from agriculture was explained upto 12.64 per cent, of which 9.70 per cent was accounted for by distance and area under ground nut.

The negative impact of cement kiln dust on agriculture was significant upto six kms south west of the source of emission. Here, a distinct environmental externality existed for cement production with respect to agriculture. This was manifested through its effect on increasing cost of production, reducing yield level, deteriorating the quality of produce and foreclosing profitable alternative enterprises. The last aspect of the above and the long run ecological impact of the cement plant need further investigation.
A co-ordinated appraisal of the opportunity cost of externality and effective pollution control measures are imperative. Under the prevailing conditions, cultivators can adopt windbreaks as pollutant sink, soil amendments to counter the changes caused to soil properties and an apt cropping sequence so as to maximise the net return from unit area.

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* Originals not seen

Appendices

Appendix - 1

Range of specific concentration of elements in cement dust (micrograms/gm)

Berylium	1 - 10
Cadmium	10 - 1000
Chromium	100 - 1000
Copper	0.1 - 1%
Manganese	100 - 1000
Nickel	100 - 1000
Lead	100 - 1000
Antimony	100 - 1000
Strontium	0.01 - 1%
Vanadium	10 - 100

Source: Natusch, D.F.S., Bauer, C.F., and Lah, A. 1978. Collection and analysis of trace elements in the atmosphere. In Air Pollution Control Part III Measuring and Monitoring Air Pollutants. Strauss Warner (Ed.). Wiley Inter Science. New York. pp.221.

Appendix-2

Norms for dust emission for cement plants with more than 200 tonnes per day capacity

	Dust load
Protected area	150 mg/Nm^3
Other areas	250 mg/Nm^3

Individual pollutants (mg/Nm^3)

	Suspended particulate matter	SO_2	NO_2	CO
Industrial and mixed area	500	120	120	5000
Residential area	200	80	80	2000
Sensitive area	100	30	30	1000

Source: Chief Executive Officer, Workshop on pollution comtrol in cement industry. 6.2.86, New Delhi.

Appendix - 3

Interview schedule for farmers to assess the economic impact of cement kiln dust on agriculture

No. Date of interview:

I. Identification

a) Name of the farmer :

b) Address :

Village :

Panchayat :

Taluk :

District :

c) Location of the farm with respect to the source of emission (distance) :

d) Family details :

Members	Age (as on last Onam)	Sex	Educational status	Occupation		Income	
				Main	Sub	Main	Sub

II. LAND HOLDING DETAILS

	Wet land	Dry land	Garden land	Total
1. a) Area owned				
b) Leased out (-)				
c) Leased in (+)				
d) Net area operated				
2. Uncultivated area				
3. Net area cropped (1d-2)				

III. STRUCTURAL CHANGES IN CROPPING PATTERN

Crop	Area					Source and mode of irrigation
	Dry land	Wet land		Garden land		
		UI	I	UI	I	
Existing						
1984						

UI = Unirrigated
I = Irrigated

IV. TEMPORAL VARIATION IN FARM INCOME

Crop	Area	Production per annum	Price	Market (with distance)	Returns over
1984					
Current year					

V. PREFORMANCE OF CROPS IN THE POLLUTED ENVIRONMENT

a)

	With retained foliar deposits low/moderate/ severe	Without foliar deposit
Tolerant		
Resistant		
Most affected		

b) Constraints if any in adopting crops with better performance:

c) Symptoms expressed by affected crops

Crop	Proportion of total area	Plant part	Symptom

d) Qualitative degradation

Crop	Produce	Nature of degration	Price differential

VI. PEST RESURGENCE OR SUPPRESSION, IF ANY

Crop	Area	Pest	Resurgence of suppression	Year and season	Low/ moderate/ severe

VII. MEASURES FOR POLLUTION ABATEMENT IN CROPS

Crop	Area	Measure adopted	Labour		Other inputs		Total
			M	W	Input	Cost	

VIII. ASSETS

1. Land holding — Present value:

2. Buildings and other structures

	Year of construction	Expected life	Present value
Residential building			
Cattle shed			
Farm shed			
Store			
Water tank			
Pond			
Compound wall			

3. Farm implements and machinery

Item	Specification	Year of purchase	Purchase value
a) Implements			
Country plough			
Improved plough			
Levelling plank			
b) Hand tools			
Spade			
Pickaxe			
Sickle			
c) Machinery			
Tractor			
Power tiller			
d) Transport			
Bullock cart			
Hand carts			
e) Plant protection			
Hand sprayers			
Power sprayers			
Dusters			
f) Dairy equipments			
Feed tray			
Milk cans			
g) Temporary			
Baskets			
Bamboomats			
Ropes			

4. Irrigation structure and equipment

Item	Specification	Year of construction/purchase	Value at purchase/construction
Well			
Tube well			
Pumpset			
Pond			
Pump shed			
Channels			

5. Livestock

Description	Breed	Age	Year of purchase/birth	Purchase price	Present worth
a) Milch animals					
Buffaloes					
Cows					
b) Young stock					
Heifers					
Male					
Female					
Buffaloes					
Male					
Female					
c) Drought animals					
d) Goats					
e) Poultry					

6. Household articles

Item	Year of purchase	Present worth
Radio		
Sewing machine		
Bicycle		
Motor cycle		
Scooter		
Motor car		
Fan		
Pressure cooker		
Electric iron		
Almirah		
Boxes		
Furniture		
Utensils		
Others		

LIABILITIES	Amount	Source	Terms of repayment
Short term loans			
Medium term			
Long term			

IX. INPUTS AND COSTS (OPERATIONAL ANALYSIS)

Crops and season	Area	Planting material		Human hired		Labour family		Bullock hours	Labour/ tractor charge	Power total cost
		Qty.	Price	M	W	M	W			

	Manuring and fertilizer application							Inter culture				Irrigation
Item	Price	Qty. FP	Qty. P	Hired M	Hired W	Labour family M.	Labour family W.	Hired M	Hired W	Labour family M	Labour family W	

Irrigation				
Hire charge	Hired M	Hired W	Labour Family M	Labour Family W

(Contd.)

		Plant protection							Miscellaneous			Harvesting							
					Labour							Labour				(Labour			
					H		F					H		F		H		F	
Crop	Area	Item	Price	Qty. M	M	W	M	W	Item	Price	Qty.	M	W	M	W	M	W	M	W

X. OUTPUT AND RETURNS:

Crop and season		Total products			Total value				Total	Remarks
	Main Qty.	Output price	By - Product		Main Output		By product			
			Qty.	Price	Q	P	Q	P		

XI. INDIRECT EFFECTS OF POLLUTION ON AGRICULTURE

Effect on

a) Soil :
b) Pond and well water :
c) Human health :
d) Livestock :

	No.	Age	Av. income month	Milk yield during last completed lactation	Incidence of death for the last 4 years	Mode of menace	
						Health care cost	Quality of produce
Bullock							
Cow							
Goat							
Poultry							
Buffaloe							

e) Sericulture :

f) Physical infrastructure:

g) Others if any :

AN ECONOMIC ENQUIRY INTO THE IMPACT OF CEMENT-KILN DUST ON AGRICULTURE BASED ON PERCEPTION OF FARMERS

By

SEEMA. P.

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University

Department of Agricultural Economics
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur
KERALA

1989

ABSTRACT

An economic enquiry into the impact of cement-kiln dust on agriculture was carried out based on farmers' perception during 1987-89. The objectives were to study the socio-economic situation in the polluted area and to arrive at the impact of cement-kiln dust on agriculture. Easterlies prevailing in November to March season determined the intensity and dispersal of cement kiln dust from the source of emission. Simple random sample of 105 cultivators with farms located at different distances from the plant upto 20 kms south west and 20 cultivators from the control zone were selected as informants.

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in the polluted zone and 49.75 per cent in the control), there was an over representation of economically weaker population in the polluted area.

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Distance emerged as the most significant explanatory factor of crop yield for paddy, groundnut, chilli, coconut and cotton in the polluted zone. Fertilizer and labour for chilli yield and irrigation in the case of cotton were also significant.

Retarded growth in ground nut, discoloured cotton fibres, foliar yellowing of paddy and coconut, and eventual drying of coconut foliage were observed along with declining yield levels in areas affected by the pollutant during November to March. Farmers perceived that the increased pest incidence, high chaff content, reduced tillering and delayed emergence of panicle in paddy; leaf crinkling, severe flower shedding and poor seed germination in chilli; stunting, smaller kernels and increased pest incidence in ground nut as due to cement kiln dust. Reduction in yield was evident in banana, maize, pulses, sugarcane, cashew and mango.

Income from crop enterprises per hectare of land at 1983-84 prices declined in the polluted zone by 8.44 per cent between 1983-84 and 1986-87, while the control area had shown 6.16 per cent improvement. Upto six km south west of the source of pollution, variation in annual income from agriculture was significantly explained upto 12.64 per cent by the selected factors of which distance and area under ground nut accounted for 9.7 per cent variation. Net return from paddy and ground nut in these regions were considerably lower to that in the control.

Under the prevailing conditions, in order to maximise net return, farmers in the affected area (upto six kms south west) can adopt suitable wind breaks, soil amendments and cropping sequence.