INVESTIGATIONS INTO THE LEVELS OF PESTICIDES AND HEAVY METALS IN AND AROUND OUSSUDU LAKE, PUDUCHERRY

Submitted to

The Department of Science Technology and Environment (DSTE), Puducherry

March 2015


SACON

ACKNOWLEDGMENTS

We express our gratitude to the persons, listed below in alphabetical order, for helps, assistance and suggestions that were valuable in successful completion of the project.

- Dr. B. Anjan Kumar Prusty, Senior Scientist, GUIDE, Bhuj
- Dr. Babu Rajendran R, Professor, Bharathidasan University, Trichy
- Dr. BhaskarRao YJ, Director, NGRI, Hyderabad
- Dr. Bhuvaneshwari R, Scientist, Centre for International Co-operation in Science (CICS), Chennai
- Dr. Dayalane R, Microbiologist, Puducherry Agro Service and Industries Corporation Ltd. (PASIC), Puducherry
- Dr. Dwarakanath M, Director, DSTE, Puducherry
- Dr. Rama Mohan Kurakalva, Senior Scientist, NGRI, Hyderabad
- Dr. Subramanian P, Professor, Tamil Nadu Agricultural University (TNAU), Coimbatore
- Dr. Vijay Kumar V, Additional Director, GUIDE, Bhuj
- Mr. E. ShivaKumar, DSTE, Puducherry
- Mr. Ganni RP, Agilent Technologies (India) Pvt. Ltd., Bangalore
- Mr. Mishra SR, JRF, GUIDE, Bhuj
- Mr. Radhakrishnan V, Hydrogeologist, Directorate of Agriculture, Puducherry,
- Mr. Radjavel S, Agricultural Officer, Department of Agriculture, Puducherry
- Mr. Ravi R, Driver, SACON, Coimbatore
- Mr. Shanmurgan R, Manager, PASIC, Puducherry
- Mr. Sharma G, JRF, GUIDE, Bhuj
- Mr. VijayKumar A, Deputy General Manager, PASIC, Puducherry
- Ms. John SS, Puducherry Water Resources Organisation (PWRO), Puducherry
- Ms. Swathy KS, Cochin University of Science and Technology (CUSAT), Cochin

This report includes primarily data generated during field surveys, and analysis of environmental samples. Information is also collected from published and unpublished reports, articles, books and other documents, which are listed under reference section. We profusely thank the authors of these documents and those who shared valuable information with us. In case any document or person, from which information was drawn, but inadvertently missed out to quote, we express our apologies.

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

TABLE OF APPENDICES

1. INTRODUCTION

Wetlands in urban areas draw attention of diverse stakeholders for providing several ecological goods and services. At the same time, they are always at receiving end of anthropogenic pressures due to urbanization and also industrialization in some cases. The problem gets aggravated in cases where urban wetlands are in close proximity to farmlands or amidst agricultural landscape. Among several anthropogenic impacts, one of the predominant ones is the inflow of several chemicals due to human, agricultural and industrial activities. In the recent past, wetlands are facing serious threats due to anthropogenic activities and many of the wetlands are fading and getting transformed (Mitsch and Gosselink 2000).

Heavy metal pollution has accelerated dramatically in recent years due to increasing industrialization, leading to highly contaminated biosphere and atmosphere (Al-Farraj et al. 2013). Industrial wastes are a major source of pollution that originate from mining industries, chemical industries, metal processing industries, and the like. Nevertheless, heavy metals also occur naturally in the ecosystem (Kabata-Pendias 1993) with large variations in concentration. River sediments, derived because of weathering, are a major carrier of heavy metals in the aquatic environment, the physico-chemical processes involved in their association being precipitation, adsorption, chelation, etc. Besides the natural processes, metals may enter into the aquatic system due to anthropogenic factors such as mining operations, disposal of industrial wastes and applications of biocides for pest, etc. Heavy metal in soil is of major environmental concern as their transport ultimately leads to deterioration of other components in the environment (Abolude et al. 2009). Wetlands of tropical and sub-tropical regions like India are characterized by large seasonal fluctuations, which are recognized as a component of normal environment for vegetation adaptation to habitats (Charan et al. 2008).

Increasing pressure on agricultural industry to produce better quality crops in a cost effective manner has led to the usage of chemical fertilizers and pesticides as a dependable component (Mahdavian and Somashekar 2010). Pesticides, due to their slower decomposition rate and longer half-life, remain in the environment for longer durations and put forth detrimental effects on non-target organisms (Muralidharan

2000). Wetlands suffer the maximum as the agricultural runoff finally finds its way into aquatic systems. Application of chemical pesticides in India started in 1948, while the production started in 1952. The pesticide consumption in India during 1954-2000 revealed that it has increased from 434 MT to 46195.16 MT (Bhardwaj and Sharma 2013). There has been a steady growth in the production of technical grade pesticides in India, from 5000 MT in 1958 to 85000 MT in 2009-2010 (Directorate of Plant Protection and Quarantine 2011, Subramanyam et al. 2012). Nevertheless, pesticide consumption in India is low (~500 g/ha) compared to other countries like Japan (12 kg/ha) and Germany (3 kg/ha). Organochlorine pesticides are extensively used for pest and vector control in India. They are characterized by high persistence, low polarity, low aqueous solubility and high lipophilicity and as a result, they have potential to bioaccumulate in fatty tissue and subsequent biomagnification.

According to Azeez et al. (2007), wetlands located in vicinity of agricultural fields are chiefly affected by agro-chemicals. As the threat to water systems and the mechanisms that cause water to become polluted are now better understood, measures are required to protect the quality of water (Agrawal et al. 2010, Chandra and Azeez 2010). Thus, recognizing the importance of protecting such water bodies, the Government of India launched National Wetland Conservation Programme during 1985-1986 (Ministry of Environment, Forest and Climate Change). This programme involved several steps towards arresting further degradation and shrinkage of water bodies due to encroachment, siltation, weed infestation, catchment erosion, surface runoff carrying agro-chemicals, and discharge of domestic sewage and effluents. Several factors *viz*., seasonal rainfall, high soil permeability and subsequent leaching, and widespread use of agro-chemicals render urban lakes potentially susceptible to the influx of chemicals.

In India, wetlands occupy an estimated 15.26 million ha, which is ~4.6% of the geographical area of the country (SAC 2011). Puducherry, earlier Pondicherry, well known for its wetlands, has 82 major and small wetlands in and around the town. Puducherry, ~162 km south of Chennai, is located on the Coromandel Coast between 11°46' and 12°30' North and 79°36' and 79°52' East. The Union Territory of Puducherry comprises of four coastal regions namely Puducherry, Karaikal, Mahe and Yanam. Puducherry and Karaikal are situated on the East Coasts in Tamil Nadu, Yanam on the

East Coast in Andhra Pradesh, and Mahe on the West Coast in Kerala. Its boundary on the east is the Bay of Bengal and on the other three sides are Cuddalore and Villupuram districts of Tamil Nadu state. The predominant land use category of the catchment in the region is agriculture (Abbasi and Chari 2008, Prusty et al. 2011). The cropping pattern indicates that paddy is grown in about 26000 ha, pulses in 6000 ha, sugarcane in 2500, groundnut in 1200 ha and vegetables in 750 ha (Promotion of Eco-friendly Technologies, KVK-Pondicherry 2007).

1.1. ORIGIN OF THE STUDY

Puducherry, well known for wetlands, has 02 major wetlands i.e. Oussudu and Bahour. These wetlands provide livelihood for the residents in close proximity. Oussudu lake, also known as the Ousteri lake is the largest lake in Puducherry region and is abode to several migratory bird species. It is one of the largest breeding sites for the Common Coot in South India (Chari and Abbasi 2003). The lake is identified as one of the heritage sites by IUCN (International Union for Conservation of Nature and Natural Resources) and has been ranked among the most important wetlands of Asia (Davidar 2011). Oussudu wetland was declared as a bird sanctuary by the Government of Puducherry in 2008 (Prusty et al. 2011). The lake is surrounded by around 18 villages practising agriculture. According to Abbasi and Chari (2008), around 50% of these villages depend on Oussudu lake for irrigation purpose. The shift in agriculture practice in recent years from organic farming to chemical farming, which involves various groups of pesticides, is presumed to have caused tremendous pressures on this lake. Abbasi and Chari (2008) and Prusty et al. (2011) mentioned that due to the elevation contours of 40m and 20m above MSL towards North and Northeast, there is a potential risk of runoff rich in nutrients, pesticides and sediments finding ways into Oussudu waters. In the recent past, the lake had been subjected to enormous pressures due to the increasing population and industrialization. In addition to this there are around 25 industries (Source: CII, Puducherry chapter), which serve as non-point source of pollution for various heavy metals. Thus, Oussudu lake may be a convenient recipient for unloading industrial wastes from the nearby-located industries. The industrial establishment within the watershed area of Oussudu is a major concern as these industries can increase the level of pollution in the catchment (Chari and Abbasi 2003). Thus,

agricultural runoff along with metal leachate from industries neighbouring the wetland may find way to this wetland.

There has been widespread concern about the long-term effects of chemicals used in agriculture. The activities associated with agriculture and urban land uses bring dramatic ecological changes that may directly affect the Oussudu basin quality. These pressures have placed significant stress on Oussudu wetland ecosystem. Given the shift in farming practice over the years from organic to inorganic and industrialization in the region, we undertook a survey in both upstream and downstream villages surrounding Oussudu to i) assess the usage of agro-chemicals, changes in cropping pattern and farming practice, ii) analyze the samples for pesticide residues and heavy metal concentrations collected from agricultural fields, and iii) analyze samples collected from nearby industrial areas. The study aimed at identifying villages as a model wherein organic farming could be promoted in future by the Puducherry Government as a long-term wetland management.

1.2. OBJECTIVES

The objectives of the present study were to:

- Assess the intensity of use of agro-chemicals in the area,
- Examine the extent of pesticide residues reaching the lake and various biological and non-biological matrices, and
- Quantify the level of heavy metals input in different environmental matrices.

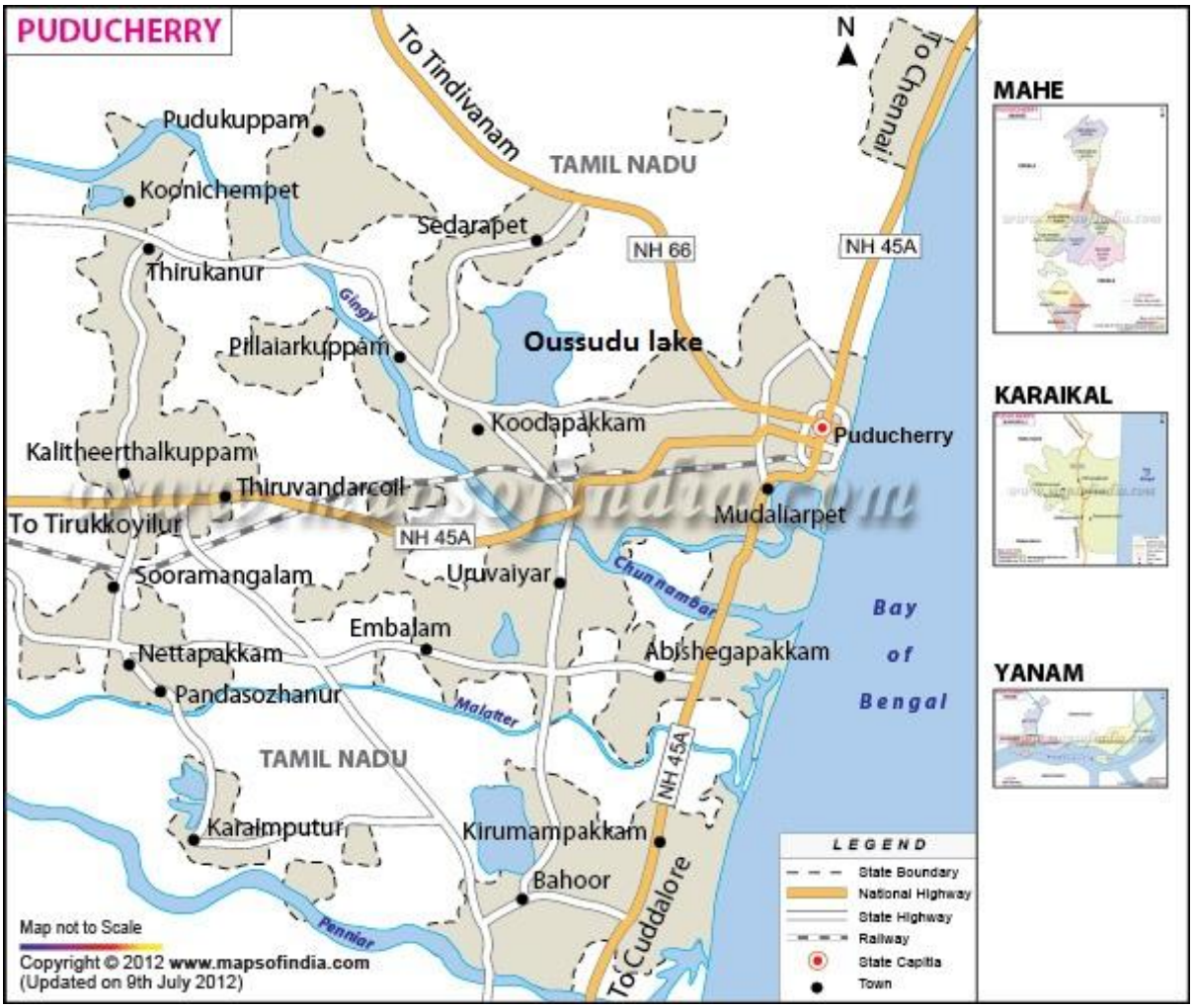

Figure 1. Study area map

2.2. GEOGRAPHY AND PHYSIOGRAPHY

Puducherry is situated along the Coramandel coast. The three major physiographic units present in Puducherry are i) coastal plains, ii) alluvial plains and iii) uplands (Source: State Ground Water Unit, Department of Agriculture, Puducherry). The landscape of this area is a product of the Cretaceous, Paleocene, Eocene, Mio-Pliocene, of recent eras (Abbasi and Chari 2008). The area comprises of charnockite overlain by a cover of sedimentary sequence. Landforms of the area are marine, fluvial and fluvio-marine regimes each sustaining individual soil assemblages. Oussudu watershed comprises mostly of alluvium, Manaveli clay stone, and Vanur sand stone.

2.3. HYDROLOGY

Oussudu lake has a circumference of 7.275 km and catchment area of 15.54 km^2 (Table 1, Abbasi and Chari 2008). It receives water from Suthukeni check dam through Suthukeni canal and runoff from the lake basin. The Suthukeni check dam is constructed across Sankarabharani river. The major water source for the Suthukeni dam is the excess water from Veedur dam (Figure 2) located in Viluppuram district, Tamil Nadu (Prusty et al. 2011).

Prior to the year 2004, Oussudu lake was a dynamic seasonal wetland that went almost completely dry during June - September. This seasonal drying helped the wetland in maintaining diverse ecological functions. However, the outflow was restricted from 2004 onwards and the lake has never been dry ever since. The lake earlier was drained before the SW monsoon and the water was used for irrigation downstream.

Table 1. Hydrology and structures associated with Oussudu lake

Sl. No.	Particulars	Details
1	Circumference of the lake	7.275 km
2	Ayacut	15.68 km^2
3	Free catchment area	10.36 km^2
4	Intercepted catchment	5.18 km^2
5	Combined catchment	15.54 km^2
6	Capacity of the lake	540 mcft
7	Full tank level	+14.184 m
8	Maximum discharge capacity	92.99 cumecs
Source: Tourism Department records, Government of Puducherry		

Figure 2. A view of Veedur dam

2.6. CLIMATE

The area experiences humid and tropical climate with an average annual rainfall of 1200mm. Of this, 63% occurs during monsoon and the remaining is scattered sporadically throughout the year. Mean temperature ranges from 28°C in winter to 39°C in summer (Abbasi and Chari 2008).

2.7. INDUSTRIAL ACTIVITIES AND HUMAN SETTLEMENTS AROUND THE LAKE

The prominent industries found near the lake are glass industry, rubber industry, coir industry, cosmetic industry, brewery, dairy, and plastic moulding factory. The major human settlements near the lake are Agaram, Karasur, Katterikuppam, Koodappakkam, Kurambapet, Oussudu, Pathukannu, Poothurai, Poraiyur, Ramanathapuram, Sedarapet Thondamanatham, Thuthipet and Villianur (Prusty et al. 2011).

3. METHODOLOGY

The survey and sampling involved (i) identification of sites/villages for intensive survey (Figure 3), (ii) collection of samples i.e. sediment, water, soil and crop (Figure 4), (iii) processing the samples for basic characterization and estimations of nitrogen (N), phosphrous (P), and potassium (K) levels, iv) quantifying select heavy metals (copper, chromium, nickel, zinc) and pesticide residue levels in samples, and (v) identifying some villages wherein organic farming can be promoted in future by the Puducherry Government. Secondary information on cropping pattern, agro-chemical usage, dependency on Oussudu Lake, etc. was gathered from various line departments of Government of Puducherry, and other published research articles and reports. Additionally, questionnaire surveys in several villages near Oussudu Lake were carried out for two months to substantiate the information on various aspects of the lake environment. Subsequently, sample collection and analysis was done following standard scientific methods.

3.1. AGRICULTURE SURVEY

To assess the intensity of use of agro-chemicals in the area, agricultural activities, and usage pattern of chemical fertilizers and pesticides, secondary data were obtained from Puducherry Agro Service and Industries Corporation Ltd. (PASIC), Directorate of Agriculture, Directorate of Economics and Statistics, shopkeepers and authorized suppliers of agro-chemicals, etc. Questionnaire (Appendix 1) based field surveys were conducted in villages around Oussudu Lake to gather information about cropping pattern, agro-chemical usage, total land holdings, dependency on Oussudu or any lake, etc. In total 22 villages *viz*., Agaram, Ammanakuppam, Auroville, Karasur, Kasipalayam, Katerikuppam, Koodapakkam, Mangalam, Nadupalayam, Oruvaiyur, Oussudu, Perambai, Pillaiyarkuppam, Pothurai, Poraiyur, Ramanathapuram, Sedarapet, Sellipet, Thiruchitrambalam, Thondamanatham, Thuthipet and Valupatalampalayam were surveyed (Figure 3) and subsequently sampling locations (Figure 4) were identified. From each village, 4-5 farmers were interviewed. For collecting information on agro-chemical usage, villages in both Puducherry and Tamil Nadu were covered based on upstream and downstream flow of water.

Figure 3. Map showing villages where questionnaire surveys were conducted

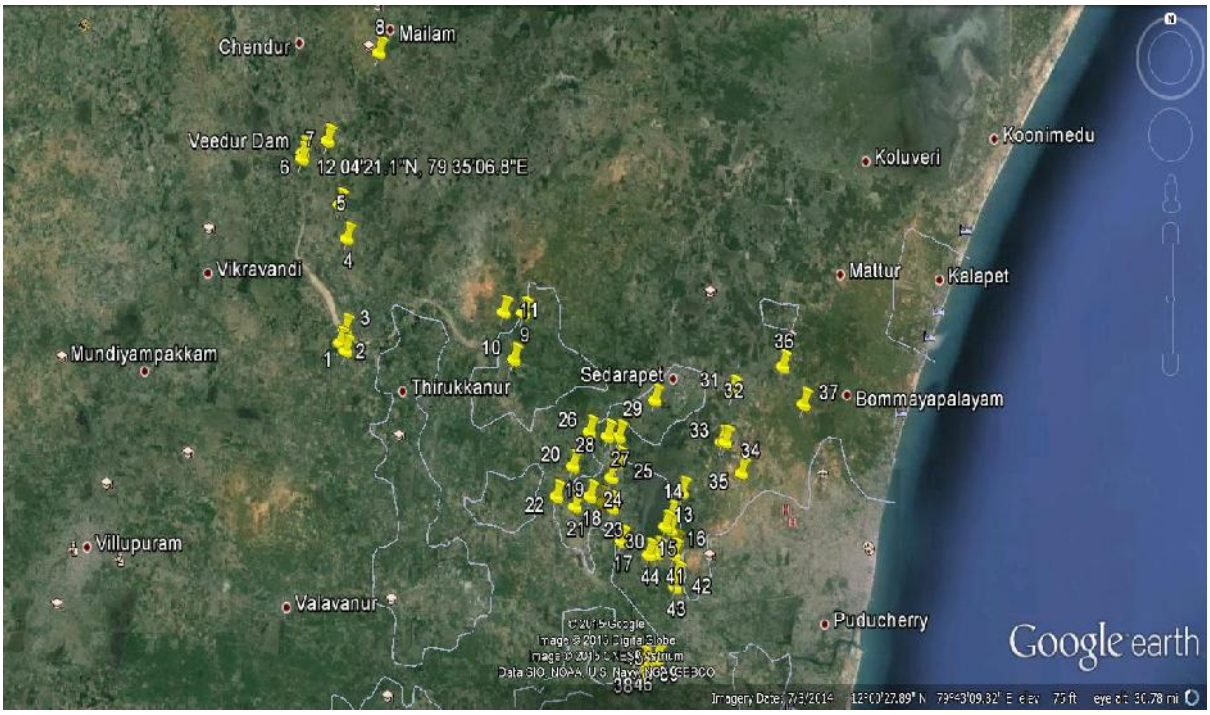

Figure 4. Map showing sampling sites

fertilizers, pests/weeds infestation, crop-wise application rate, frequency of application, source of irrigation, chemical group, quantity and mode of application, cropping pattern and common crop pests, etc. Attempts were made to gain information on the shift in cropping practice, if any, over last 30 years. This helped in screening the upstream and downstream villages and fixing up the sampling stations.

3.2. SAMPLING

Based on the secondary information and questionnaire survey results, sampling locations were identified (Appendix 2). Selection of sampling sites was based on the following criteria:

- location of the village with respect to Oussudu lake,
- elevation of the village / sampling location,
- major cropping practice,
- organic farming, if practiced,
- broad groups of agro-chemicals being used in the farm lands, and
- proximity of the location to industries, if any.

These criteria helped us in anticipating probable source of contaminants to the wetland ecosystem, if any. To quantify the levels of heavy metals and chemical pesticide residues input into the wetland ecosystem, and their levels in different matrices, standard systematic sampling of different environmental samples was done followed up by appropriate laboratory analyses. Thus, subsequent to the reconnaissance, select villages as well as select locations in and around Oussudu Lake were prioritized, from where different samples were collected. From wetland sites: dam/reservoir, river bed sediment, water and aquatic vegetation were collected. From agricultural fields: soil and crop samples were collected (Figure 5). Attempts were made to get representative sample from sites both in upstream and downstream locations. All the samples were labelled and packed in clean polythene bags, transported in icebox to the laboratory and stored in refrigerator / deep freezer until further processing.

A

B

Figure 5. Sample collection in and around Oussudu lake

water from industrial units, etc. Soil samples were also collected from nearby industries and analyzed for heavy metal content. Samples of various matrices from 34 locations were collected during the survey. One portion of these samples was analyzed for pesticide residue levels and the other for heavy metals (copper, chromium, nickel, and zinc). Soil and sediment samples were analyzed for basic characterization and also for levels of nitrogen (N), phosphorous (P) and potassium (K). For pesticide residue levels, the plant samples were segregated into root, stem, leaf and fruit/grain. All the samples collected during the study were processed following standard methods (Walkley and Black 1934, Allen 1989, Anastassiades et al. 2003, Tandon 2005).

Samples for pesticide residues were homogenized and extracted with appropriate suite of organic solvents following QuEChERS method. The elute was concentrated on a rotary evaporator, and residues of pesticide groups were quantified on SIM mode using Gas Chromatography-Mass Spectrometry (GC-MS) at National Geophysical Research Laboratory (NGRI), Hyderabad. An aliquot from the final extract was injected into a GC-MS equipped with appropriate detectors (Perkin Elmer). A mixture of synthetic standards from Supelco was used to calibrate the instrument. The final extracts were analyzed for following 18 pesticide residues: i) alpha-BHC, ii) beta-BHC, iii) gamma-BHC (Lindane), iv) delta-BHC, v) Heptachlor (Purified), vi) Aldrin, vii) Heptahlorepoxide Isomer, viii) gamma-Chlordane, ix) alpha-Chlordane, x) 4,4'-DDE, xi) Dieldrin, xii) Endrin, xiii) Endosulfan-I (alpha), xiv) 4,4'-DDD, xv) Endrin Aldehyde, xvi) 4,4'-DDT, xvii) Endrin Ketone, and xviii) Methoxychlor. The concentrations of the individual compounds were quantified from the peak area of the sample to that of the corresponding external standard. The minimum detection limit for all the compounds analyzed was 1 μg/L.

For basic characterization, soil/sediment samples were air dried at room temperature (Jackson 1958) in the laboratory and homogenized using an agate mortar and pestle. The homogenized samples were then passed through a standard sieve of 02 mm mesh size (Tandon 2005), and stored in pre-cleaned plastic containers until further analysis. pH was analyzed in the soil water extracts (1:5 w/v) using digital electrodes. Total Organic Carbon (TOC, %) was estimated following modified chromic acid wet digestion method of Walkley and Black (1934). Total Nitrogen (TN, %) and Total Available

Phosphorous (TAP, %) were estimated spectrophotometrically using a UV-Visible Spectrophotometer (Perkin Elmer, Lambda 35). Total Nitrogen was determined following persulphate oxidation method of Raveh and Avnimelech (1979) coupled with indophenol blue method of Kaplan (1965). Total Available Phosphorous was determined following both Olsen's method (Jackson 1958) and Bray and Kurtz (1945) method. Concentrations of TN, TAP in the samples were determined using linear regressions. For potassium analysis, the samples were extracted with 1M neutral ammonium acetate solution (Wang and Scott 2001) and analyzed using a Flame Photometer (Systronics-128).

Another portion of samples was processed for heavy metal content analysis. Estimation of Cu, Cr, Ni and Zn was done after digesting the samples following mixed acid digestion technique (Allen 1989). The acid digest was stored in acid-cleaned metal-free polypropylene bottles and later analyzed using Atomic Absorption Spectrometer (AAS). Calibration curves were calculated for metal concentrations. The precision and accuracy of the method was verified by running blanks and internal standards simultaneously. The precision and bias were generally <10%. Re-analysis of pre-analyzed samples showed a recovery rate of 95.2%. For quality assurance throughout the experiments and analyses, all extracting reagents were prepared using metal-free, AnalaR grade chemicals. Reagent preparation was done using double-distilled water, which was prepared using a quartz double distillation assembly.

4. RESULTS AND DISCUSSION

The present study includes i) primary information gathered during a customized questionnaire survey and informal interaction with villagers especially farmers, ii) data and records from various line departments of Government of Puducherry (Appendix 3), and iii) findings from laboratory analysis. These details are described in the following sections:

4.1. AGRICULTURE SURVEY

Twenty-two villages around Oussudu in Puducherry and Tamil Nadu region were surveyed, and the findings in subsequent sections are based on the information collected from 90 respondents (of questionnaire survey). The present survey revealed the followings:

- Intensive agricultural practice was followed in land adjoining Oussudu Lake. Many of the farmers practice monoculture with triple cropping of paddy grown during September - January, February – May, and June - August. The preferred paddy varieties grown in the area were White Ponni, Chinna Ponni, Andhara Ponni, CR 1009, ADT-37 and ADT-45.
- Major crops cultivated in the region included paddy, sugarcane, *Casuarina*, tapioca, groundnut, blackgram and coconut. The farmers also cultivated other crops such as cashew nut, brinjal, lady finger, tomato, chilli, other vegetables, etc.,
- Cropping pattern varied according to seasons, quantity of rainfall and availability of water. During good rainfall and surplus of water, farmers cultivated paddy and/or sugarcane. However, during lean periods farmers choose crops which do not require much water for growth such as cashew nut, *Casuarina*,
- Most of the farmers were using bore-wells for irrigation purpose, and it was evident that for several years Oussudu lake water was not used for agriculture.
- Agro-chemicals usage in the study area started around 30-40 years ago and before that, farmers practiced only organic farming. Farmers apparently got inclined towards inorganic farming for better yield and immediate returns,
- Around 70% of the respondents were reportedly cultivating paddy for past 40 years. Remaining farmers had changed the cropping pattern recently (i.e. in past 15 years) and preferred cultivation of paddy to sugarcane and *Casuarina*,

- Only 03% respondents (from Koodapakkam, Mangalam and Nadupalayam village) were practicing organic farming, wherein Jeevamirtham (a mixture of cow urine, dung, sucrose, flower, soil and water), Azolla, Dhaincha and Neem cake were the major inputs. The questionnaire survey also revealed that the yield from both organic and inorganic farming were similar, and
- Agriculture, the predominant land-use category in Oussudu catchment, is a potential risk as runoff rich in nutrients, pesticides and heavy metals may find ways into lake waters due to extensive agriculture.

4.2. AGRO-CHEMICALS USAGE PATTERN

For the details related to agro-chemicals usage and cropping pattern i) Directorate of Agriculture, Puducherry, ii) PASIC (Puducherry Agro Service and Industries Corporation Ltd.), iii) Department of Agriculture, Vembakeerapalayam, Puducherry, and iv) Directorate of Economics and Statistics, Puducherry were approached. Several agro-chemicals were being extensively used based on the data obtained through questionnaire as well as from other relevant sources. The present study revealed the following:

- use of Persistent Organic Pollutants (POPs) was prevalent in the area and the common ones included Acephate, Carbendazim, Endosulphan, Factomphos Malathion, Monocrotophos and Profenofos (Table 1),
- other compounds being used in the region were Lindane, Dieldrin, Endrin and Aldrin. Along with these, synthetic pyrethroids were also used for improved growth and high yields,
- two banned insecticides i.e. Endosulfan and Polydol (as per The Stockholm Convention on POPs) were used for blackgram, tapioca and cashew nut cultivation in many villages (Table 2). Application of DDT, a banned insecticide, by few farmers in the area was also recorded,
- Apart from pesticides other regular fertilizers such as Aluminium sulphate Diammonium Phosphate (DAP), mixed fertilizers, Potash and Urea were also applied to the crops (Figure 6, Table 3) in large quantities,
- many farmers applied pesticides as a precautionary measure and were unaware of chemical/pesticide names. Thus, they directly consulted with shopkeepers, who were selling pesticides, and

A

B

Figure 6. A snapshot of agro-chemicals sold in a retail shop nearby Oussudu

Endosulphan (25%) > Malathion (20%) and for coconut it was Endosulphan (65%) > Monocrotophos (40%) > Factomphos (20%) > Carbofuran (05%). In the case of blackgram 60% respondents used Endosulphan.

Table 2. Cropwise agro-chemicals used in select villages

Village	Crop	Agro-chemicals used
Poraiyur	Paddy	Acephate, Bifenthrin, Dicholrvos, Dithane M-45, Monocrotophos, Profenofos, Tricyclozole
Koodapakkam	Paddy	BHC, Bifenthrin, Carbofuran, Dicholrvos, Dimethoate, Dithane M-45, Malathion, Monocrotophos, Phorate, Triazophos, Tricyclozole
	Sugarcane	Carbofuran, Phorate
	Banana, *Casuarina*, Blackgram, Groundnut	Phorate
	Brinjal, Tomato	Dimethoate
Thondamanatham	Paddy	Bifenthrin, Endosulfan, Cartap
Ramanathapuram	Paddy	Acephate, Bifenthrin, Dicholrvos, Malathion, Monocrotophos
	Sugarcane	Carbofuran, Metribuzin, Phorate, 2-4-D
	Banana	Bifenthrin
	Casuarina	2'4 D
	Tapioca	Bifenthrin
Pillaiyarkuppam	Paddy	Acephate, Bifenthrin, Carbofuran, Carboryle, Dimethoate, Factomphos, Malathion, Monocrotophos, Profenofos, 710 powder
	Tapioca	Endosulfan, Monocrotophos, 710 powder
	Sugarcane	Carbofuran
	Groundnut	Complex, Gypsum, Potash, 710 powder
Ammanakuppam	Paddy	Acephate, Bifenthrin, Malathion, Monocrotophos, Profenofos
	Sugarcane	Phorate
	Casuarina, Groundnut	710 powder
Agaram	Paddy	Bifenthrin, Dicholrvos, Malathion, Monocrotophos, Polydol, Tricyclozole
	Sugarcane	Atrazin
Valupatalampalayam	Paddy	Bifenthrin, Carbofuran, Cytoxyme, Monocrotophos, Quinalphus, Carboryle, Cartap, 710 powder
	Groundnut	710 powder, Monocrotophos, Cytoxyme

Village	Crop	Agro-chemicals used
	Blackgram	710 powder, Monocrotophos
	Coconut	Carbofuran
Nadupalayam	Paddy	Monocrotophos, Tricyclozole, Bifenthrin
	Sugarcane	2'4 D
	Coconut	Monocrotophos
Karasur	Coconut	Factomphos
	Groundnut	Monocrotophos
	Blackgram	Polydol
Thutipet	Groundnut	710 powder
	Paddy	Carbofuran, Carboryle
Perambai	Paddy	Tricyclozole, Cartap, Triazophos, Monocrotophos, Macozeb, Polydol, 710 powder, Carbofuran, Kitazin
	Groundnut	Carbofuran
Pothurai	Cashewnut	Dimethoate, Dicholrvos, Monocrotophos
	Paddy	Monocrotophos
Kasipalayam	Paddy	Monocrotophos, Malathion, Endosulfan
	Cashewnut	Endosulfan, Polydol, Monocrotophos, Cartap Hydrochloride
	Casuarina	Monocrotophos, Polydol
Thiruchitrampalayam	*Casuarina*	Polydol, Quinalphos
	Blackgram	Bifenthrin, Quinalphos
Mangalam	Paddy	Endosulfan, Bifenthrin, Phorate, Cartap, Monocrotophos, 710 powder, Acepahte, Dicholrvos, Carbofuran, Triazophos
	Tapioca	Endosulfan
	Coconut	Endosulfan, Carbofuran
	Banana	Cartap, Carbofuran
Oruvaiyur	Paddy	Monocrotophos, Macozeb, Phorate, Malathion, 710 powder, Endosulfan, Carboryle, Quinalphos, Carbofuran
	Groundnut	Monocrotophos
Sellipet	Tapioca	Malathion
	Paddy	Monocrotophos, 710 powder, Malathion, Carbofuran, Carboryle
	Sugarcane	Malathion
Auroville	Cashewnut	Monocrotophos, Malathion, Endosulfan, Cypermethrin, Carboryle, Methyl parathion
	Paddy, *Casuarina*	Monocrotophos, Cypermethrin, Carbofuran

Table 3. Fertilizer usage in Puducherry region during 2004 – 2013

Year	Nitrogenous Fertilizers M.T	Phosphoric Fertilizers M.T	Potasic Fertilizers M.T	Complex Fertilizers M.T	Mixed Fertilizers M.T	En & Press Fertilizers M.T	Micro Fertilizers M.T	Neem Cake M.T	Soil Amendments
2004-05	7503.349	1064.048	3242.076	7560.908	587.864	5070.478	84.455	341.048	954.345
2005-06	7212.544	1275.37	2877.831	7924.447	670.397	4592.176	100.398	339.250	652.208
2006-07	6454.023	1014.550	2766.628	7669.852	82.880	3428.563	79.986	307.842	663.650
2007-08	4559.269	453.538	2196.985	6670.014	2.150	3762.700	46.629	252.727	560.700
2008-09	4569.841	306.550	2380.678	6028.915	NIL	3117.550	38.351	212.776	356.100
2009-10	2856.294	194.050	1341.345	3433.132	NIL	3377.250	22.593	212.819	288.200
2010-11	1511.898	141.500	708.550	1296.562	NIL	1747.400	13.074	43.125	16.400
2011-12	1512.305	153.650	524.451	1358.030	NIL	2415.200	13.465	67.774	99.250
2012-13	1376.585	173.850	539.505	1036.546	NIL	2658.350	24.965	302.678	171.200
Source: PASIC, Puducherry									

A B

C D

Figure 7. Industries operational in and around Oussudu lake during the survey

4.4. PHYSICO-CHEMICAL CHARACTERIZATION OF SOIL AND SEDIMENTS

In total, 44 samples were collected from farmlands, industrial locations and wetland/rivers, and were analyzed for pH, TOC (%), TN (%), TAP (%) and K (mg/kg). The sample pH varied between 5.1 and 7.9. The highest and lowest pH was reported from soil in industrial location i.e. Godown of JCB parts and in sugarcane farmland in Kuchipalayam, respectively. The pH of soil samples from farmlands, industrial locations and wetland sediments ranged from 5.1 - 7.6, 6.9 – 7.9, and 7.2 - 7.7, respectively (Table 4). At low pH, acidity can directly inhibit plant growth and make most of the heavy metals in soil bioavailable.

The TOC (%), TN (%), TAP (%) and K (mg/kg) of the samples ranged from 0.2% - 4.9%, BDL - 0.6417%, BDL - 0.0086% and 41.0 - 499.5mg/kg, respectively (Table 4). The higher concentration of TOC in agricultural fields is likely due to the plant growth and decay, which are great accumulators of TOC. While nitrogen affects the rate of nutrient uptake by plants, the levels of TN and TAP did not vary much among the samples and the matrices. The values of TN, TAP and K were well within the limits reported for farmlands. Soils high in organic matter generally exhibit relatively low levels of phosphorus. Phosphorous availability and soil acidity are closely related and different phosphorous fractions in soil depend upon the magnitude and proportion of different forms of soil acidity.

Table 4. Physico-chemical characterization of soil/sediment samples

Village	Crop practiced	pH	TOC (%)	TN (%)	TAP (%)	K (mg/kg)
Farmland Soil						
Kuchipalayam (near Veedur dam)	Blackgram	7.4	2.8	0.2557	0.0027	167.5
Kuchipalayam	Paddy	7.6	4.1	0.1852	0.0024	159.0
Kuchipalayam	Sugarcane	5.1	1.6	0.0958	0.0051	125.5
Siruvai (Vanur taluka)	*Casuarina*	7.6	4.1	0.1779	0.0010	79.0
Veedur dam	Blackgram	7.3	1.3	0.2310	0.0025	106.5
Koraloor	Paddy	7.2	2.2	0.2048	0.0013	51.5
Suthukanni	Paddy	6.9	1.7	0.1431	0.0004	52.0
Suthukanni	Paddy	7.0	1.6	0.3053	0.0022	49.5
Koodapakkam	Paddy (Organic)	7.3	1.3	0.2616	0.0023	120.5
Pillaiyarkuppam	Tapioca	7.3	1.9	0.4141	0.0042	83.5

Pillaiyarkuppam	Brinjal	7.6	2.9	0.5679	0.0036	66.0
Pillaiyarkuppam	Sugarcane	7.5	1.6	0.3471	0.0028	85.5
Sellipet	Paddy	7.0	2.1	0.4186	0.0021	99.5
Ramanathapuram	Banana	7.6	2.1	0.4494	0.0005	115.5
Thuthipet	Paddy	6.3	2.9	0.3565	BDL	100.5
Thuthipet	*Casuarina*	7.3	3.4	0.2780	0.0017	88.0
Karasur	Coconut	7.2	1.1	0.1889	0.0016	142.0
Agaram	Sugarcane	6.9	2.7	0.6417	0.0068	189.5
Thiruchitrambalam	*Casuarina*	6.4	1.1	0.0323	0.0045	170.0
Thiruchitrambalam	*Eucalyptus*	6.5	2.3	0.0353	0.0052	471.0
Kasipalayam	*Eucalyptus*	5.9	2.2	0.4109	0.0028	95.5
Kasipalayam	Coconut	6.8	1.1	BDL	0.0062	319.0
Manavelli	Cashew nut	6.0	4.9	0.0690	0.0064	41.0
Auroville	*Casuarina*	7.0	1.0	0.2974	0.0009	66.5
Auroville	Cashew nut	5.8	3.3	0.4904	0.0011	50.0
Mangalam	*Casuarina*	7.5	2.2	0.3824	0.0019	86.0
Mangalam	Banana	7.2	2.7	0.3799	0.0086	499.5
Mangalam	Tapioca (Organic)	7.0	0.7	0.0310	0.0027	284.0
Ousteri	Paddy	7.3	1.9	0.4589	0.0011	67.5
Poraiyur	Coconut	6.4	2.1	0.3920	0.0050	103.0
Poraiyur	Chilli	7.1	1.8	0.3802	0.0036	107.5
Mangalam	Tomato	7.4	0.8	0.3703	0.0023	125.0
Industrial Soil						
Ingots making industry, Thuthipet		7.4	0.6	0.4010	0.0020	87.5
Plastics industry, Valluvanpet		7.4	2.0	0.0773	0.0052	159.0
Tube/wings manufacturing unit, Poraiyur		7.4	4.5	0.5057	0.0009	88.0
Plastic furniture industry, Agaram		6.9	2.0	0.0926	0.0014	118.0
Sulphonic acid manufacturing unit, Mangalam		7.5	2.7	0.4093	0.0019	101.5
Polythene reprocessing unit, Sattiva		7.9	0.6	0.2973	0.0006	62.5
Packing industry, Thondamanatham		7.5	1.3	BDL	0.0004	76.5
Foam/sponge industry, Manavelli		7.6	2.7	0.2878	0.0012	150.0
Wetland sediment						
Thondamanatham		7.2	0.2	0.0284	0.0009	74.0
Veedur dam		7.5	1.5	0.4780	0.0012	100.5
Suthukanni canal		7.3	1.8	0.1124	0.0015	113.5
Sankarabharani river (near Sellipet flyover)		7.7	1.5	0.0790	0.0015	151.0
BDL: Below Detectable Limits						

4.5. PESTICIDE RESIDUES IN SAMPLES

Samples from 34 locations including agricultural fields, bore-wells, sediments, and water bodies were collected for pesticide residues. In total, 134 samples were collected and were further prioritized based on sampling locations. One portion of these samples was processed for agro-chemical residues and other for heavy metal concentrations. Around 45 samples were analyzed for various pesticide residues. The samples for pesticide analyses comprised of paddy (stem, leaves, grain), lotus (stem), tapioca (stem, leaves, fruit), brinjal (stem, leaves, fruit), sugarcane (stem, leaves, fruit), banana (stem, leaves, fruit), tomato (stem, leaves), *Eucalyptus* (stem), *Casuarina* (stem, leaves), farmland soils (types of crop cultivated: banana, blackgram, brinjal, cashew nut *Casuarina*, coconut, *Eucalyptus*, paddy, sugarcane, tapioca and tomato), water samples and sediments.

The organochlorine pesticide residues were below detectable levels (BDL) in all the soil and water samples collected under this study. Of the various samples analyzed, pesticide residues were detected only from certain plant samples at select locations (Table 5) only. Of the 18 chemical pesticide residues analyzed, 06 compounds *viz*., γ-BHC (Lindane), Heptahlorepoxide Isomer, Dieldrin, Endrin, Endrin Aldehyde and Endrin Ketone were detected in 07 plant samples. γ-BHC (Lindane) residues were detected in paddy stem (581.14 µg/L) collected from Ousteri village, tomato leaf (583.3 µg/L) and tapioca stem (585.82 µg/L) collected from Mangalam village. Heptahlorepoxide Isomer was detected in 07 plant samples and ranged from 512.53 - 1173.8 µg/L. Dieldrin was detected in paddy stem (489.97 µg/L) collected near Suthukanni, and tapioca stem (490.21 µg/L) and leaf (490.32 µg/L) collected from Mangalam.

The Ministry of Agriculture has banned and restricted nearly 30 pesticides, including some of the POPs under the provisions of Insecticides Act, 1968. Among these, Endrin was detected in 03 samples and ranged from 542.39 µg/L in brinjal leaf collected from Mangalam to 647.96 µg/L in paddy stem collected from Suthukanni. Endrin Aldehyde was recorded only in tapioca stem (629.88 µg/L) collected from Mangalam. Endrin Ketone was detected in tapioca stem (557.03 µg/L) and leaf (578.65 µg/L) collected from Mangalam.

Table 5. Pesticide residue levels in plant samples in µg/L

Chemical residue	Village						
	Suthukanni	Ousteri		Mangalam			
	Paddy (Stem)	Paddy (Stem)	Paddy (Leaf)	Tomato (Leaf)	Tapioca (Stem)	Tapioca (Leaf)	Brinjal (Leaf)
γ-BHC (Lindane)	BDL	581.14	BDL	583.3	585.82	BDL	BDL
Heptahlor epoxide Isomer	729.29	527.67	512.53	558.34	524.49	1155.4	1173.8
Dieldrin	489.97	BDL	BDL	BDL	490.21	490.32	BDL
Endrin	647.96	628.4	BDL	BDL	BDL	BDL	542.39
Endrin Aldehyde	BDL	BDL	BDL	BDL	629.88	BDL	BDL
Endrin Ketone	BDL	BDL	BDL	BDL	557.03	578.65	BDL
BDL: below detectable limit, Detection limit: 1 µg/L							

A study by Amaraneni (2002) reported γ-BHC, Endosulfan Dieldrin levels in sediment and water sample in fish farms in Kolleru lake, Peninsular India. Dieldrin was detected only in one sediment (21.6 µg/g) and one water sample (12.9 ng/L) by Amaraneni (2002). However, our study did not report Dieldrin and other compounds in sediment, soil and water samples collected during the survey. Interestingly, chemical residues during our study were not detected in fruit/grain/vegetables samples of these plants. Reported levels from stem and leaves may be attributed to the fact that mostly the chemicals were sprayed on the standing crop before the fruiting season. Moreover, the growth stages at which these chemicals were applied could also be a contributing factor in their detections.

As mentioned earlier, no pesticide residues were detected in Oussudu lake water and sediment samples. However, chemical residues were detected in crop samples collected from the villages surrounding Oussudu lake. During our interaction with the farmers in these villages, it was evident that farmers practiced triple cropping system for paddy. The paddy was grown during September - January, February - May, and June - August. Since one of the cropping seasons is during pre-monsoon wherein Endosulfan, BHC,

Monocrotophos, Malathion, Polydol and DDT, are applied it is presumed that Oussudu lake receives loads of such chemical residues as runoff during subsequent monsoon.

4.6. HEAVY METALS

Akin to pesticides several heavy metals as an outcome of application of agro-chemicals in nearby agriculture fields of Oussudu lake and industrial locations, can get accumulated in various trophic levels (macrophytes, fish, etc.) in the wetland ecosystem and may ultimately affect the apex of the food chain, i.e. birds. As mentioned in section 4.5. samples from 34 locations including agricultural fields, bore-wells, sediments, and water bodies were collected for heavy metal concentrations. Of the 134 samples collected, 54 samples were analyzed (30 samples from farmlands soil, 08 soil samples from industrial locations, 05 samples of sediments, and 11 water samples) for heavy metal concentrations.

4.6.1. HEAVY METAL LEVELS IN AND AROUND AGRICULTURAL SOIL

The levels of Cu, Cr, Ni and Zn in soils of agricultural field varied from 5.8 - 40.3 mg/kg, 23.9 - 69.4 mg/kg, BDL - 65.6 mg/kg and 14.9 - 689.7 mg/kg, respectively (Table 6). The Cu concentration in soils under paddy cultivation (n=7), blackgram cultivation (n=2) and *Casuarina* cultivation (n=5) varied from 9.8 - 30.5 mg/kg, 14.6 - 15.8 mg/kg, and 9.2 - 40.3 mg/kg, respectively. The Cr concentration in soils under paddy cultivation, blackgram cultivation, *Casuarina* cultivation and coconut cultivation (n=3) varied from 23.9 - 39.0 mg/kg, 28.5 -31.8 mg/kg, 33.9 – 68.1 mg/kg, and 27.4 - 69.4 mg/kg, respectively. The Ni concentration in soils under paddy cultivation varied from BDL - 65.6 mg/kg, and under sugarcane cultivation (n=2) it was from 39.9 - 41.9 mg/kg. Similarly, Zn concentrations in soils under paddy cultivation varied from 32.6 - 59.4 mg/kg. In general Zn concentration in soils can be classified as deficient if <10 mg/kg, normal if between 25 and 150 mg/kg and excessive or toxic if >400 mg/kg (Kiekens 1990, Prusty et al. 2008). With an exception, the Zn concentrations in soil are considered as normal in the present study.

Table 6. Levels of heavy metals (mg/kg) in farmland soil

Site/Village name	Crop practiced	Heavy metals (mg/kg)			
		Cu	Cr	Ni	Zn

Site/Village name	Crop practiced	Heavy metals (mg/kg)			
		Cu	Cr	Ni	Zn
Kuchipalayam (near Veedur dam)	Blackgram	15.8	31.8	34.8	35.4
Kuchipalayam	Paddy	26.5	32.6	42.7	54.1
Siruvai (Vanur taluk)	*Casuarina*	27.1	33.9	43.7	85.9
Veedur dam	Blackgram	14.6	28.5	33.5	66.3
Koraloor	Paddy	12.5	23.9	34.2	40.0
Suthukanni village	Paddy	21.1	32.7	43.3	46.6
Suthukanni village	Paddy	9.8	26.5	BDL	45.8
Pillaiyarkuppam	Tapioca	19.0	35.6	38.2	89.9
Pillaiyarkuppam	Brinjal	14.5	43.6	53.2	81.3
Pillaiyarkuppam	Sugarcane	24.4	33.1	39.9	89.3
Sellipet	Paddy	16.2	29.7	37.5	37.6
Ramanathapuram	Banana	24.4	29.8	38.7	94.2
Thuthipet	Paddy	30.5	39.0	65.6	59.4
Thuthipet	*Casuarina*	40.3	68.1	60.9	689.7
Karasur	Coconut	11.6	69.4	51.0	47.4
Agaram	Sugarcane	17.4	31.9	41.9	39.6
Thiruchitrambalam	*Casuarina*	12.2	40.2	42.1	38.1
Thiruchitrambalam	*Eucalyptus*	12.5	50.1	50.3	50.3
Kasipalayam	*Eucalyptus*	5.8	36.0	28.9	26.1
Kasipalayam	Coconut	26.5	35.6	53.0	56.1
Manavelli	Cashewnut	6.4	34.0	24.6	39.2
Auroville	*Casuarina*	9.2	41.6	35.2	20.4
Auroville	Cashewnut	6.0	28.2	22.9	14.9
Mangalam	*Casuarina*	14.2	35.4	37.5	44.1
Mangalam	Banana	21.3	35.3	42.6	85.0
Ousteri	Paddy	16.4	30.1	39.9	32.6
Poraiyur	Coconut	17.8	27.4	32.1	104.7
Poraiyur	Chilli	16.0	29.3	33.7	84.6
Mangalam	Tomato (Organic)	15.3	32.1	39.2	47.4
Mangalam	Tapioca (Organic)	15.6	28.4	32.0	40.1

4.6.2. HEAVY METAL LEVELS IN INDUSTRIAL SAMPLES

Soil samples from 08 different localities under industrial sites were collected and analyzed for heavy metal contents. Copper in these samples varied from 13.4 – 65.7 mg/kg, Cr from 31.9 - 88.2 mg/kg, Ni from 34.3 - 73.1 mg/kg, and Zn from 35.2 - 147.2 mg/kg (Table 7). The highest concentrations of Cr, Ni and Zn analyzed were reported from a plastics industry near Villianur.

The mean value of normal distribution of Cu and Zn in soil is around 30 mg/kg and 200 mg/kg, respectively. According to Alloway (1990), the critical concentration of Zn metal in soil is 70-400 mg/kg. The normal range of Cr in soils is 100 mg/kg (Krishna and Govil 2004) and of Ni is 50 mg/kg (Kashem and Singh 1999). Thus, Cr and Zn levels in industrial soil of present study are well within the normal range. However, Cu concentrations at Ingots making industry near Thuthipet, Plastic industry near Valluvanpet, Tube/wings manufacturing unit near Poraiyur and Sulphonic acid manufacturing unit near Mangalam exceeded the normal range. Nickel concentration in 50% of the sampling locations exceeded the set limits.

Table 7. Levels (mg/kg) of heavy metals in soil samples from industrial area

Industry type / location	Heavy metal concentration (mg/kg)			
	Cu	Cr	Ni	Zn
Polythene reprocessing unit, Sattiva	13.4	42.1	43.5	35.2
Packing industry, Thondamanatham	18.5	60.4	68.0	85.7
Ingots making industry, Thuthipet	32.7	43.1	63.4	66.9
Foam/sponge industry, Manavelli	13.7	39.8	34.3	65.9
Plastic industry, Valluvanpet	59.1	88.2	73.1	147.2
Tube/wings manufacturing unit, Poraiyur	65.7	60.6	47.1	80.4
Plastic furniture industry, Agaram	24.5	31.9	41.3	100.0
Sulphonic acid manufacturing unit, Mangalam	35.0	55.6	50.0	60.7

4.6.3. HEAVY METAL LEVELS IN SEDIMENT

Of the 05 sediment samples collected near water bodies, Cu ranged from 10.9 - 26.5 mg/kg, Cr from 25.2 - 52.1 mg/kg, Ni from 26.5 - 54.5 mg/kg and Zn from 21.2 – 90.9 mg/kg (Table 8).

Table 8. Levels (mg/kg) of heavy metals in sediments samples

Location	Heavy metal level (mg/kg)			
	Cu	Cr	Ni	Zn
Veedur dam	26.5	37.8	54.5	46.2
Suthukanni canal	23.7	34.7	49.0	90.9
Oussudu lake	10.9	52.1	26.5	21.2
Sankarabharani River (near Sellipet flyover)	15.4	37.4	38.1	29.1
Glass industry, Thondamanatham	22.4	25.2	44.2	46.3

Highest and lowest concentrations of Cu and Ni were reported from Veedur dam sediments and Oussudu lake sediments, respectively. Chromium levels were highest in Oussudu lake sediments and lowest in Thondamanatham sediments (near glass industry). The Zn levels were highest in Suthukanni canal and lowest in Oussudu Lake. Mathew et al. (2002) reported Zn levels between 56.3 and 613.8 mg/kg in bed sediment of some of the urban wetlands of Coimbatore city. Thus, the present reported Zn levels are well within the limit.

4.6.4. HEAVY METAL LEVELS IN WATER

Around 11 water samples from various locations were collected and analyzed for metal levels. Copper in water samples ranged from 0.1 - 0.6 mg/L, Cr 0.3 – 1.6 mg/L, Ni 0.4 – 0.8 mg/L and Zn BDL – 1.59 mg/L (Table 9). Among all the locations, Zn was found in below detectable limits in Suthukanni canal water, Oussudu lake of Tamil Nadu region and at one sampling location of Oussudu lake of Puducherry region.

Table 9. Levels (mg/L) of heavy metals in water samples

Location	Heavy metal level (mg/L)			
	Cu	Cr	Ni	Zn
Siruvai (hand pump-100 ft deep)	0.3	0.5	0.5	1.59
Veedur dam	0.6	0.4	0.8	0.55
Suthukanni lake	0.2	0.3	0.5	0.21
Suthukanni canal	0.2	0.4	0.5	BDL
Oussudu lake-sample 1(Tamil Nadu region)	0.1	0.5	0.5	BDL
Oussudu lake-sample 2 (Puducherry region)	0.2	0.9	0.8	BDL
Oussudu lake-sample 3 (Puducherry region)	0.2	0.4	0.5	0.08
Pillaiyarkuppam (Borewell water for sugarcane field)	0.3	1.6	0.5	0.68
Sankarabharani River (near Sellipet highway flyover)	0.3	0.4	0.5	0.25
Thondamanatham (near glass industry)	0.3	0.3	0.4	0.26
Tube/wings manufacturing unit, Poraiyur	0.3	0.5	0.5	0.20

Concentrations of Cu, Cr, Ni and Zn within the desirable limits of drinking water prescribed by BIS (2012) are 0.05 - 1.5 mg/L, 0.05 mg/L, 0.02 mg/L and 5 – 15 mg/L, respectively. The concentrations of Cu, Cr and Zn in Oussudu waters during post-monsoon reported by Abbasi and Chari (2008) ranged from BDL - 0.009 mg/L, BDL -

0.002 mg/L and BDL - 0.046 mg/L, respectively. Thus, heavy metal levels reported by Abbasi and Chari (2008) in Oussudu waters were well within the desirable limits. Contrary to this, our data revealed that Cr and Ni concentrations in Oussudu water exceeded the desirable limits of drinking water prescribed by BIS (2012). Nevertheless, the results of our study are in accordance with that of a study undertaken on urban wetlands in Coimbatore by Mohanraj et al. (2000), which reported higher levels of Cr (0.030 – 0.388 mg/L) and Ni (0.006 – 0.025 mg/L) in wetland waters.

4.7. SELECTION OF VILLAGE AS A MODEL TO PROMOTE ORGANIC FARMING

Questionnaire survey revealed that very few respondents from Koodapakkam, Mangalam and Nadupalayam villages had started organic farming in last 05 years. The respondents who practised organic farming were well aware of the cost effectiveness and better crop yield in organic farming as compared with farming using fertilizers/chemicals. Nevertheless, respondents other than those practising organic farming were keen to learn suitable alternate environmental friendly techniques for promoting agriculture. Thus, considering the respondents' willingness and awareness about problems associated with chemical residues, these 03 villages may be considered and developed as a model to promote organic farming.

Around 21 major revenue villages (Appendix 3) practiced farming in Puducherry. Of these, Koodapakkam, Mangalam and Oussudu village together comprise of 21% of the total area under agriculture. The total area under cultivation in these villages being large, a shift in farming practice (towards organic farming) would considerably reduce the agro-chemical usage in this region. Thus, alternately Koodapakkam, Mangalam and Oussudu may also be selected for promoting organic farming. This, in turn would also help reducing any inflow to Oussudu Lake.

5. SALIENT FINDINGS AND CONCLUDING REMARKS

- The Government of India implemented the National Wetlands Conservation Programme (NWCP) during 1985-86. In Puducherry, Oussudu is the only lake that is declared as a wetland of national importance.
- Oussudu Lake in Puducherry is surrounded by 18 villages practising agriculture. The shift in agriculture practice in recent years from organic farming to chemical farming, which involves various groups of pesticides, has caused tremendous pressures on this lake. In addition to this, there are around 25 industries, which serve as non-point source of pollution for various heavy metals.
- In total, 22 villages around Oussudu Lake were surveyed. Ninety respondents were surveyed for cropping pattern, etc. Nearly 70% respondents cultivated paddy for past 40 years. Major crops cultivated in the region included paddy, sugarcane, *Casuarina*, tapioca, groundnut, blackgram and coconut.
- Incidentally, all the respondents were reportedly dependent on ground water (bore-wells) for irrigation purpose.
- Usage of agro-chemicals started 30-40 years ago and before that, organic farming was in practice. Only 03% respondents were practicing organic farming during the present study.
- Use of POPs was common in the study area. The common chemicals used were Acephate, Carbendazim, Endosulphan, Factomphos Malathion, Monocrotophos and Profenofos.
- Two banned insecticides (Endosulphan and Polydol) were used for blackgram, tapioca and cashew nut cultivation in many villages. Application of DDT by few farmers in the area was also recorded.
- For paddy, the respondents (within parenthesis) used Monocrotophos (80%) > Acephate (30%) Endosulphan = Polydol (27%) > Profenofos (20%) > Carbendazim (08%). For sugarcane the order was Carbendazim (70%) > Malathion (30%) and for *Casuarina* plantations it was Monocrotophos (70%) > Endosulphan = Polydol (30%).
- Printing, garments, steel beams/ingots, electrical fitting, PVC pipes, glass, rubber, cosmetic and plastic molding industries were found near the study site. The industrial waste was dumped in open places.

- The pH, TOC (%), TN (%), TAP (%) and K (mg/kg) of the soil and sediment samples ranged from 5.1 - 7.9, 0.2% - 4.9%, BDL - 0.6417%, BDL - 0.0086% and 41.0 - 499.5mg/kg, respectively.
- Of 45 samples, analyzed, organochlorine pesticide residues were below detectable levels in all the soil and water samples. However, they were detected only from certain plant samples at select locations. Six compounds *viz*., γ-BHC (Lindane), Heptahlorepoxide Isomer, Dieldrin, Endrin, Endrin Aldehyde and Endrin Ketone were detected in 07 plant samples.
- The levels of Cu, Cr, Ni and Zn in soils of agricultural field varied from 5.8 - 40.3 mg/kg, 23.9 - 69.4 mg/kg, BDL - 65.6 mg/kg and 14.9 - 689.7 mg/kg, respectively.
- Copper, Cr, Ni and Zn in industrial locations varied from 13.4 – 65.7 mg/kg, 31.9 - 88.2 mg/kg, 34.3 - 73.1 mg/kg, and 35.2 - 147.2 mg/kg, respectively.
- Copper, Cr, Ni and Zn in sediment samples ranged from 10.9 - 26.5 mg/kg, 25.2 - 52.1 mg/kg, 26.5 - 54.5 mg/kg and 21.2 – 90.9 mg/kg, respectively. Zinc levels in sediment samples were highest in Suthukanni canal and lowest in Oussudu Lake.
- Copper in water samples ranged from 0.1 – 0.6 mg/L, Cr 0.3 – 1.6 mg/L, Ni 0.4 – 0.8 mg/L and Zn BDL – 1.59 mg/L.
- Based on the primary survey in villages and laboratory analysis, Koodapakkam, Mangalam and Nadupalayam villages may be considered on a model basis for promoting organic farming. The respondents were keen to learn suitable alternate environmental friendly techniques for agriculture. They seemed to be aware of the cost effectiveness and better crop yield in organic farming as compared with farming using fertilizers/chemicals. Thus, these villages may be suitable option for promoting organic farming in the region.
- Of the 21 major revenue villages doing farming, Koodapakkam, Mangalam and Oussudu together comprise of 21% of the total area under agriculture. Thus, these villages may alternately be selected for organic farming. This would considerably reduce the agro-chemical usage in this region.

6. REFERENCES

Abbasi SA and Chari KB (2008). Environmental management of urban lakes: with special reference to Oussudu. Discovery Publishing House, New Delhi. 269 pp.

Abolude DS, Davies OA and Chia AM (2009). Distribution and concentration of trace elements in Kubanni: reservoir in northern Nigeria. Research Journal of Environmental and Earth Sciences. 1(2): 39–44.

Agrawal A, Pandey RS, Sharma B (2010). Water Pollution with Special Reference to Pesticide Contamination in India. Journal of Water Resource and Protection. 2: 432-448.

Al-Farraj AS, Al-Sewailem M, Aly A, Al-Wabel M, El-Maghraby S (2013). Assessment and heavy metal behaviors of industrial waste water: A case study of Riyadh city, Saudi Arabia. Proceedings of the International Academy of Ecology and Environmental Sciences. 3(3): 266-277.

Allen SE (1989). Chemical Analysis of Ecological Materials. 2nd Edition, Blackwell Scientific Publications, Oxford, London. 368 pp.

Alloway BJ (1990). Heavy Metals in Soils. John Wiley and Sons, New York. 339 pp.

Amaraneni SR (2002). Persistence of pesticides in water, sediment and fish from fish farms in Kolleru Lake, India. Journal of the Science of Food and Agriculture. 82: 918-923.

Anastassiades M, Maštovská K, Lehotay SJ (2003). Evaluation of analyte protectants to improve gas chromatographic analysis of pesticides. Journal of Chromatography A. 1015 (2003): 163–184.

Azeez PA, Nadarajan NR and Prusty BAK (2007). Macrophyte decomposition and its impact on the water quality. In: (Edited book) Environmental Degradation and Protection, Volume – II, MD Publications, New Delhi, 115-156.

Bhardwaj Tulsi and Sharma JP (2013). Impact of Pesticides Application in Agricultural Industry: An Indian Scenario. International Journal of Agriculture and Food Science Technology. 4(8): 817-822.

Bray RH and Kurtz LT (1945). Determination of total organic and available forms of phosphorus. Soil Science. 59: 39-45.

Chandra R and Azeez PA (2010). Floral diversity of Kottuli: a wetland of national importance, Kozhikode, Kerala. Journal of Economic and Taxonomic Botany. 34(2): 440-450.

Charan PD, Patni A and Sharma KC (2008). Pesticide contamination in lake Anasagar of Ajmer, Rajasthan. In: Sengupta M, Dalwani R (Eds.), Proceedings of Taal2007: The 12th World Lake Conference. pp 360-365.

Chari KB and Abbasi SA (2003). Ecology, habitat and bird community structure at Oussudu lake: towards a strategy for conservation and management. Aquatic Conservation: Marine Freshwater Ecosystem. 13: 373-86.

Davidar P (2011). Wetland birds of Pondicherry region: a pictorial field guide. ECOS Puducherry. pp 80.

Jackson ML (1958). Soil Chemical Analysis. Constable & Co Ltd., London. 498 pp.

Kabata-Pendias A (1993). Behaviour properties of trace metals soils. Applied Geochemistry Supplementary Issue. 2: 3–9.

Kaplan A (1965). The determination of urea, ammonia and urease. In: Glick D (Eds.), Methods of Biochemical Analysis. John Wiley and Sons, New York, Volume-17. pp. 311-321.

Kashem A and Singh BR (1999). Heavy metal contamination of soil and vegetation in the vicinity of industries in Bangladesh. Water Air and Soil Pollution. 115(1-4): 347–361.

Kiekens L (1990). Zinc. In Alloway BJ (Ed.) Heavy Metals in Soils. John Wiley and Sons, New York. pp. 261-277.

Krishna AK and Govil PK (2004). Heavy metal contamination of soil around Pali Industrial Area, Rajasthan, India. Environmental Geology. 47:38–44.

Mahdavian SE and Somashekar RK (2010). Synthetic pyrethroides multiresidue in grapes from southern India. Kathmandu University Journal of Science Engineering and Technology. 6(2): 104-110.

Mathew M, Sathishkumar M, Azeez PA, Sivakumar R and Pattabi S (2002). Sediment quality of wetlands in Coimbatore, Tamil Nadu, India. Bulletin of Environmental Contamination and Toxicology. 68: 389-393.

Mitsch WJ and Gosselink JG (2000). Wetlands (Third Edition), John Wiley & Sons, New York.

Mohanraj R, Sathishkumar M, Azeez PA and Sivakumar R (2000). Pollution Status of Wetlands in Urban Coimbatore, Tamilnadu, India. Bulletin of Environmental Contamination and Toxicology. 64: 638-643.

Muralidharan S (2000). Organochlorine Residues in the Waters of Keoladeo National Park, Bharatpur, Rajasthan. Bulletin of Environmental Contamination and Toxicology. 65:35-41.

Nobi EP, Umamaheswari R, Stella C and Thangaradjou T (2009). Land use and Land cover assessment along Pondicherry and its surroundings using Indian Remote Sensing Satellite and GIS. American-Euresian Journal of Scientific Research. 4(2): 54-58.

Prusty BAK, Arun PR, Bhupathy S, Murugesan M and Chandra R (2011). Comprehensive Management Action Plan for Conservation of Oussudu Sanctuary, Puducherry. 127 pp.

Prusty BAK, Chandra R and Azeez PA (2008). Vertical and temporal variation of Zn in the soils of a multiple habitat system. Journal of Food, Agriculture and Environment. 6(2): 381-387.

Raveh A and Avnimelech Y (1979). Total nitrogen analysis in water, soil and plant material with persulphate oxidation. Plant Research. 13: 911-9112.

SAC (2011). National Wetland Atlas. Space Applications Centre, Indian Space Research Organization, Ahmedabad, India. 310 pp.

Subramanyam D, Lokanatha V, Rajendra W and Vijayalakshmi B (2012). Biomanagement of pesticides for sustainable environment: an Indian scenario. International Journal of Biological & Pharmaceutical Research. 3(7): 826-834.

Tandon HLS (2005). Methods of analysis of soils, plants, water and fertilizers. Fertilizer Development and Consultation Organization (FDCO), New Delhi. 143 pp.

Walkley A and Black IA (1934). An Examination of the Degljareff method for determining the soil organic matter and a proposed modification of the chromic acid titration method. Soil Science. 37: 29-38.

Wang JJ and Scott AD (2001). Determination of exchangeable potassium in soil using ion-selective electrodes in soil suspensions. European Journal of Soil Science. 52: 143-150.

Appendix 1. Questionnaire used during field survey

Name of the Surveyor:	Questionnaire number: Date:

1. Details of the respondent

Name	Village
Age	Taluk
Gender	Educational qualification
Main Occupation	Other Occupations
Number of family members with age	

2. Landholdings (in hectares)

Agriculture	Housing Plot	Other

3. Type of land (in hectares)

Irrigated land	Non- irrigated
Wasteland	Other, Pls. specify

4. What are the lakes around your village
5. Dependent on lake

Fully	Partially	No dependency

6. Type of irrigation practice followed

Attributes	Groundwater	Surface water
Source		
Duration (in hours)		
Quantum (per hour)		
Do you pay water tariff? How much do you pay monthly? What is its rate?		

7. Cropping pattern

Monoculture / Polyculture	Season	Crop Name	Cost of seeds (Rs./kg)	Quantum of seeds required (kg/ha)	Area Cultivated (in ha)	Product yield (in kg/ha)

8. Complications / problems being faced during practicing agriculture
    - What are the problems with crop quality
        - Are any agro-chemicals used to improve crop quality?
    - What are the problems with crop quantity
        - Are any agro-chemicals used to improve crop quality?
    - General agro-chemicals used
    - Hormones used
    - Fertilizers used
    - Organic fertilizers used
    - Any other agro-chemicals used

9. Are you facing any problem in agriculture land, if yes, then

Table A

Weeds (Yes/No)	Associated crop			
	Weeds names			
	Herbicides names			
Pests/insects (Yes/No)	Associated crop			
	Pests/insects names			
	Pesticides names			
Fungal diseases (Yes/No)	Associated crop			
	Diseases names			
	Fungicides names			

If Table A is applicable then fill Table B

Name of the • Agro-chemical • Hormones/Growth Promoters • Fertilizers • Organic fertilizers	
Cost (Rs./kg)	
Crop Associated	
For what purpose it is applied	
Stages of Application with Application rate (kg/ha) • Initial Stage: Seed Treatment (soaking) • Second stage	

• Third Stage • Fourth Stage • Fifth Stage • Sixth Stage • Seventh Stage • And so on	
How many days is the waiting period (the period between the last application of pesticide on a crop and the date of its harvest)	
When do you apply pesticides • Visible pests • The damage symptoms • Do you use pesticides in advance (even without noticing the pest/symptom)	
Frequency of Application	
Source of Irrigation	
Chemical group	
Mode of application	
Mode of harvest	
Overall farming is for Sustenance or Commercial purpose	
W.r.t. crop farming is for Sustenance or Commercial purpose	
From whom do you take advice about usage of correct dosage of pesticide • Agricultural technicians • On your own • On your own or take the advice of the Agricultural Technicians	
Any side effects seen due to pesticides on the user	

10. Are you cropping any GM plants?
11. Is agro-chemical quantum per hectare is same irrespective of crop species?
12. Distance between land and seed storage place
13. Seed Preservation Techniques followed after harvesting
14. Changes in preference of crops cultivated over the 30 years
15. Cropping pattern with respect to each year
16. Changes in land use over 30 years
17. Information on the shift in cropping practice (organic / in-organic), if any, over last 30 years

Appendix 2. Sampling locations

Sl. No.	Location	GPS reading
1	Kuchipalayam	12°00'28.2"N, 79°36'06.4E
2	Siruvai (Vanur taluka)	12°02'39.7"N, 79°36'17.1"E
3	Veedur dam	12°04'21.1"N, 79°35'06.8"E
4	Veedur	12°04'43.4"N, 79°35'46.9"E
5	Koraloor	12°06'34.7"N, 79°37'04.1"E
6	Suthukanni village	12°01'05.7"N, 79°40'54.0"E
7	Suthukanni lake	12°01'07.0"N, 79°40'23.0"E
8	Suthukanni canal	11°57'05.9"N, 79°42'58.0"E
9	Oussudu lake (Tamil Nadu region)	11°57'18.5"N, 79°45'02.6"E
10	Oussudu lake (Pondicherry region)	11°56'47.9"N, 79°44'45.6"E
11	Koodapakkam village	11°56'16.9"N, 79°43'27.4"E
12	Pillaiyarkuppam	11°57'52.3"N, 79°42'11.3"E
13	Sankarabharani river (near Sellipet highway flyover)	11°57'00.7"N, 79°42'14.7"E
14	Sellipet	11°57'13.8"N, 79°41'45.3"E
15	Ramanathapuram	11°56'59.3"N, 79°43'13.2"E
16	Thondamanatham	11°57'37.7"N, 79°43'11.6"E
17	Polythene reprocessing unit, Sattiva	11°57'56.5"N, 79°43'22.4"E
18	Packing industry, Thondamanatham	11°58'12.2"N, 79°43'22.4"E
19	Thuthipet	11°58'35.5"N, 79°42'37.6"E
20	Karasur	11°59'15.2"N, 79°44'20.1"E
21	Agaram	11°56'01.7"N, 79°44'23.7"E
22	Thiruchitrambalam	11°59'25.6"N, 79°46'22.3"E
23	Kasipalayam	11°58'22.7"N,

		79°46'10.3"E
24	Manavelli	11°57'43.5"N, 79°46'35.3"E
25	Foam/sponge industry, Manavelli	11°57'43.5"N, 79°46'35.5"E
26	Auroville	11°59'57.7"N, 79°47'40.2"E
27	Mangalam	11°53'39.9"N, 79°44'02.5"E
28	Ousteri	11°56'11.0"N, 79°44'53.1"E
29	Poraiyur	11°56'00.4"N, 79°44'49.8"E
30	Plastics Industry, Valluvanpet	11°56'31.2"N, 79°44'53.9"E
31	Tube/wings manufacturing unit, Poraiyur	11°55'19.2"N, 79°44'51.4"E
32	Plastic furniture industry, Agaram	11°55'59.7"N, 79°44'10.2"E
33	Sulphonic acid manufacturing unit, Mangalam	11°53'47.5"N, 79°44'22.3"E
34	Mangalam	11°53'44.6"N, 79°43'59.2"E

Appendix 3. Crop production in revenue village in Puducherry during 2011-12.
(Source: Directorate of Economics and Statistics, Puducherry)

1. Koodapakkam revenue village					
Sl.No	Crops	Season (Area in Ha.)			
		Khariff	Rabi-I	Rabi-II	Total
1	Paddy	37.6145	64.3545	46.9495	148.9185
2	Sugarcane	18.0150	0.0000	0.0000	18.0150
3	Chillies	0.0100	0.0100	0.0000	0.0200
4	Tamarind	0.1400	0.0000	0.0000	0.1400
5	Mangoes	0.0600	0.0000	0.0000	0.0600
6	Banana	2.4050	0.0000	0.0000	2.4050
7	Coconut	7.3120	0.0000	0.0000	7.3120
8	Green Manure	2.1550	0.0000	0.0000	2.1550
9	Fodder crops	0.1450	0.0000	0.0000	0.1450
10	*Casuarina*	31.8745	0.0000	0.0000	31.8745
11	ONFG (flower Garden)	0.2800	0.0000	0.0000	0.2800
Total		100.0110	64.3645	46.9495	211.3250

2. Oulgaret revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	0.0000	4.1750	0.0000	4.1750
2	Mangoes	0.6255	0.0000	0.0000	0.6255
3	Banana	1.6770	0.0000	0.0000	1.6770
4	Guava	0.0500	0.0000	0.0000	0.0500
5	Jack Fruit	0.1600	0.0000	0.0000	0.1600
6	Other Fruits	0.0300	0.0000	0.0000	0.0300
7	Coconut	5.7285	0.0000	0.0000	5.7285
8	Green Manure	4.1750	0.0000	0.0000	4.1750
9	*Casuarina*	3.3900	0.0000	0.0000	3.3900
Total		15.8360	4.1750	0.0000	20.0110

3. Thondamanatham revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	9.9992	23.9492	0.0000	33.9484
2	Blackgram	0.0900	0.0000	0.0000	0.0900
3	Sugarcane	2.4630	0.0000	0.0000	2.4630
4	Palmyrah	0.0100	0.0000	0.0000	0.0100
5	Tamarind	0.2000	0.0000	0.0000	0.2000
6	Mangoes	0.0150	0.0000	0.0000	0.0150
7	Banana	0.0100	0.0000	0.0000	0.0100
8	Coconut	0.1400	0.0000	0.0000	0.1400
9	Green Manure	10.5850	0.0000	0.0000	10.5850
10	Eucalyptus	0.4991	0.0000	0.0000	0.4991
11	*Casuarina*	33.8009	0.0000	0.0000	33.8009
Total		57.8122	23.9492	0.0000	81.7614

4. Villianur revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	10.5850	63.5820	22.4398	96.6068
2	Palmyrah	0.5650	0.0000	0.0000	0.5650
3	Betlevine	0.6400	0.0000	0.0000	0.6400
4	Mangoes	3.4287	0.0000	0.0000	3.4287
5	Banana	1.3950	0.0000	0.0000	1.3950
6	Brinjal	0.0300	0.0000	0.0550	0.0850
7	Lady's Finger	0.0000	0.0300	0.0000	0.0300
8	Other Vegetables	0.0000	0.0000	0.0300	0.0300
9	Coconut	7.4300	0.0000	0.0000	7.4300
10	Green Manure	52.9970	0.0000	0.0000	52.9970

11	*Casuarina*	2.5550	0.0000	0.0000	2.5550
Total		79.6257	63.6120	22.5248	165.7625

5. Ouruvaiyar revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	17.7126	44.8458	9.0100	71.5684
2	Cumbu	0.0000	0.0000	0.1000	0.1000
3	Ragi	0.0000	0.0000	0.0950	0.0950
4	Palmyrah	0.9248	0.0000	0.0000	0.9248
5	Mangoes	0.0750	0.0000	0.0000	0.0750
6	Banana	0.2400	0.0000	0.0000	0.2400
7	Jack fruit	0.0247	0.0000	0.0000	0.0247
8	Banana- Rabi	0.0000	1.3700	0.0000	1.3700
9	Coconut	7.5596	0.0000	0.0000	7.5596
10	Green Manure	13.5340	0.0000	0.0000	13.5340
11	Fodder crops	0.0875	0.0000	0.0000	0.0875
12	Bamboos	0.0100	0.0000	0.0000	0.0100
13	*Casuarina*	2.5303	0.0000	0.0000	2.5303
Total		42.6985	46.2158	9.2050	98.1193

6. Sathamangalam revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	89.8896	98.6909	96.8739	285.4544
2	Sugarcane	7.3900	0.0000	0.0000	7.3900
3	Palmyrah	0.1900	0.0000	0.0000	0.1900
4	Chillies	0.0000	0.0250	0.0250	0.0500
5	Tamarind	0.1750	0.0000	0.0000	0.1750
6	Mangoes	0.0200	0.0000	0.0000	0.0200
7	Banana	1.4950	0.0000	0.0000	1.4950
8	Brinjal	0.0250	0.0000	0.0000	0.0250
9	Lady's Finger	0.1900	0.0000	0.0000	0.1900
10	Other vegetables	0.0000	0.1900	0.1900	0.3800
11	Sesamum	0.0000	0.0000	1.9000	1.9000
12	Coconut	2.8759	0.0000	0.0000	2.8759
13	Green Manure	6.0828	0.0000	0.0000	6.0828
14	Fodder crops	0.2600	0.0000	0.0000	0.2600
15	*Casuarina*	19.4027	0.0000	0.0000	19.4027
Total		127.9960	98.9059	98.9889	325.8908

7. Mangalam revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	54.9950	91.5585	88.1035	234.6570
2	Cumbu	0.0000	0.0000	0.3850	0.3850
3	Ragi	0.0000	0.0000	0.2000	0.2000
4	Sugarcane	9.3800	0.0000	0.0000	9.3800
5	Palmyrah	0.0050	0.0000	0.0000	0.0050
6	Chillies	0.0000	0.2650	0.0000	0.2650
7	Tamarind	1.0198	0.0000	0.0000	1.0198
8	Mangoes	1.3950	0.0000	0.0000	1.3950
9	Banana	3.5700	0.0000	0.0000	3.5700
10	Guava	0.0350	0.0000	0.0000	0.0350
11	Jack Fruit	0.1000	0.0000	0.0000	0.1000
12	Brinjal	0.1850	0.0000	0.0000	0.1850
13	Pumpkin	0.1400	0.0000	0.0000	0.1400
14	Tapioca - Rabi	0.0000	0.2500	0.0000	0.2500
15	Other Vegetables	0.1850	0.0000	0.0000	0.1850
16	Groundnut	0.0000	2.7750	0.1500	2.9250
17	Sesamum	0.0000	0.1500	0.4800	0.6300
18	Coconut	16.0200	0.0000	0.0000	16.0200
19	Green Manure	36.5635	0.0000	0.0000	36.5635
20	Fodder Crops	0.5000	0.0000	0.0000	0.5000
21	ONFC (Flower Garden)	1.0300	0.0000	0.0000	1.0300
22	Eucalyptus	0.2000	0.0000	0.0000	0.2000
23	Bamboos	0.0900	0.0000	0.0000	0.0900
24	*Casuarina*	4.8850	0.0000	0.0000	4.8850
25	ONFC (Flower Garden)	0.0050	0.0000	0.0000	0.0050
Total		130.3033	94.9985	89.3185	314.6203

8. Kurumbapet revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	13.9900	18.0100	20.7200	52.7200
2	Cumbu	0.0000	0.0000	0.2050	0.2050
3	Sugarcane	2.6700	0.0000	0.0000	2.6700
4	Palmyrah	0.0500	0.0000	0.0000	0.0500
5	Tamarind	0.1100	0.0000	0.0000	0.1100
6	Mangoes	14.9240	0.0000	0.0000	14.9240
7	Lemon	0.7500	0.0000	0.0000	0.7500
8	Banana	8.5205	0.0000	0.0000	8.5205
9	Guava	1.1200	0.0000	0.0000	1.1200
10	Cashew	2.4934	0.0000	0.0000	2.4934
11	Jack Fruit	0.0400	0.0000	0.0000	0.0400

12	Other Fruits	2.2050	0.0000	0.0000	2.2050
13	Tapioca	0.6350	0.0000	0.0000	0.6350
14	Brinjal	0.4000	0.2000	0.0000	0.6000
15	Lady's finger	0.0000	0.0000	0.1500	0.1500
16	Other Vegetables	0.0000	0.2000	0.0850	0.2850
17	Groundnut	0.0000	0.0000	0.3450	0.3450
18	Coconut	12.5400	0.0000	0.0000	12.5400
19	Green Manure	4.0200	0.0000	0.0000	4.0200
20	Fodder Crops	0.7350	0.0000	0.0000	0.7350
21	ONFC (Flower Garden)	0.1400	0.1400	0.1400	0.4200
22	Other Medicinal Plants	0.1350	0.1350	0.1350	0.4050
23	*Casuarina*	1.5000	0.0000	0.0000	1.5000
Total		66.9779	18.6850	21.7800	107.4429

9. Perungalore revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	31.8641	40.9495	37.1795	109.9931
2	Cholam	0.0000	0.0000	0.3350	0.3350
3	Cumbu	0.0000	0.0000	0.8350	0.8350
4	Blackgram	0.0000	0.5450	0.0000	0.5450
5	Palmyrah	0.0700	0.0000	0.0000	0.0700
6	Tamarind	0.0300	0.0000	0.0000	0.0300
7	Mangoes	0.3250	0.0000	0.0000	0.3250
8	Banana	1.0780	0.0000	0.0000	1.0780
9	Tapioca	3.2700	0.0000	0.0000	3.2700
10	Brinjal	0.0000	0.0000	0.0500	0.0500
11	Other Vegetables	0.0000	0.0000	0.0500	0.0500
12	Sesamum	0.0000	0.0000	0.9350	0.9350
13	Coconut	21.6250	0.0000	0.0000	21.6250
14	Green Manure	9.0854	0.0000	0.0000	9.0854
15	Fodder Crops	0.4150	0.0000	0.0000	0.4150
16	Bamboo	0.0500	0.0000	0.0000	0.0500
17	*Casuarina*	2.1950	0.0000	0.0000	2.1950
Total		70.0075	41.4945	39.3845	150.8865

10. Ariyur revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	37.6793	67.2243	12.0750	116.9786
2	Blackgram	1.4850	4.5800	0.0000	6.0650
3	Other Pulses	0.0000	1.9200	0.0000	1.9200
4	Sugarcane	75.3138	0.0000	0.0000	75.3138
5	Palmyrah	1.6960	0.0000	0.0000	1.6960

6	Tamarind	1.1870	0.0000	0.0000	1.1870
7	Mangoes	0.3650	0.0000	0.0000	0.3650
8	Banana	1.5400	0.0000	0.0000	1.5400
9	Jack Fruit	0.0150	0.0000	0.0000	0.0150
10	Other Vegetables	0.6400	0.0000	0.0000	0.6400
11	Groundnut	0.0000	2.6800	0.0000	2.6800
12	Sesamum	0.6322	1.1792	3.8592	5.6706
13	Coconut	7.0155	0.0000	0.0000	7.0155
14	Green Manure	4.0550	0.0000	0.0000	4.0550
15	Fodder Crops	0.2530	0.0000	0.0000	0.2530
16	ONFC (flower garden)	0.2750	0.2750	0.0000	0.5500
17	Eucalyptus	0.0100	0.0000	0.0000	0.0100
18	*Casuarina*	12.6000	0.0000	0.0000	12.6000
19	ONFC (flower garden)	0.2250	0.0000	0.0000	0.2250
Total		144.9868	77.8585	15.9342	238.7795

11. Sedarapet revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Tamarind	0.7400	0.0000	0.0000	0.7400
2	Mangoes	0.1100	0.0000	0.0000	0.1100
3	Banana	0.3100	0.0000	0.0000	0.3100
4	Coconut	11.6598	0.0000	0.0000	11.6598
5	Eucalyptus	0.9661	0.0000	0.0000	0.9661
6	*Casuarina*	52.1522	0.0000	0.0000	52.1522
Total		65.9381	0.0000	0.0000	65.9381

12. Manakuppam revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	1.4078	1.2028	1.3028	3.9134
2	Blackgram	0.0000	0.0900	0.0000	0.0900
3	Sugarcane	6.8044	0.0000	0.0000	6.8044
4	Tamarind	0.0100	0.0000	0.0000	0.0100
5	Mangoes	0.0250	0.0000	0.0000	0.0250
6	Banana	1.4200	0.0000	0.0000	1.4200
7	Banana- Rabi	0.0000	0.1850	0.0000	0.1850
8	Tapioca	4.3650	0.0000	0.0000	4.3650
9	Brinjal	0.0300	0.2400	0.2500	0.5200
10	Lady's finger	0.1750	0.1500	0.1500	0.4750
11	Pumpkin	0.0500	0.0000	0.0450	0.0950
12	Other Vegetables	0.0000	0.0050	0.0700	0.0750

13	Groundnut	0.0000	7.6450	0.0400	7.6850
14	Sesamum	0.0000	0.0000	1.2050	1.2050
15	Coconut	0.6030	0.0000	0.0000	0.6030
16	Green Manure	0.1400	0.1000	0.0000	0.2400
17	Fodder Crops	0.0400	0.0000	0.0000	0.0400
18	*Casuarina*	3.7320	0.0000	0.0000	3.7320
Total		18.8022	9.6178	3.0628	31.4828

13. Thuthipet revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	0.0000	4.0100	1.6200	5.6300
2	Cumbu	0.0000	0.0000	0.8000	0.8000
3	Sugarcane	1.5000	0.0000	0.0000	1.5000
4	Palmyrah	0.3350	0.0000	0.0000	0.3350
5	Tamarind	0.0500	0.0000	0.0000	0.0500
6	Mangoes	0.0600	0.0000	0.0000	0.0600
7	Banana	0.8100	0.0000	0.0000	0.8100
8	Guava	0.0500	0.0000	0.0000	0.0500
9	Other Fruits	0.0800	0.0000	0.0000	0.0800
10	Tapioca	0.4600	0.0000	0.0000	0.4600
11	Brinjal	0.1000	0.0000	0.2100	0.3100
12	Lady's Finger	0.0300	0.0000	0.0000	0.0300
13	Sesamum	0.0000	0.0000	1.2950	1.2950
14	Coconut	4.0492	0.0000	0.0000	4.0492
15	Green Manure	4.0100	0.0000	0.0000	4.0100
16	Fodder Crops	0.2300	0.0000	0.0000	0.2300
17	Eucalyptus	0.1700	0.0000	0.0000	0.1700
18	Bamboos	0.0600	0.0000	0.0000	0.0600
19	*Casuarina*	40.1403	0.0000	0.0000	40.1403
20	Medicinal Plants	0.0300	0.0000	0.0000	0.0300
Total		52.1645	4.0100	3.9250	60.0995

14. Oussudu revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	62.1650	96.1510	50.9148	209.2308
2	Palmyrah	0.0100	0.0000	0.0000	0.0100
3	Tamarind	0.1350	0.0000	0.0000	0.1350
4	Betlevine	3.4100	0.0000	0.0000	3.4100
5	Mangoes	0.5500	0.0000	0.0000	0.5500

6	Banana	2.7850	0.0000	0.0000	2.7850
7	Jack Fruit	0.0150	0.0000	0.0000	0.0150
8	Yam (Karunai)	0.7580	0.0000	0.0000	0.7580
9	Other Vegetables	0.2750	0.1900	0.0000	0.4650
10	Coconut	5.0710	0.0000	0.0000	5.0710
11	Green Manure	16.1898	0.0000	0.0000	16.1898
12	Fodder Crops	1.4050	0.0000	0.0000	1.4050
13	ONFC (flower Garden)	0.2000	0.2000	0.2000	0.6000
14	Eucalyptus	0.1150	0.0000	0.0000	0.1150
15	*Casuarina*	5.4900	0.0000	0.0000	5.4900
Total		98.5738	96.5410	51.1148	246.2296

15. Ramanathapuram revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	34.6849	81.0504	13.6150	129.3503
2	Blackgram	0.0000	2.7650	0.0000	2.7650
3	Sugarcane	27.2603	0.0000	0.0000	27.2603
4	Palmyrah	0.0500	0.0000	0.0000	0.0500
5	Tamarind	0.0250	0.0000	0.0000	0.0250
6	Mangoes	0.8991	0.0000	0.0000	0.8991
7	Banana	0.3550	0.0000	0.0000	0.3550
8	Jack Fruit	0.0150	0.0000	0.0000	0.0150
9	Tapioca	1.5800	0.0000	0.0000	1.5800
10	Groundnut	0.0000	2.3950	0.0000	2.3950
11	Sesamum	0.0000	0.0000	2.3950	2.3950
12	Coconut	4.1744	0.0000	0.0000	4.1744
13	Green Manure	46.3655	0.0000	0.0000	46.3655
14	Fodder Crops	0.5350	0.0000	0.0000	0.5350
15	Eucalyptus	1.2300	0.0000	0.0000	1.2300
16	Bamboos	0.0400	0.0000	0.0000	0.0400
17	*Casuarina*	36.7697	0.0000	0.0000	36.7697
Total		153.9839	86.2104	16.0100	256.2043

16. Pillaiyarkuppam revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	27.3544	28.8094	24.8579	81.0217

2	Sugarcane	46.4562	0.0000	0.0000	46.4562
3	Palmyrah	0.4700	0.0000	0.0000	0.4700
4	Chillies	0.1300	0.0100	0.0000	0.1400
5	Tamarind	0.3850	0.0000	0.0000	0.3850
6	Mangoes	1.7225	0.0000	0.0000	1.7225
7	Lemon	0.0100	0.0000	0.0000	0.0100
8	Banana	0.5100	0.0000	0.0000	0.5100
9	Jack Fruit	0.0800	0.0000	0.0000	0.0800
10	Other Fruits	0.0300	0.0000	0.0000	0.0300
11	Tapioca	4.3198	0.0000	0.0000	4.3198
12	Brinjal	0.0700	0.0000	0.0000	0.0700
13	Groundnut	0.0000	1.1800	0.0000	1.1800
14	Sesamum	0.0000	0.0600	5.7409	5.8009
15	Coconut	7.3472	0.0000	0.0000	7.3472
16	Green Manure	0.4550	0.0000	0.0000	0.4550
17	Fodder Crops	5.4395	0.0000	0.0000	5.4395
18	Eucalyptus	0.3250	0.0000	0.0000	0.3250
19	Bamboos	0.0200	0.0000	0.0000	0.0200
20	*Casuarina*	4.2441	0.0000	0.0000	4.2441
21	ONFC(Flower Garden)	0.5730	0.0000	0.0000	0.5730
Total		99.9417	30.0594	30.5988	160.5999

17. Olavaikkal revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	31.4850	57.5628	25.6333	114.6811
2	Sugarcane	11.6350	0.0000	0.0000	11.6350
3	Palmyrah	0.3200	0.0000	0.0000	0.3200
4	Tamarind	0.1850	0.0000	0.0000	0.1850
5	Mangoes	0.1900	0.0000	0.0000	0.1900
6	Lemon	0.1000	0.0000	0.0000	0.1000
7	Banana	0.7500	0.0000	0.0000	0.7500
8	Guava	0.4300	0.0000	0.0000	0.4300
9	Jack Fruit	0.0150	0.0000	0.0000	0.0150
10	Other Fruits	1.0800	0.0000	0.0000	1.0800
11	Tapioca	3.0150	0.0000	0.0000	3.0150
12	Groundnut	0.0000	2.4500	0.0000	2.4500
13	Sesamum	0.0000	0.0000	1.3100	1.3100

14	Coconut	5.3067	0.0000	0.0000	5.3067
15	Green Manure	26.0778	0.0000	0.0000	26.0778
16	Fodder Crops	2.4250	0.0000	0.0000	2.4250
17	Bamboos	0.0123	0.0000	0.0000	0.0123
18	*Casuarina*	35.4827	0.0000	0.0000	35.4827
Total		118.5095	60.0128	26.9433	205.4656

18. Thirukanji revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	29.7725	72.1641	1.4600	103.3966
2	Cumbu	0.0000	0.0000	0.2250	0.2250
3	Blackgram	0.0000	0.4000	0.0000	0.4000
4	Sugarcane	13.8247	0.0000	0.0000	13.8247
5	Palmyrah	1.5750	0.0000	0.0000	1.5750
6	Tamarind	0.8150	0.0000	0.0000	0.8150
7	Mangoes	6.4592	0.0000	0.0000	6.4592
8	Lemon	0.0750	0.0000	0.0000	0.0750
9	Banana	1.5753	0.0000	0.0000	1.5753
10	Jack Fruit	0.0400	0.0000	0.0000	0.0400
11	Other Fruits	0.6400	0.0000	0.0000	0.6400
12	Tapioca	0.5000	0.0000	0.0000	0.5000
13	Brinjal	0.1450	0.0000	0.0000	0.1450
14	Lady's finger	0.0000	0.1000	0.0000	0.1000
15	Other guard	0.2300	0.0000	0.0000	0.2300
16	Other Vegetables	0.5395	0.0000	0.0000	0.5395
17	Groundnut	0.0000	1.3145	0.5395	1.8540
18	Coconut	36.4573	0.0000	0.0000	36.4573
19	Green Manure	42.3916	0.0000	0.0000	42.3916
20	Fodder Crops	0.2700	0.0000	0.0000	0.2700
21	ONFC (Flower Garden)	0.1900	0.1900	0.1900	0.5700
22	Eucalyptus	2.2550	0.0000	0.0000	2.2550
23	*Casuarina*	11.6150	0.0000	0.0000	11.6150
Total		149.3701	74.1686	2.4145	225.9532

19. Kizhoor revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	93.2009	103.0314	53.8022	250.0345
2	Blackgram	0.2500	0.4850	0.2100	0.9450
3	Sugarcane	12.7764	0.0000	0.0000	12.7764
4	Palmyrah	0.3950	0.0000	0.0000	0.3950
5	Chillies	0.0000	0.0450	0.0000	0.0450
6	Tamarind	2.9136	0.0000	0.0000	2.9136
7	Mangoes	0.0664	0.0000	0.0000	0.0664
8	Banana	1.7450	0.0000	0.0000	1.7450
9	Guava	-	-	-	0.0000
10	Other Fruits	1.0000	0.0000	0.0000	1.0000
11	Tapioca	2.3300	0.0000	0.0000	2.3300
12	Lady's finger	0.0300	0.0000	0.0000	0.0300
13	Other Vegetables	0.0300	0.0450	0.0750	0.1500
14	Groundnut	0.0000	1.9450	0.0000	1.9450
15	Sesamum	0.0000	0.2400	0.5200	0.7600
16	Coconut	5.6285	0.0000	0.0000	5.6285
17	Green Manure	6.0800	0.0000	0.0000	6.0800
18	Fodder Crops	0.2100	0.0000	0.0000	0.2100
19	*Casuarina*	19.8729	0.0000	0.0000	19.8729
Total		146.5287	105.7914	54.6072	306.9273

20. Odiampet revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Paddy	103.4830	112.5130	3.4650	219.4610
2	Blackgram	0.0000	0.4050	0.3450	0.7500
3	Sugarcane	2.9100	0.0000	0.0000	2.9100
4	Palmyrah	0.7350	0.0000	0.0000	0.7350
5	Tamarind	0.2000	0.0000	0.0000	0.2000
6	Betlevine	2.0500	0.0000	0.0000	2.0500
7	Mangoes	4.2150	0.0000	0.0000	4.2150
8	Banana	3.2160	0.0000	0.0000	3.2160
9	Guava	0.2250	0.0000	0.0000	0.2250
10	Other Fruits	0.1000	0.0000	0.0000	0.1000
11	Other Vegetables	0.1600	0.0500	0.0300	0.2400

12	Sesamum	0.0000	0.0000	0.4000	0.4000
13	Coconut	28.8429	0.0000	0.0000	28.8429
14	Green Manure	7.2550	0.0000	0.0000	7.2550
15	Fodder Crops	1.0700	0.0000	0.0000	1.0700
16	*Casuarina*	14.2450	0.0000	0.0000	14.2450
Total		168.7069	112.9680	4.2400	285.9149

21. Karasur revenue village					
		Season (Area in Ha.)			
Sl.No	Crops	Khariff	Rabi-I	Rabi-II	Total
1	Blackgram	0.3300	0.4650	0.0000	0.7950
2	Palmyrah	0.4300	0.0000	0.0000	0.4300
3	Tamarind	0.0550	0.0000	0.0000	0.0550
4	Mangoes	0.2100	0.0000	0.0000	0.2100
5	Banana	1.0850	0.0000	0.0000	1.0850
6	Guava	0.3000	0.0000	0.0000	0.3000
7	Other Vegetables	0.0150	0.0800	0.0000	0.0950
8	Groundnut	0.4085	0.6250	0.0000	1.0335
9	Sesamum	0.0000	0.0000	0.2050	0.2050
10	Coconut	19.5370	0.0000	0.0000	19.5370
11	Fodder Crops	0.1275	0.0000	0.0000	0.1275
12	Eucalyptus	18.7384	0.0000	0.0000	18.7384
13	*Casuarina*	67.3025	0.0000	0.0000	67.3025
Total		108.5389	1.1700	0.2050	109.9139