Assessment of the Impacts of Pesticide Use in Agricultural Land on the Ecological Resources of Arial Beel

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It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Kazy Mohammad Iqbal Hossain

Dedicated to My

Beloved Mother

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ABSTRACT

The green revolution package was introduced in Bangladesh agriculture in mid 1960s. It promised to increase production of cereal crops, particularly rice, by the introduction of HYV seeds, application of chemical fertilizers and pesticides, and irrigation. HYV rice has contributed significantly to the progress towards the food self sufficiency of Bangladesh. The use of pesticides has increased by 400% per hectare and its cost has increased by 600% during the last couple of decades. At present, 84 pesticide active ingredients belonging to 242 trade names are registered in Bangladesh. Out of the total pesticide use, over 80% are in rice fields. The rapid increase of pesticide use is causing detrimental effect on the environment, and health of farm workers and consumers. Pesticides are contaminating ground and surface water, which is causing depletion of inland fishing resources and ecosystem. This study was carried out to assess the impacts of pesticide used in rice fields on the ecological resources of the Arial beel, an agroecological zone. Four ecological indicators catfish, daphnia, algae and rat were used in this assessment and the assessment was done by using a linear model known as Pesticide Impact Rating Index (PIRI). Various input data required to evaluate the impacts were gathered from field measurements, Focus Group Discussions with the farmers and fishermen, informal interviews of local leaders, secondary sources, etc. Field data revealed that most of the farmers (44%) used Basudin, a Carbamate pesticide which has high impact on all of the four selected indicator species (catfish, daphnia, algae and rat). Besides this, Furadan also has high impacts on the indicators. Some other pesticides, like Sumithion, Ripcord, Sevin and Malathion, have relatively lower impacts on the ecological resources of the Arial Beel. Most of the farmers of the beel area believed that Integrated Pest Management (IPM) is the most reliable technique to minimize the offsite impacts of pesticides. Local farmers and elite persons opined that training of farmers to build their capacity in adoption of IPM techniques could be one of the suitable strategies to reduce the use of pesticides.

Table of Contents

List of Tables

List of Figures

List of Photos

ABBREVIATIONS

AEZ	Agro Ecological Zone
B. Aman	Broadcasted Aman
BARC	Bangladesh Agricultural Research Council
BBS	Bangladesh Bureau of Statistics
BHC	Benzene Hexa Chloride
CARE	Community of American Relief Everywhere
CEC	Cation Exchange Capacity
CENET	Cornell Cooperative Extension Network
CSIRO	Commonwealth Scientific and Industrial Research Organization
DDT	Dichloro Diphenyl Tricholor Ethane
EcoRR	Ecological Relative Risk
EIQ	Environmental Impact Quotient
ERI	Environmental Risk Index
EXTOXNET	Extension Ecological Network
FAO	Food and Agricultural Organization
HOST	Hydrology of Soil Type System
HYV	High Yielding Varieties
IPM	Integrated Pest Management
IUCN	International Union for Conservation
LC_{50}	Lethal Concentration 50
LD_{50}	Lethal Dose 50
LRI	Land Research Institute
NERI	Norwegian Environmental Risk Indicator
PIRI	Pesticide Impact Rating Index
SWAT	Surface Water Attenuation model
T. Aman	Transplanted Aman
USEPA	United Nation Environmental Protection Agency
WHO	World Health Organization

Chapter I
INTRODUCTION

1.1 Background and Present State of the Problem

The Arial Beel is one of the major wetlands of Dhaka and Munshigonj districts. The beel itself is an Agro-Ecological Zone (AEZ-15) (FAO, 1988). The area of the beel is approximately 14500 ha. Agriculture is the main practice in relatively higher zone of the beel and the deeper portion of the beel is important for faunal diversity. In the past, monocropping of broadcasted Aman or mixed cropping of broadcasted Aman and local Aus was practiced there. With the introduction of Low Lift Pumps (LLPs) in the 1960s and Shallow Tube Wells (STWs) in the 1970s and 1980s, high yielding variety (HYV) Boro production, particularly in the perennial wet patches, became the predominant Rabi cereal. In the shallowly flooded areas, where the soils usually become cultivable by the end of October, wheat, pulses or oilseeds are followed by the HYV Boro, which is harvested just before the normal flooding in May-June and Aman follow the HYV Boro. This has now become the major cropping pattern of the area (Zaman, 1993).

Pesticides are used by the farmers to protect the crops from pests. These pesticides with rainfall are washed out and discharged into the nearby depressions, locally known as 'Ponds'. There are two types of Ponds: (i) unprotected small ponds from where poor fishermen usually catch fish and (ii) protected large ponds (locally known as dighis), which are usually leased out by the local government. Ponds are important dry season habitats of fishes. Chowdhury (2003) found 82 to 90 μg/l residue in a rice field where Phenthoate pesticide was applied one day before his sampling. On the other hand, in the same field he found 5.25 to 8.55 μg/l residue of the same pesticide two weeks after application. This means that a large fraction of the applied pesticide had lost from the field within this time to the nearest depressions except some loss by evaporation.

Pesticides drastically affect the growth and productivity of the fishes in the aquatic community. As a result, ecological resources of the unprotected small ponds are decreasing alarmingly. The reduction of biodiversity, aquatic and amphibian resources, and wildlife habitats had led to a change in the wetland-based human occupations and shrinkage of socio-economic activities (Islam and Sadque, 1992). As a consequence of resource degradation, the beel dependent fishermen had lost their occupations. From several field surveys, it was found that the poor fishermen after losing their previous occupations could not easily adapt to new occupations and in some cases they engaged in illegal work like catching fish from the government leased ponds, which ultimately led to social conflicts between the fishermen and the landowners in the adjacent areas. The records of Dohar and Sirajdikhan police stations show that about 25 people have been died from 1980 to 2006 due to the conflicts in the beel area. Most of the fishermen of the beel area blamed the agricultural practices, especially the use of pesticides in agricultural land, for the degradation of ecological resources of beel. So this study was conducted to identify the impacts of pesticide on ecological resources and to identify convenient options for pest management.

1.2 Objectives with Specific Aims and Possible Outcome

The specific objectives of this study are as follows:

I. To evaluate the impact of pesticide use on the ecological resources of the Arial Beel;

II. To identify the most convenient pest management options for minimizing the impacts of pesticide on ecological resources.

The study has revealed how the use of pesticides in agricultural lands affects the ecological resources of freshwater wetlands. The outcome of the study will be very helpful for the sustainable management of wetland system by adapting eco-friendly pest management options.

1.3 Limitations of the Study

The major limitations of the study are given below:

- Due to time and budgetary constraints, only fifteen ponds were selected for this study. Though this number meets the criteria for sampling as the total numbers of such ponds were 147, if more ponds could be used in the assessment process more accurate result might be obtained.

- It is not easy to access the entire beel areas during the study time, so all surveys were done by considering the proximity of the areas to the road network.
- In this study only the impacts of pesticide on ecological indicator species in Boro and Aman seasons of a year were evaluated which may not be enough for a firm conclusion. If assessment could be done in two to three consecutive years, more accurate result might be obtained.
- Due to the lack of availabilities of toxicity data for the pesticides used in the Arial Beel, the guidelines of EPA (2000) were used to find the 48-hour LC_{50} and LD_{50} values.

1.4 Organization of the Thesis

The thesis contains six chapters. The organization of the chapters is as follows:

Chapter I: The introductory aspects like background and present state of the problem, objectives of the study, limitations of the study and how the thesis is organized are discussed in this chapter. This chapter also reveals the research problems on the basis of the real context of the study area.

Chapter II: The available literatures related to the study have been reviewed in this chapter. It briefly describes the relation between agriculture and pesticides and trends of pesticides use in Bangladesh. This chapter also shows the application of various models in different countries for pesticide impact assessment. Field verification of the model required in this study is also discussed in this chapter.

Chapter III: This chapter outlines the brief description of the study area. It includes some important characteristics of the study area such as soil characteristics, meteorological characteristics and hydrological features.

Chapter IV: This chapter outlines the methodological aspects of the study. It includes different materials and methods which were followed in this study to achieve the intended objectives.

Chapter V: This chapter describes in detail the results of the assessment of the impacts of pesticides on selected ecological indicators in both Boro and Aman seasons. It also shows seasonal variations of impacts including the average impact, cumulative impacts and the field verification such impacts. Some convenient pest management options are also suggested in this chapter.

Chapter VI: This chapter draws some conclusions on the basis of the findings of this study. It also makes some recommendations for further study.

Chapter II

LITERATURE REVIEW

2.1 Introduction

Many groups of individuals and types of institutions--including farmers and other land managers, consumers and consumer groups, food retailers and agribusinesses. regulatory agencies and regulatory "watchdogs" have a stake in better understanding of the non-target impacts of pesticides used in agriculture, landscaping, materials preservation, and elsewhere in modern society. In the past, much of the attention on pesticides focused narrowly on monitoring costs to producers and efficacy in controlling target pests. When non-target impacts were considered, the quantity of pesticides applied was generally used as the only indicator of risk. However. especially as new classes of more potent chemicals have been developed which require far lower dosages than older types of pesticides; it has become increasingly apparent that pesticide weight is not a sufficient proxy for risk. Thus a diverse research community is working to develop methods for more accurately estimating the impacts of pest control products and methods on one or more environmental indicators (Livitan, 1997). In this chapter a number of literatures have been reviewed for better understanding of pesticides, their impacts and models for assessment of impacts on ecological resources.

2.2 Agriculture and Pesticides

Parveen and Nakagoshi (2001) conducted a study in Bangladesh and found that a fundamental contributor to the green revolution has been the development and application of pesticides for the control of a wide variety of insectivorous and herbaceous pests that would otherwise diminish the quantity and quality of food produce. The use of pesticides coincides with the "chemical age" which has transformed society since the 1950s. In areas where intensive monoculture is practiced, pesticides were used as a standard method for pest control. Unfortunately, with the benefits of chemistry have also come disbenefits, some so serious that they now threaten the long-term survival of major ecosystems by disruption of predator-prey relationships and loss of biodiversity. Also, pesticides can have significant human health consequences. So assessment of pesticide impact on ecological components turn to a demand of time and many researchers are consuming their valuable times to develop a convenient technique for the assessment of pesticide impact.

McLaughlin and Mineau (1996) conducted a study and found that pesticide use in crop production has been suspected of being a major contribution to environmental pollution. There are widespread and growing concerns of pesticide over-use, relating to a number of dimensions such as contamination of ground water, surface water, soils and food, and the consequent impacts on wildlife and human health. Farmers often spray hazardous insecticides like organophosphates and organochlorine up to five to six times in one cropping season while only two applications may be sufficient. The usual practice of draining paddy water into irrigation canals may cause river and lake contamination. Residues carried by the water can be taken up by non target flora and fauna, leach in to soil, and possibly contaminate groundwater or potable water.

Farah (1994) found that to reduce crop losses due to pest attack, farmers in parts of Asia are spraying as much as 800 times the original recommended dosage of pesticides.

Dahal (1995) found that the use and abuse of pesticides has disturbed the ecological balance between pests and their predators in developed and developing countries.

FAO (1995) found that the lesser-developed countries still don't use as much pesticide as does the industrialized world. It also apprehended that in 21st century the pesticides use would increase in the developing countries.

Yudelman et al. (1998) described that pest control becomes a social need in countries where the food supply is short and there is an urgent necessity to increase rice production. Before the green revolution, pesticide use was largely confined to the industrialized nations. Today, pesticides are produced and used globally. The third world's use of pesticides increased greatly during the green revolution in the 1960`s and beyond, and it is related to the changed growing conditions which was brought about by the use of green revolution varieties and technologies. Monocultures coupled with increases in irrigation and fertilization often improve conditions for pests, necessitating more control efforts. Insecticide choice in the developing world is often older, broad-spectrum compounds belonging to the organophosphate and carbamate classes chemical families noted for their acute toxicity. These products are popular partly because they are no longer under patent protection thus are considerably cheaper than the newer, still-proprietary pesticides increasingly used in more developed countries. Organochlorine insecticides such as DDT, lindane, and toxaphene are still widely used in the developing world, although their danger to humans and animals is well known. In fact, about half of the pesticides used in the lesser developed countries are persistent organo chlorine, such as DDT. They are used because they are cheaper and are considered safer for farmers to apply because of their relatively low short-term toxicity to mammals (including farmers).

2.3 Pesticide Use in Bangladesh

PAB (2000) and Islam (2000) conducted two separate studies to find out the use of pesticides in Bangladesh. They found that pesticide as agricultural input was introduced in Bangladesh in 1957 and mainly DDT and BHC were distributed by the Government to the farmers free of cost until 1973. The pesticides became very popular to the farmers for two reasons; firstly quick and visible effect on pest and secondly, no cost involvement. In 1974, the subsidy was reduced to 50% and in 1979 it was withdrawn completely. As a result, at first pesticide use declined and again gradually increased and in 1999 the amount reached 15000 metric tons (Figure 2.1). At present 84 pesticides with 242 trade names have been registered in Bangladesh.

Karim (1998) found that the use of pesticides in Bangladesh is less in comparison to other developing countries. He found that approximately 0.03 kg/ha pesticides were used in Bangladesh whereas it was 0.3 kg/ha in India and 0.4 kg/ha in Sri Lanka and 0.8 kg/ha in Indonesia. He also reported that 14,340.40 metric tons of commercial pesticides are used annually, primarily in the cultivation of rice, tea, jute, sugarcane and vegetables. About 70% of pesticides were used on rice. Pesticides used on rice consist almost exclusively of insecticides, but fungicides are used occasionally. In 1989-90 almost 90% of pesticides were used on rice. In Bangladesh, insect pests' outbreak is frequent in rice and crop losses occur due to rice insect pest attack up to 80%.

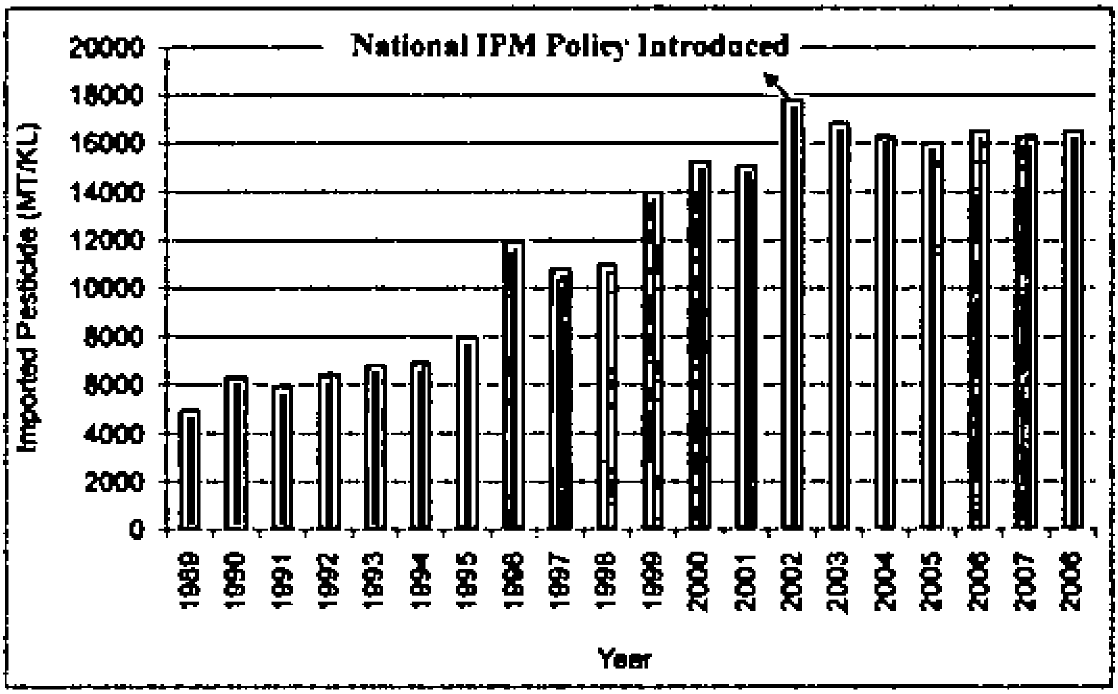

Figure 2.1: Trends of pesticide use in Bangladesh (Data Source: BBS)

Barzman and Das (2000) conducted a study to investigate the impact of pesticides on biodiversity. They found that biodiversity is declining due to the effect of pesticide and fertilizer use. Population of native fish species (Channa spp., Heteropneustes clarias, and Anabas testudineus) is now endangered and the traditional rice fish systems have disappeared. The bird and other small wild animals are in threat of wide spread because of the use of pesticides in rice and vegetables. The rice-based agroecosystem is showing signs of unsustainability. Most of the rice farmers are dependent on insecticides for pest control.

A survey conducted in 2001 by a Non Government Organization, Community of American Relief Everywhere (CARE) of rice farmers in Comilla district, a high-input use area showed that 96% used insecticides during the dry season. But despite of or due to the prevalence of insecticide use, old farmers reported that insect pests are now more difficult to control than in their youth.

Rahman et al. (1995) conducted a survey on the use of pesticides in Bangladesh as part of the IAEA agrochemical residues project. They found that total pesticide consumption doubled over the past 6 years. Among the pesticides applied to agricultural crops, insecticides comprised more than 95% of the total used, fungicides, weedicides, and rodenticides made up the remaining 5%. By chemical composition, organophosphorus compounds comprised 60.4%, carbamates 28.6%, organochlorines 7.6% and others 3.4% of the total pesticides. It was found that those used the least were the most environmentally caustic pesticides. Although much is known about the potential impact of pesticides on the environment and health, more data is required to ascertain the present effects and future risks of increased pesticide use.

Parveen and Nakagoshi (2001) describe that in Bangladesh in the recent years growing use of pesticides by the farmers, beings unaware of the negative effects, poses a big challenge to health, environment and the declining of the economy of the country. Cropland is a major source of sediment and the sediment resulting from soil erosion is regarded as the largest pollutant that affects the water quality. The occurrence of fish epidemics in different parts of the country is apprehended by the scientist and local people that fish mortalities in the open water of Bangladesh have occurred due to the uncontrolled use of pesticides in irrigated rice field.

Rola and Widawsky (1998) conducted a study and found that some extremely hazardous pesticides are used in Bangladesh, although these are prohibited in the producing countries. Among the insecticides used by the Bangladeshi farmers, Bashudin 10 G, Diazinon 60 EC, Sumithion 60 EC and Padan 50 SP have already been banned for use on rice in Indonesia in 1986. But in Bangladesh, these are not restricted yet. Moreover, in Bangladesh the existing pesticide laws and regulations are not strictly enforced in relation to import, formulation, repackaging, distribution, advertising and use. Therefore, obsolete pesticides like Bashudin are also still being used by the farmers and available in market even at low price compared to others.

Pingali and Roger (1995) conducted a study to find the intensity of pesticide use in Bangladesh and found that in Bangladesh the cropping intensity is higher. farmers are producing three crops in a year and more or less the pesticide is being in used for three of the crops. Therefore, the health and environment are continuously exposed to the pesticide that is being used in the crop field. Moreover, the farmers used mostly hand sprayer and other traditional methods. The spray methods they used are associated with high risk of exposure and contamination.

Meisner (2004) and NOVIB (1998) found that many pesticides used in Bangladesh are banned or restricted under international agreements. Pesticide suppliers in Bangladesh even continue to sell the 12 particularly controversial pesticides known by activists campaigning worldwide as the "dirty dozen".

Ramaswamy (1992) stated that, substantial anecdotal evidence suggests that user's lack of information have led to widespread overuse or misuse of pesticides. As a result, pesticide poisonings and ecological damage have become common in Bangladesh.

Islam (2000) describe that there is a suspicion that pesticide residues are common in surface water system, especially in irrigation drains, which ultimately pollute the pond and river water. There are many undocumented cases of chronic health effect of pesticides on farmers and other people. Several factors are supposed to be responsible for chronic health effect, such as improper handling, lack of protective measure, improper storage, use of obsolete pesticides, etc.

2.4 Impact of Pesticides on Freshwater Ecology

Pingali and Roger (1995) found that a greater problem lies in the bioaccumulation of pesticides in beneficial organisms like fish. Residues in food pose to consumers if the maximum residue limit set by the Food and Agriculture Organization (FAO) and World Health Organization (WHO) is exceeded.

Byard (1995) describes that since the early 1980s, when molinate was demonstrated to have killed carp in agricultural drains, an intensive research effort has been undertaken to assess the impact of rice pesticides on aquatic ecosystems in the Sacramento River and Delta. No impact has been found that can be clearly attributed to rice pesticides. However, the rice insecticides methyl parathion and carbofuran, and probably also bufencarb, reached levels in the River and Delta that based on laboratory bioassays, would have been toxic to aquatic microinvertebrates and, in the case of bufencarb, to early life stages of striped bass. Reductions in micro invertebrate populations could have impacted higher organisms in the aquatic food chain such as striped bass and Chinook salmon. Bufencarb was not used after 1981. Since then, changes in the management of the remaining rice pesticides have resulted in dramatic decreases in the levels of these chemicals in the River and Delta. Levels achieved today have no known toxicity to aquatic organisms. As releases of rice pesticides were reduced to achieve nontoxic levels in the River and Delta, however, commensurate recoveries of striped bass and Chinook salmon did not occur, suggesting that rice pesticides may have had little or no role in the decline of these species.

Parveen and Nakagoshi (2001) conducted a study in Bangladesh to know the farmers' perceptions regarding ecological impact of pesticides and found that the level of perception of the farmers about the ecological impact and the impact on air and health hazard were higher than the impact on soil and water. They found that farmers have poor perception regarding the impact on water. A good proportion of the farmers did not have any perception about any of the issues. Some respondents did not response to the statement either.

Handa et al. (1999) conducted a study and found that due to continuous use of pesticides, appreciable quantities of pesticides and their degraded products may accumulate in the soil ecosystem. Microbes and plants are among the most important biological agents that remove and degrade waste materials to enable their recycling in the environment. Soil micro flora, mainly bacteria, fungi, algae and protozoa, makes a valuable contribution in making the soil fertile through their primary catabolic role in the degradation of plants and animal residues in the cycling of the organic. inorganic nutrient contents of soil. Pesticides that disrupt the activities of the soil microorganisms could be expected to affect the nutritional quality of soils and would therefore have serious ecological consequences.

Schueler (1995) described that when pesticides contaminate water they can be harmful to the fish that live there. Insecticides can be particularly toxic to fish. Chlorpyrifos, a common contaminant of urban streams, was found very highly toxic to fish, and had caused fish kills in waterways near treated fields or buildings. Diazinon, also commonly found in urban streams, was acutely toxic to many species of fish, including salmon.

Kalam (1998) conducted a study and found that the intensification of agriculture has been accompanied by the rapid increase of insecticide use. Increased use of pesticides leads to two primary concerns:

1) Adverse effects on the health of farm workers as well as others exposed to the pesticides.
2) Polluted ground water and surface water, causing harm to the water users as well as inland fisheries and other aquatic animals.

Bues et al. (2004) conducted a study to find the environmental impacts of pesticides used on processing tomato crops at 10 experimental sites of five Mediterranean countries and on the Reunion Island. Those were assessed over 3 years using two different methods. The indicator obtained using the environmental impact quotients (EIQ) of pesticides method was highly correlated with the amount of active ingredients used, whereas the indicator based on the pesticide environmental impact (IPEST) method was highly correlated with the number of treatments applied. Both methods showed that fungicides were largely responsible for the estimated impacts. The EIQ method showed that the impact was greater on non-human biota than farm workers and consumers. The indicators obtained using these two methods were only slightly correlated with each other but both methods used together provided a more complete analysis of the impacts of pesticides.

Nwigwe (2006) conducted a review on the effects of carbamate pesticide on fish in freshwater ecosystems and found that Carbaryl is a methyl-carbamate 1- naphtholenol marketed in Nigeria as Vetox 85R and used in controlling soil insects and many insect pests of cash crops. It is also employed in controlling mites, lice, fleas, and ticks on poultry, cattle and domestic pets. Indiscriminate application on crop farms by aerial and ground spray, accidental spillages, dumping of empty pesticide containers into freshwaters and open fields, and leakages from containers are important means through which Vetox 85R gains entry into the environment. Vetox 85R is also applied on ponds and stagnant water purposely to control aquatic insects. Research reports reveal chronic and acute toxic effects of this chemical on fish and fish food. The deleterious effects of sublethal concentrations of carbaryl on fish during spawning period include rupture of blood vessels supplying the ovary with blood, rupture of ovigerous lamellae and enlargement of oocysts. Behavioral impact on fish includes restlessness. Chronically sub-lethal concentrations also resulted in hypoglycemia and depletion of liver glycogen. Other effects include rupture of the columnar epithelium of fish stomach. Carbamate insecticides are generally neurotoxic, inhibiting activity of cholinesterase. High concentration of carbaryl in water leads to fish and fish-food mortality.

Chang et al.(2005) assessed the responses of zooplankton communities with different population densities of an invertebrate predator, Mesocyclops pehpeiensis, to insecticide (carbaryl, 0.5 mg L−1) in small-scale mesocosm tanks (20 L). Cladocerans were eliminated by carbaryl application at both high and low predator densities. The density of rotifers increased after the elimination of the cladocerans by carbaryl application at low-predator density but not at high-predator density. Carbaryl application increased the relative importance of predatory interactions in the zooplankton community. The results suggest that predator abundance can affect the response of a zooplankton community to carbaryl application through predation on surviving zooplankton.

2.5 Review of Pesticide Impact Assessment Models

Maud et al. (2001) reviewed five pesticide impact assessment models and stated that the measurement of the direct environmental impact of pesticide use requires some objective criteria for assessing those effects. A range of indices of pesticide risk to the environment has been proposed. The models he studied are:

- The Environmental Impact Quotient (EIQ) of Kovach et al. (1992)
- The insect pest management index of Metcalf (1975)
- The environmental health policy program ranking system of Pease et al. (1996)
- The pesticide Index (PI) of Penrose et al. (1994)
- The integrated farming systems and environmental exposure to pesticides of Wijnands and Dongen (1995).

After reviewing. Maud et al. (2001) suggests that an index should have the following properties:

- . use easily available data
- . be simple

- be transparent
- avoid contentious weighting systems
- have a large range of scores that allows differentiation of the products
- explicitly exclude risks to humans and concentrate on environmental risks
- be more analogous to the technical concept of risk = magnitude of damage x probability of occurrence.

None of the five indices listed above demonstrated all these criteria, and most failed on several of them. For those reasons Maud et al. (2001) were unable to recommend any of those indices. On the other hand PIRI includes all of the following properties, so it can be safely used for assessment of pesticides on ecological resources in any part of the world. Other models which have been reviewed for this study are:

2.5.1 The NERI model

Spikkerud et al. (2005) describe a model for pesticide impact assessment in Norway. According to him Norwegian Environmental Risk Indicator (NERI) was developed by a project group under the Norwegian Agricultural Inspection Service (now part of the Norwegian Food Safety Authority) in 1998. It was developed for tax banding of pesticides and as a tool to evaluate the risk reduction from different measures and recommendations implemented under the National Action Plan for reduced risk from use of plant protection products (1998–2002). A summary of the risk classification (possible risk values ranging from 0 to 4) for the different model components was presented to give an introduction to the model specifics.

Ganzelmeier et al. (1995) conducted a study to estimate the spray drift of pesticides based on the investigations. For surface runoff the basic assumption, asserted in ECPA (1995) with reference to Wauchope (1978), is that surface runoff for the majority of pesticides is less than 0.5%. with the following modifications; 0.5% loss of pesticides with high potential, 0.3% loss of pesticides with medium potential, and 0.1% loss of pesticides with low potential for particle-bound transport. The potential for particle-bound transport is judged according to a system based on Goss and Wauchope (1990), focusing on pesticide half-life in soil (DT50), sorption to soil organic matter (K_{OC}) and solubility. Details on the breakpoints are given by Spikkerud et al. (2005). Due to the complexity of mathematical leaching models and NERI's intended use in the agricultural administration, no calculation of runoff into the drainage systems is included. A total score for environment is calculated for each active ingredient in each product in accordance with the equation below:

Total score for environment = Te+Ta+Tb+A+L+P+B+F

where Te being score for earthworms, Ta for bees and other arthropods, Tb for birds. A for aquatic organisms (daphnia/ fish and algae/water plants), L for leaching potential, P for persistence, B for bioaccumulation, and F for formulation type. The breakpoints for the individual organisms and processes are given by Spikkerud et al. (2005), and are for the organisms based on toxicity tests in relation to the predicted environmental concentration of the pesticide. The SCI-GROW model (US EPA, 2001) calculates a score for leaching risk, based on pesticide dosage, mobility (K_{OC}) and persistence (DT50). This is used to assign a score L for leaching. Based on half-life in soil, each substance is assigned a persistence factor (P), and the score for bioaccumulation (B) is assigned according to different combinations of log POW and half-life in soil. In order to take the spillage risk during the mixing of pesticides into consideration, a score for type of formulation (F) is assigned. A total Environmental Index Risk (ERI) is calculated for each active ingredient in each individual product. In this way an active ingredient that is used in several products can have several (different) environmental risks depending on the application rate and type of use. The total Environmental Risk Index (ERI), for each individual active ingredient (j) in each product is multiplied by the area on which the product is used at a particular year, to give the relative environmental load from a specific pesticide. These indices are summed for the area and time period investigated to obtain a cumulative risk index (see formulas below), to monitor the changes in total environmental load from using pesticides within a defined area over time. Here, they limit their analysis to active ingredient, not separating between different formulations. The equation of environmental risk calculation is:

$$\text{Total environmental risk} = \sum_{all\ pesticides} E_{ri\ pesticide\ j} \times area_{pesticide\ j}$$

The necessary input of toxicity data for each active ingredient was taken from a database established by the Norwegian Food Safety Authority, which is based on official documents provided by manufacturers for the approval process in Norway. For a few compounds, values were taken from the literature (Tomlin, 2002).

2.5.2 The EIQ model

Kovach et al. (1992) describe the Environmental Impact Quotient (EIQ) model. The model was developed by experts at Cornell University, New York State, with a focus on Integrated Pest Management (IPM). It provides an overview of the extensive toxicological data available on some common fruit and vegetable pesticides to help growers and other IPM practitioners make more environmentally sound pesticide choices. The EIQ is an average of three general risk components calculated for each pesticide: (1) potential health risk to farm workers, (2) potential health risk to consumers either through direct food residues or via groundwater contamination, and (3) potential negative effects on the environment including terrestrial and aquatic organisms.

The basic pesticide data used in the EIQ model were gathered from a variety of sources. The Extension Toxicology Network (EXTOXNET) was the primary source (Hotchkiss et al., 1989) and conveys pesticide-related information on the health and environmental effects of approximately 100 pesticides. Further, CHEM-NEWS of Cornell Cooperative Extension Network (CENET) that contains approximately 310 US EPA—Pesticide Fact Sheets, describing health, ecological, and environmental effects of the pesticides (Smith and Barnard, 1992), was utilized.

The impact of pesticides on arthropod natural enemies was determined by using the SELCTV database (Theiling and Croft, 1988). Leaching, surface loss potentials (runoff) and soil half-life data of approximately 100 compounds are contained in the National Pesticide/Soils Database developed by the USDA Agricultural Research Service and Soil Conservation Service, developed from the GLEAMS computer model (Leonard et al., 1987) that simulates leaching and surface loss potential. Bee toxicity was determined using tables by Morse (1989) in the 1989 New York State pesticide recommendations. In order to fill as many data gaps as possible, Material Safety Data

Sheets and technical bulletins developed by the agricultural chemical industry were also used when available. To simplify the interpretation of the data, the toxicity of the active ingredient of each pesticide and the effect on each environmental factor evaluated were grouped into low, medium, or high toxicity categories and rated on a scale from 1 to 5, with 1 having a minimal impact on the environment or of a low toxicity and 5 considered to be highly toxic or having a major negative effect on the environment. The specific ratings are given by Kovach et al. (1992).

2.5.3 The SWAT model

Brown and Hollis (1996) describe the details on the Surface Water Attenuation (SWAT) model. According to them, this is a semi empirical model that simulates concentrations of agriculturally applied pesticides moving to surface waters. The model is based upon a direct hydrological link established between soil type and the amount of water moving rapidly to streams in response to rainfall. Attenuation factors describe the decrease in concentrations of pesticide between field application and water moving from the site into surface waters. The soil types in the Skuterud catchment have been classified by the Norwegian Forest and Landscape Institute and can be aggregated into three groups, represented by the main types classified as Rk8, He8 and Je3. The Je type (37 ha) includes marine sand and moraine deposits while Rk (205 ha) and He (30 ha) are mainly marine silt clay deposits. Prior to simulation with SWAT, all soil types in the Skuterud catchment were classified according to the Hydrology of Soil Types system (HOST-class) (Boorman et al., 1995). SWAT-model simulations were run with local weather data from the time period in question, retrieved from http://lmt.bioforsk.no (in Norwegian).

The model estimates a best- and worst-case pesticide concentration in drainage water, from information of pesticide dose and physical/chemical properties, soil properties and precipitation. From this, each spraying is designated to a risk class (Low, Low/Medium, Medium, Medium/High, and High) on a unit area basis. Here we also substituted the risk classes with numbers (1–5). A total risk index for the catchment was calculated by summing the risk numbers for all sprayings, giving outputs comparable to the two other models on a catchment scale. Pesticide property data were taken from the database of the Norwegian Food Safety Authority—being the same data as utilized in the NERI-model.

2.5.4 The E$_{CO}$RR model

Sanchez-Bayo et al. (2006) describe a site-specific methodology which was developed to assess and compare the eco-toxicological risk that agricultural pesticides pose to ecosystems. The ecological relative risk (EcoRR) is a composite scoring index for comparing relative risks between different plant protection products, and is used to assess the potential ecological impact their residues have after being applied to agricultural systems. The EcoRR model is based on standard frameworks for risk assessment (e.g. PEC/toxicity), but takes account of factors such as persistence of residues and biodiversity of ecosystems. The exposure module considers the environmental concentrations of a substance, its persistence, bioaccumulation and probability of exposure in several environmental compartments (water, sediment, soil, vegetation, air). The toxicity module takes into account the biodiversity of the ecosystems affected, whereby the endpoints used are weighted by the proportional contribution of each taxon in a given environmental compartment. EcoRR scores are calculated independently for each compartment and affected areas, thus enabling pinpointing of where risks will occur. The procedure to calculate EcoRR scores is explained using an example, and a sensitivity analysis of the model is included. A simulated risk assessment of 37 pesticides intended for use in a cotton development is also given as a case study. Exposure data were obtained using fugacity model II in areas previously defined by spray drift models. Toxicity data to vertebrate taxa and crustaceans were obtained from several databases, and biodiversity data from local sources. EcoRR scores were calculated for each compartment both on- and off-farm, during a normal growing season and during a flood, and a comparative relative assessment for all pesticides is discussed. EcoRR scores were also compared to traditional assessments using quotients for some taxa in the aquatic and terrestrial environments, revealing a good correlation between both models in some cases. It is apparent that EcoRR scores reflect adequately the potential risk of those chemicals to ecosystems, though they are less dependent on toxicity to sensitive species than the simple quotient. This methodology can be used either with field measured data or model predicted data. so management options for new chemicals can be tested prior to their application on crops.

2.6 Pesticide Impact Assessment Using PIRI

Levitan et al. (1995) and Werf (1996) described that systematic methods that allow a relative assessment of off-site impacts of pesticides are of great value to many people, including pesticide users, natural resource managers and regulators. as an aid in choosing the pesticides and practices with the least detrimental impact on the environment. Risk indicators are regarded as useful tools in minimizing off-site impacts of pesticides and can assist in decision making and policy formulation (Reus et al., 2002). Generic methods for assessing pesticide effects on the environment are currently imperfectly developed and consequently are a field of current interest (Levitan, 1997; Reus et al., 2002).

Several approaches and tools have been developed to carry out the relative assessment of pesticides impact on the environment (Levitan 1997; Sanchez-Bayo et al., 2002; Reus et al., 2002; Brown et al., 2003). These approaches vary considerably in complexity and comprehensiveness; include tabular databases, single- and multiple-parameter hazard assessments, composite impact rating systems, a combination of economic and site-specific parameters, and holistic assessments that include agro-ecological impacts and pest control practices (Levitan et al., 1995; Reus et al., 2002). The objectives of these approaches may include assessments of the toxicity of pesticides to a particular organism (e.g. honeybees), the potential impact of pesticides on the health of farm workers, the suitability of a pesticide for an IPM system or the use of the approach as a decision-making tool for choosing a pesticide with minimum potential for water contamination. Consequently, the packages differ in terms of the pesticide parameters taken into account and their emphasis on various components of the environment (Balmer and Frey, 2001; Reus et al., 2002). The choice of the specific tool or risk indicator should be made carefully, considering not only the environmental component of interest, but also a range of other factors. For example, Levitan (1997), based on a comparison of assessments made by three different methods, demonstrated that the rank order of pesticides depends in part upon the components of the analysis. These components being, as Levitan (1997) stated:

"The pesticides considered, the variables assessed, the choice of specific measurable endpoints as the indicators of impacts on these variables; the mathematical structure of the model, including relative weighting of variables and scoring of results; the method for filling data gaps; and whether usage data are factored into the equation."

Reus et al. (2002) compared and evaluated eight pesticide risk indicators that had been developed in Europe and observed a large variation in environmental compartments considered and risk ranking of pesticides. Ideally, an indicator needs to deal not just with the inherent hazard of a pesticide but rather with the potential risk it poses. This involves taking into account the rate and method of application of the pesticide as well as environmental and site conditions and taking into consideration the asset threatened by use of that pesticide.

Brimner et al. (2005) used the EIQ risk indicator of Kovach et al. (1992) in a study of the effect of herbicides used in herbicide tolerant crops on environmental impact of weed management. In that study the EIQ data were multiplied by the amount of active ingredient per hectare to give an Environmental Impact (EI) for each pesticide. The EIQ risk indicator was limited by the three point ranking scales used for a variety of measures (such as toxicity to birds, bees, other beneficial arthropods, persistence in the soil and on the leaf) and the arbitrary weighting given to chronic toxicity to mammals, bees, beneficial arthropods, birds and fish, as well as the manner in which environmental persistence both in soil and in the plant is incorporated.

Kookana et al.(1998) have developed a software package named Pesticide Impact Rating Index (PIRI) that provides an improved pesticide risk indicator for water quality. PIRI is based on pesticide use, the pathways through which the pesticides are expected to migrate to the water resources (asset), and the value of the asset. Each component is quantified using site conditions (soil type, soil organic matter content, water input, slope of land, soil loss, recharge rate, depth of water table etc.) and environmental conditions (rainfall and temperature). For each pesticide, the rate and method of application, its sorption and persistence properties, its toxicity to a range of receptor organisms (chosen to represent different trophic levels, e.g. algae, daphnia, fish and rat) is assessed.

Pesticide environmental risk indicators vary greatly in terms of their purpose. compartments, methodology and are often very broad in scope covering, for example, the impact on aquatic organisms, soil organisms, bees, occupational exposure, human health effects. PIRI, in contrast, focuses solely on assessing, with greater rigour, the off-site migration potential of pesticides and risk of surface or groundwater contamination. PIRI, however, allows considerations of consequent effects on (potential toxicity to) aquatic organisms and a comparison with drinking or environmental water quality guidelines. Based on the literature, the following unique properties of PIRI were found based on which the present study was conducted.

- In assessing the risk to the groundwater, PIRI takes into account the decrease in soil organic carbon with soil profile depth, recognizing its major impact on sorption and degradation of pesticides and consequently on leaching. Hence the attenuation of a pesticide in different zones of the soil profile is calculated separately to assess the overall leaching potential of each pesticide. This is a more rigorous treatment of pesticide leaching than that in other risk indicators.

- Cooper (1996) and Muschal (1997) stated that calculations of potential off-site migration of pesticides to both surface and ground waters in PIRI have a much stronger mechanistic and logical basis, rather than using relative scoring tables to differentiate between pesticides. Examples of this include (i) the incorporation of the effect of decreasing organic carbon content with depth (as mentioned above), and (ii) the effect of sorption of pesticide to soil organic carbon (represented by the parameter Koc) on the transport through erosion, which is based on a sigmoid curve rather than often assumed linear relation. This is a better way to incorporate the progressively diminishing effect of Koc on pesticide transport at either the higher or the lower end of the Koc scale.

- PIRI covers all the major pathways for surface transport of pesticides, namely transport through soil colloids (due to water erosion), dissolved phase in runoff and spray drift. Some existing indicators consider only one (spray drift) or two pathways (drift and runoff). The colloid (soil erosion) pathway is often ignored in risk indicators (e.g. OECD, 1998; Verro et al., 2002; Reus et al., 2002). However, soils in parts of Australia and other tropical countries are likely to be more erosion prone than Europe, where most work on risk indicators has been carried out.

- Leonard (1990) stated that the outputs from PIRI have realistic bounds, which are guided by published experimental data, e.g. a maximum of 10% of the applied mass of a pesticide transported to a surface water asset under a worst case scenario is based on the review of experimental and monitoring data.
- The rigour in PIRI has been achieved without making it a data-hungry model and sacrificing its practicability. PIRI's assessment has been corroborated by monitoring data from case studies.

2.7 Verification of PIRI Assessment

A study was conducted by Kennedy et al. (2001) on endosulfan levels in runoff water from two farms and found endosulfan levels in the range of 2.5 to 45 μg L−1, depending on the timing of runoff after spraying. The exception in this category was dimethoate which, although it was assessed to migrate, was not detected in the residue monitoring program. On the other hand, the pesticides that were monitored and found to have low risk ratios (<1.0) by PIRI included amitraz, chlorpyrifos, demeton-s-methyl, dicofol, omethoate, parathion methyl and thiadizuron. Except for chlorpyrifos, none of the above pesticides was detected in the water samples from the area (Cooper, 1996, Muschal, 1997). In the case of chlorpyrifos, the survey found that only 10% of farms in the area used it that year, therefore risk rating was low. Overall, PIRI assessment was correct for more than 85% cases. This general consistency between residue monitoring data and risk rating by PIRI demonstrates that despite being a simple risk indicator, PIRI is able to make a reasonable qualitative prediction of off-site migration potential of pesticides to surface water.

Daniel et al. (2005) conducted a study where the pesticide impact rating index (PIRI) has been integrated with a Geographic Information System (GIS) to enable regional assessment of pesticide impact on groundwater and surface water resources. The GIS version of PIRI (PIRI-GIS) was used to assess the impact of pre-planting atrazine use in the pine plantations on the Gnangara Mound, Western Australia. The impact on groundwater was found to be spatially variable, mainly dependent on soil type and depth to groundwater, because land use variables were spatially constant. Areas with the greatest impact on groundwater were those where the soil had a low sorption capacity for atrazine. Knowledge of the spatial distribution of the sorption coefficient based on organic carbon (Koc) for atrazine was found to significantly improve the results from PIRI-GIS. Average values for Koc (i.e. based on overseas data) were too low for most of the local soil types, resulting in a general overestimation of pesticide impact on groundwater resources, but an underestimation of impact in areas that should be of greatest concern (i.e. where the soil has a low sorption capacity for atrazine). They concluded in their work that, PIRI assessment was able to deliver a reasonable output on offsite migration of pesticides to surface and groundwater.

Chapter III

DESCRIPTION OF THE STUDY AREA

3.1 Introduction

The Arial Beel lies approximately between 23°32′ to 23°48′ N latitudes and 90°08′ to 90°27′ E longitudes. It is a large depression of about 723 km^2 lying between the Ganges and Dhaleshwari rivers south of Dhaka. Heavy clays occupy almost the whole landscape. Despite the proximity to the two major river channels, the deep seasonal flooding is caused predominantly by accumulated rainwater which is unable to drain into rivers when they run at high levels. Much of this beel remains wet through the dry season. It has much in common with the lower Atrai Basin and the Gopalganj-Khulna Beel. The soils of this area are dark grey and acidic heavy clays. Non-calcareous dark grey floodplain soil is the chief general soil type. Organic matter content generally exceeds two percent in the top subsoil. Available moisture holding capacity is inherently low. General fertility level is medium to high. The Arial Beel itself is an agro-ecological zone according to the Food and Agricultural Organization classification (FAO, 1988).

3.2 Areal Distribution of the Beel

The total area of the Arial Beel is about 14436 ha. It belongs to Dhaka and Munshigonj districts and located at four upazillas namely Dohar, Nawabgonj, Sreenagar and Sirajdikhan (Figure 3.1) of which Dohar and Nawabgonj are in Dhaka district and Sreenagar and Sirajdikhan are in Munshigonj district. The areal distribution of the beel among the four upazillas is given in Figure 3.2. It can be seen from the figure that the greatest portion (67%) of the beel belongs to Sreenagar upazilla which is followed by Nawabgonj upazilla (24%). The least portion of the beel (4%) belongs to Dohar upazilla and it is followed by Sirajdikhan upazilla (5%).

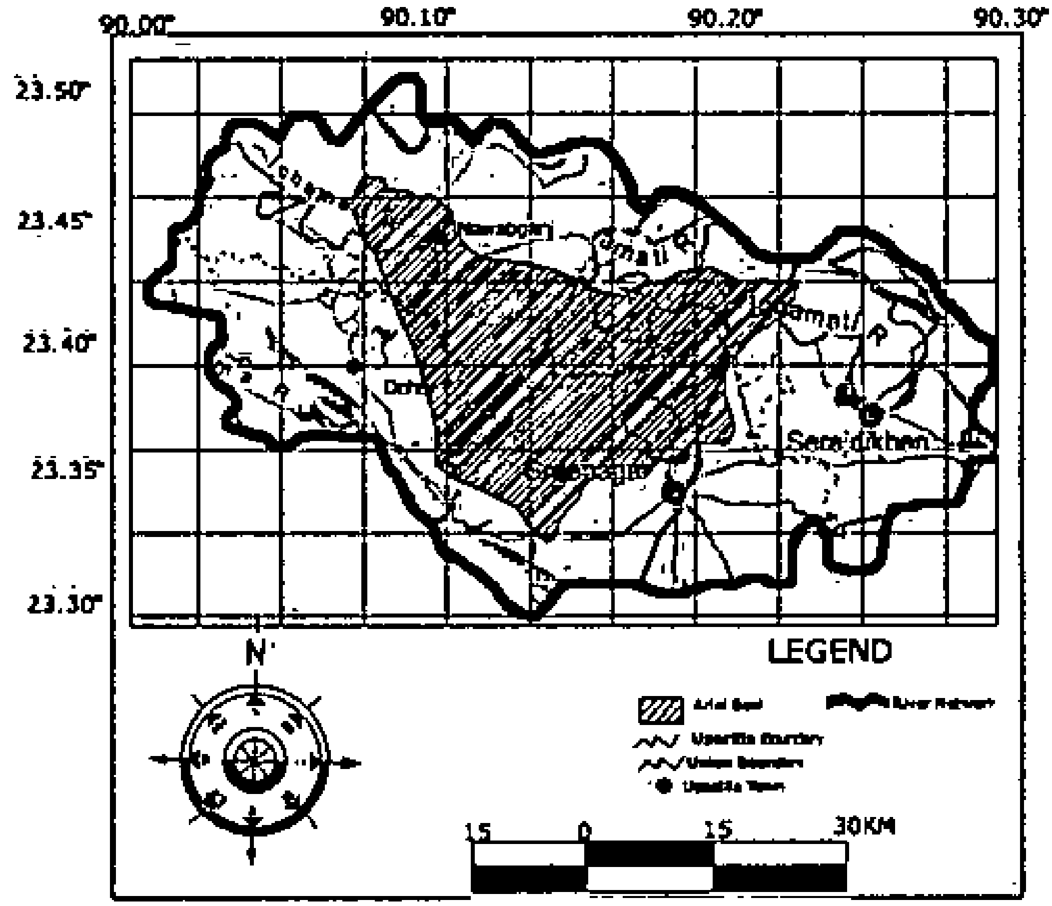

Figure 3.1: Location of the Arial Beel among four upazillas

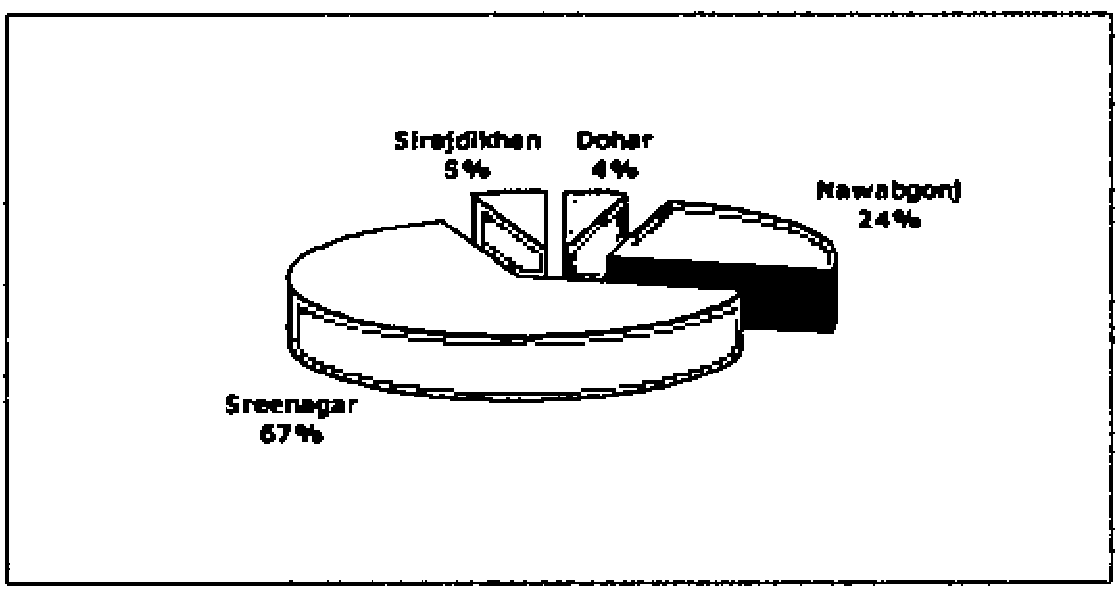

Figure 3.2: Distribution of the Arial Beel in four upazillas

3.3 Climatic Condition

The Arial Beel area has a tropical and humid monsoon climate. From December to March (winter) air flows from the northeast, while from June to September (monsoon) it flows from the southwest; these two periods of air movement are called the northeast and the southwest monsoons respectively. The southwest monsoon originates over the Indian Ocean and carries warm moist air that produces some of the highest rainfalls in the area. So, southwest monsoon is often simply referred to as the "monsoon" meaning rainy season. A reversal of the monsoon takes in about two months. The first reversal occurs in April-May when the change of regional wind direction is from the northeast to the southwest via the northeast monsoon and the second reversal occurs in October-November when the change is from the southwest to the northeast via the southwest monsoon. These periods of changing wind direction are called the pre-monsoon and post-monsoon seasons, respectively. Climate is mainly influenced by the Indian Ocean monsoon climate. Average annual rainfall ranges from 1400 mm to 2200 mm. About 85% of the rainfall occurs during the monsoon i.e. from June to October. Flood comes from three sources: direct rainfall, over bank spills from the major rivers like the Ganges and the Dhaleshwari. Each phenomenon occurs alone or in combination with others. Average temperature varies from 25° to 35° C during the year. Sometimes it falls below 10° C during the winter (Source: Bangladesh Meteorological Department).

3.4 Hydrological Features

The Arial beel is a low laying basin between the Ganges and the Dhaleshwari Rivers. The Ichamati River also flows through the beel area. A satellite image of the Arial Beel is given in Figure 3.3 which shows the major rivers of the study area. It receives a large quantity of runoff during the monsoon from its territorial settlements (Figure 3.4). It is the drainage outlet of the Dohar, Nawabgonj, Sreenagar and Sirajdikhan upazillas.

There are a number of large and small depressions in the beel which are locally known as ponds. Figure 3.5 shows the satellite image of some ponds of the Arial Beel. These depressions of the beel are able to store a large amount of water even in winter and are the main reservoirs of freshwater fisheries. The approximate hydrological setting of the Arial Beel is given in Figure 3.6. Due to the flooding of the major rivers

Figure 3.3: Satellite image showing the hydrologic setting of the Arial Beel

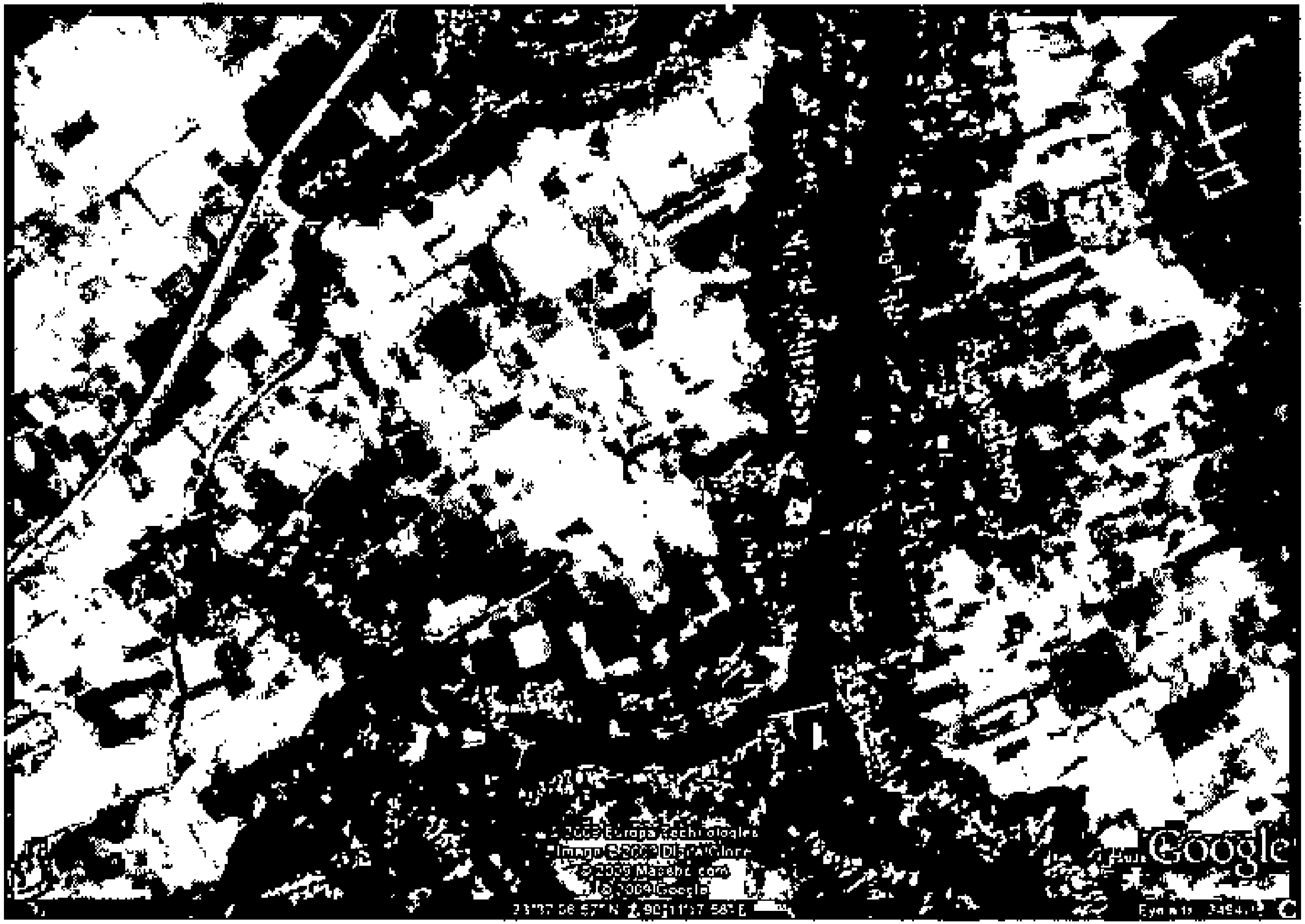

Figure 3.4: Satellite image of the Arial Beel showing its territory settlement

Figure 3.5: Some large ponds in the Arial Beel

in this region, the greatest portion of the beel (approximately 10105 ha) is inundated round the year and the completed surface drainage of this portion does not occur (Table 3.1) and some of this portion remains wet even through the dry season The flooding depth of this portion is as much as 1.53- 3.05 m (Table-3.2). A number of canals like Modonkhali canal, Jahanabad canal, Morichputi canal, Rarikhal, Sreenagar canal, etc. help drain out the water when the water level of major rivers of this region begins to decrease. Figure 3.7 shows a satellite image of a canal network of the Arial Beel.

Table 3.1: Distribution of lands of the Arial Beel according to drainage

Surface Drainage Condition	Amount of Land (ha)
Poorly Drained but Surface Drains Early	2,310
Poorly Drained and Surface Drains Late	10,105
Total	12,415

Source of data: Bangladesh Agricultural Research Council (BARC)

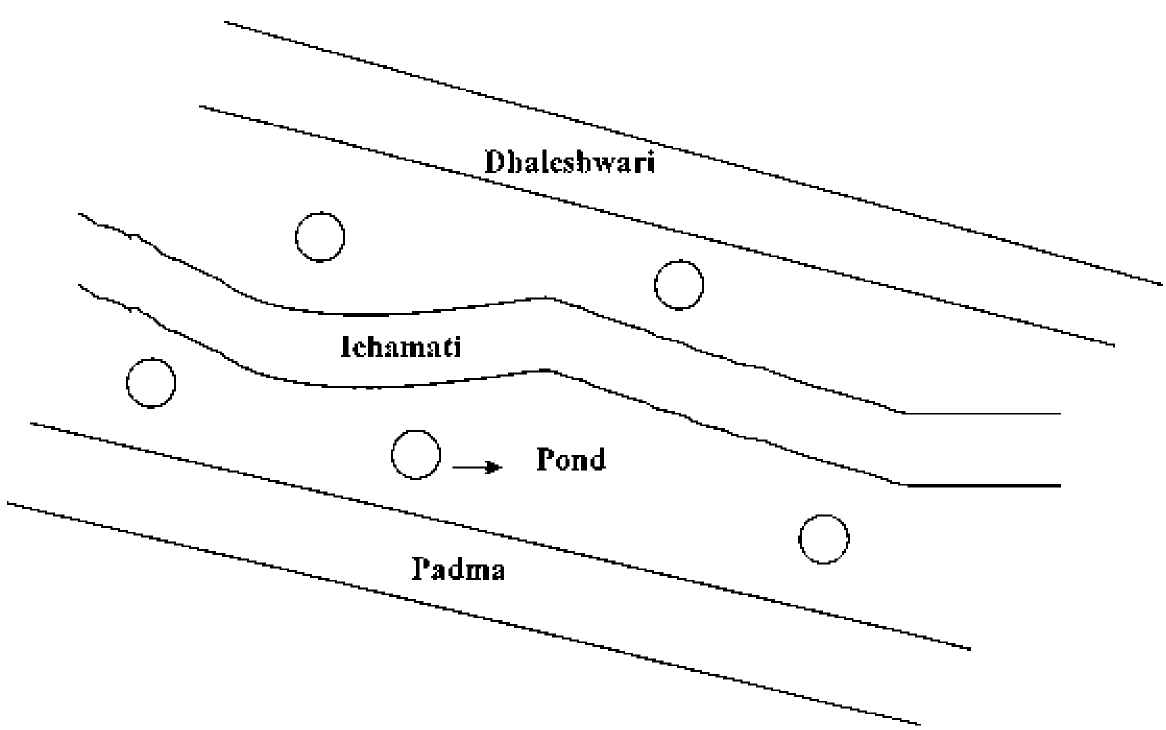

Figure 3.6: Hydrological Setting of the Arial Beel

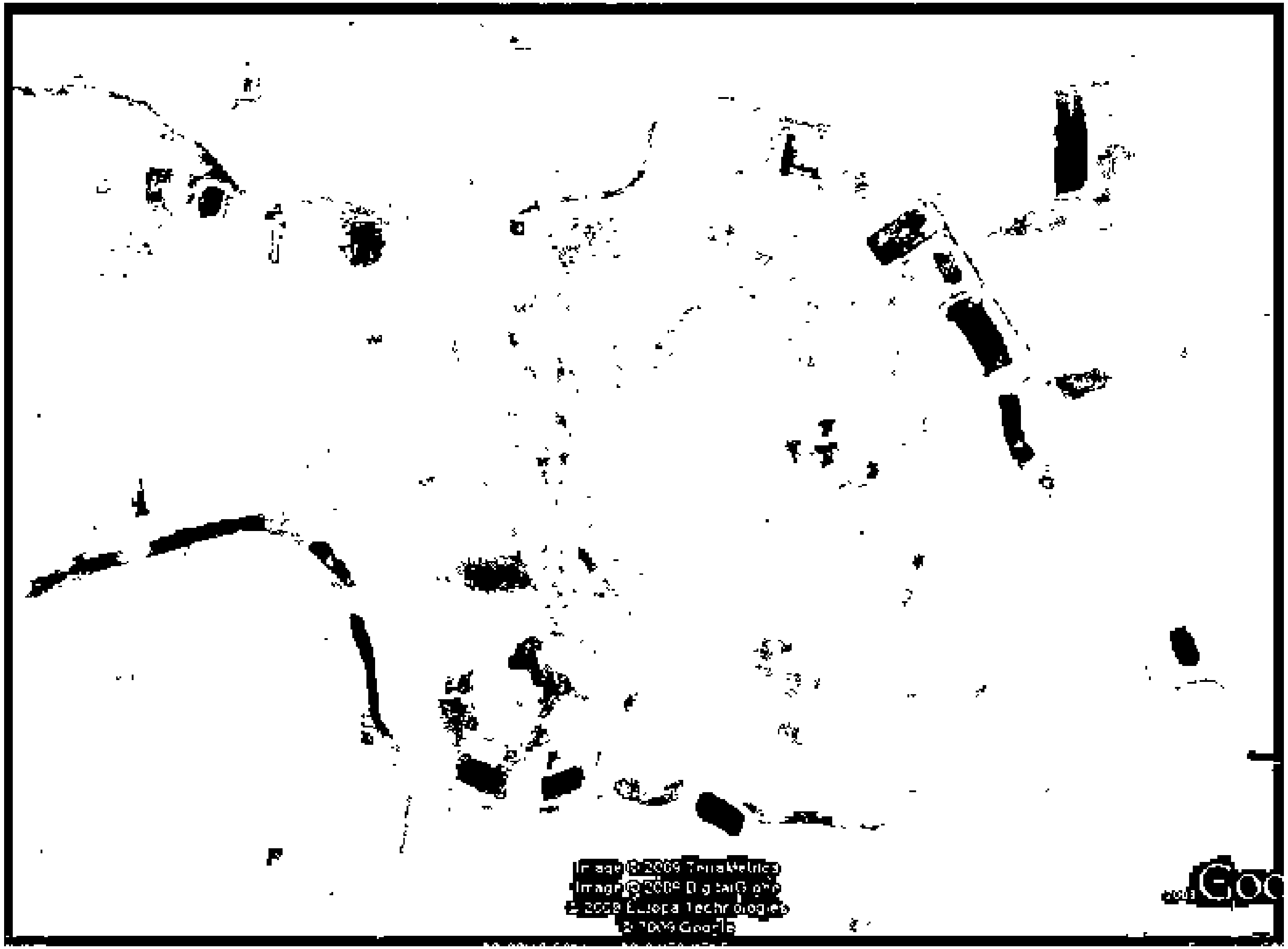

Figure 3.7: Satellite image of the Arial Beel showing some canal

3.5 Ecological Resources of the Arial Beel

The Arial Beel has a great ecological, economic, commercial and socio-economic importance. It contains very rich components of biodiversity of local, national and regional significance. Approximately 500 species of flowering plants, 150 of vertebrates and 400 species of vertebrates were found in the beel area (Islam, 2000). It also provides habitat for a variety of resident and migratory waterfowls, a significant number of endangered species of international interest, and a large number of commercially important plants and animals. Approximately 260 species of fin fishes and 25 shell fishes are available in the beel. The fish species found in the Arial Beel are koi, kholisha, bele, mola, dhela, taki, punti, meni, singi, magur, chanda, baim, pholi, darkina etc. Fishes like aire, boal, shol, gazar and fry and fingerlings of river breeding major carps like rui, catla, mrigal and kalbasu also visit the Arial Beel to feed and grow. Besides fish, several species of freshwater prawn such as kucha chingree, gura icha, golda chingree, thengua chingree etc and their larvae & juveniles are also found. In addition, several species of freshwater mussels and snails also occur.

Some important plant species of the Arial Beel are Hizal (*Barringtonia acutangula*), Tamal (*Diospyros cordifolia*), Barun (*Crataeva nurvala*), Madar (*Erythrina variegata*), Gab (*Diospyros peregrina*), Dumur (*Ficus hispida*), Chalta (*Dillenia indica*) and Dehua (*Artocarpus lacucha*). Paniphal (Trapa bispinosa and T. maximowickzii) is plentifully available in the beel and provides nutritious starchy kernels to the poor community. Large varieties of aquatic vegetation and fruits like Makna (*Euryale ferox*), Singara (*Trapa bispinosa*), Lotus, Lily and Hogla (*Typha elephantina*) have created a source of livelihoods of the local people. The beel is also important for medicinal plants. A number of species of Polygonum. locally known as bishkatali of kukra are available in the beel which are used as antibacterial agents. The flowers and seeds of paddo (*Indian lotus*) are used for the treatment of piles and as cardiac tonic. The flowers of water lilies are reputed as a remedy for heart ailments. Local quacks harvest these medicinal resources for their livelihood income earning and many local people use these for the remedies from various diseases (Islam, 2000).

3.6 Soils Characteristics

The greatest portion (approximately 10538 ha) of the Arial Beel is lowland where the flooding depth is about 1.53-3.05 m. On the other hand. 1877 ha of land can be classified as medium lowland and there the flooding depth varies from 0.93 m to 1.52 m and approximately 2021 ha of land contain variable flooding depth (Table 3.1). The land slopes of the beel are not so steep and in most cases it does not exceed 3%. The relief of the lands of the beel is almost regular. The beel does not contain a large depth of effective soil and the effective soil depth of the largest portion of the beel (10105 ha) is only 0.60-0.90 m. Only 722 ha of land of the beel contains the highest effective soil depth (>1.22 m) (Table 3.3). The soils of the beel are dark grey, acidic heavy clays. A non calcareous dark grey floodplain soil is the major general soil type. Most of the soils of the Arial Beel are clay soils and other dominating soil classes are: silty clay, silty loam, and silty clay loam (Table 3.4). Almost all soils of the Arial Beel contain more than 2% organic matter and organic matter contents are high in topsoil only. The soils of the beel also have high Cation Exchange Capacity (CEC) and the soil salinity does not exceed 2 μmohs/cm. The moisture holding capacity of the soils of the beel is inherently low and the moisture holding capacity of the greatest portion of the beel (approximately 10538 ha) is only 100-200 mm (Table 3.5). Most of the soils (10115 ha) of the Arial Beel have moderate permeability and it varies from 12 to 305 cm/day (Table 3.6).

Table 3.2: Soil classification according to inundation

Inundation Type	Amount of Land (ha)
Medium low land (Flooding 0.91-1.52 m)	1877
Low land (Flooding 1.53-3.05 m)	10538
Miscellaneous land	2021
Total	14436

Source of data: Bangladesh Agricultural Research Council (BARC)

Table 3.3: Classification of land according to their effective soil depth

Effective Soil Depth	Amount of Land (ha)
D3 (0.60-0.90 m)	10105
D4 (0.90-1.22 m)	1588
D5 (>1.22 m)	722
Total	12415

Source of data: Bangladesh Agricultural Research Council (BARC)

Table 3.4: Classification of land according to their soil textures

Textural Class	Amount of Land (ha)
Silt Loam	289
Silty Clay Loam	289
Silty Clay	1299
Clay	10538
Miscellaneous	2021
Total	14436

Source of data: Bangladesh Agricultural Research Council (BARC)

Table 3.5: Classification of land of according to their moisture holding capacity

Moisture Holding Capacity	Amount of Land (ha)
100-200 mm	10538
200-300 mm	1877
Total	14436

Source of data: Bangladesh Agricultural Research Council (BARC)

Table 3.6: Classification of land according to soil permeability

Soil Permeability	Amount of Land (ha)
Slow (< 12 cm/day)	2,310
Moderate (12-305 cm/day)	10,105
Total	12415

Source of data: Bangladesh Agricultural Research Council (BARC)

3.7 pH and Nutrient Status of Soils

As much as 73% of the total lands of the Arial Beel are lowland which has flooding depth of 1.83 m-3.05 m (Table 3.2). The soils of the lowland are acidic in nature (pH 4.7-5.4). On the other hand, pH of medium lowlands is 5.3-6.8. Table 3.7 shows the nutrient status and pH of the lands of the Arial Beel according to their heights. From the table it can be found that the soils of the Arial Beel contain low amount of Nitrogen but optimum amount of Ca and Mg, B and Mo. The P content is low to medium there and Zn content is medium. The contents of K and S are medium to optimum in the beel soils. However, there are no difference in the nutrient contents between the medium lowlands and lowlands.

Table 3.7: pH and nutrient status of soils of the Arial Beel

Major land type	Soil pH	Soil OM	Nutrient status								
			N	P	K	S	Ca	Mg	Zn	B	Mo
Medium lowland (13%)	5.3-6.8	M-H	L	L-M	M-Opt	M-Opt	Opt	Opt	M	Opt	Opt
Lowland (73%)	4.7-5.4	M-H	L	L-M	M-Opt	M-Opt	Opt	Opt	M	Opt	Opt

Source of data: Bangladesh Agricultural Research Council (BARC)

3.8 Cropping Pattern of the Arial Beel

Table 3.8 shows the cropping pattern of the Arial Beel with estimated goal for production. From the table it can be found that both rainfed and irrigated crops are cultivated in the beel though most of the lands of the beel are lowland and surface drainage is not very frequent (Table 3.1). Potato is cultivated in the medium lowland as a rabi crop and jute is cultivated in the same land as a kharif-1 crop. On the other hand, in kharif-2 most of the medium lowlands remain as fallow land. Besides this, in some cases it was found that Grasspea and Mustard is cultivated as rabi crops and B. Aus and B. Aman are cultivated as kharif crop. On the other hand, in lowland, only Boro is cultivated as rabi crop which is irrigated by LLP and shallow tube well but in kharif season almost all lands remain fallow.

The overall nutrient status of Arial Beel is medium to low. According to BARC (2005), the yield goal of HYV Boro in Arial Beel is about 4.80±0.50 t/ha. On the other hand, for medium lowland, where the flooding depth is about 0.91-1.83 m, yield goal is set as 20±0.20 t/ha for potato. HYV Boro rice is cultivated in both medium lowland and lowland and the yield goal is the same for the both lands.

Table-3.8: Crop grown the Arial Beel

Land Type	Water Source	Category	Season	Crop	Yield Goal (t/ha)
Medium Low Land	Raifed	Category-1	Rabi	Potato	20.00±0.20
			Kharif-1	Jute	2.80±0.30
			Kharif-2	Fallow	-
		Category-2	Rabi	Grasspea	1.00±0.10
			Kharif	B.Aus+B.Aman	2.50±0.30
		Category-3	Rabi	Mustard	1.00±0.10
			Kharif	B.Aus+B.Aman	2.50±0.30
	Irrigated	Category-1	Rabi	Boro	4.80±0.50
			Kharif	Fallow	-
Low Land	Irrigated	Category-1	Rabi	Boro	4.80±0.50
			Kharif	Fallow	-

Source of data: Bangladesh Agricultural Research Council (BARC)

3.9 Socio-economic Status of the Beel Dependent People

Surveys were conducted to find out the socio-economic conditions of the community residing in the deep zone of the beel who directly or indirectly depend on the beel for their lives and livelihood. From the surveys, it was found that most of the people belonged to the low income group who had annual income of less than Tk 20000 (Figure 3.8) and most of the members of this group were professional fishermen. The live and livelihood of the fishermen mostly depend on the availabilities of fishes in the beel. On the other hand, only 7% of the total population had the annual income of more than Tk. 100,000. The poor fishermen and their families spent their whole day in fishing and its associated activities like weaving and repairing of nets (Photo 3.1), processing of fish for selling in the market, etc. The living standard of the fishermen communities was found to be very simple and mainly regulated by the availabilities of fish in the beel. Due to decreases of fish in the beel areas, the socio-economic conditions of those communities became worse day by day. Usually the children of fishermen communities do not go to school and help their parents in fishing and its associated activities.

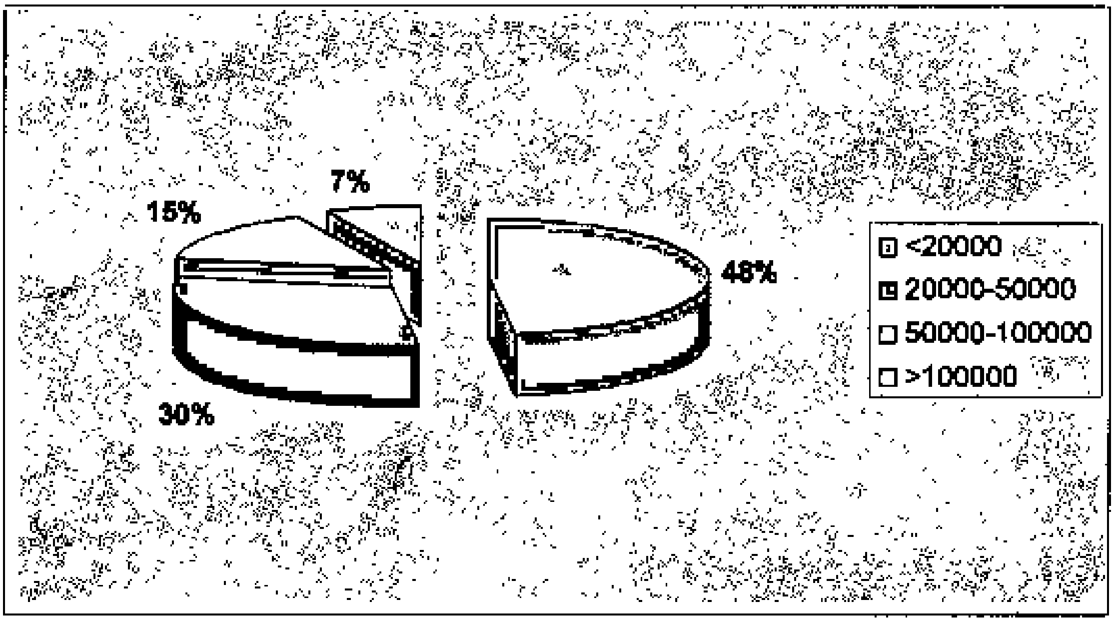

Figure 3.8: Socio-economic status of the fishermen communities of the Arial Beel area

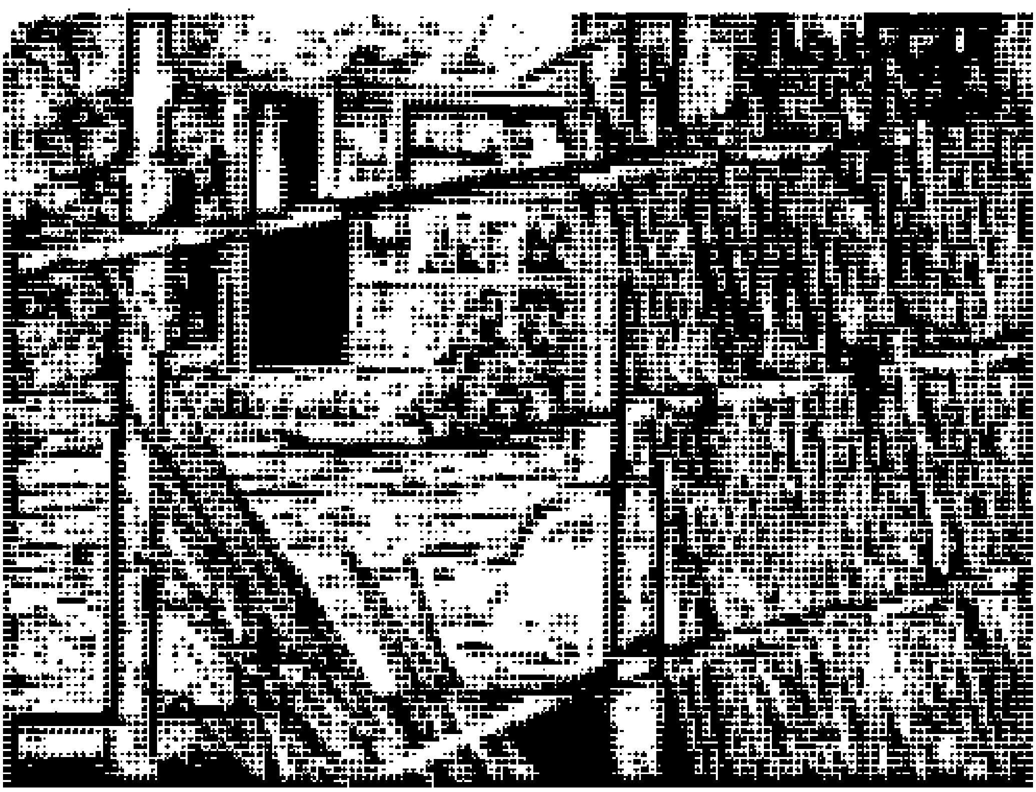

Photo 3.1: A fisherman family busy with repairing of fishing net

Chapter IV
METHODOLOGY AND DATA COLLECTION

4.1 Introduction

In this study, assessment of pesticide impact on the ecological resources of the Arial Beel was done by using a linear model, which is latter developed as a software package, known as Pesticide Impact Rating Index (PIRI). The model was developed by the Commonwealth Scientific and Industrial Research Organization (CSIRO), Land and Water, Australia. The software is used to assess the impact of pesticides on ecological resources on the basis of some inputs. There are two types of inputs, such as user input and built in data. Usually some specific constants which mainly depend on other parameters are the built in data. On the other hand some climatic, hydrologic parameters are user input data. User input data can be provided from primary as well as secondary sources.

4.2 Methodology

4.2.1 Overviews

Assessment of pesticide impact through PIRI includes three major works such as estimation of total load of pesticides in the catchment of a definite water body, estimation of total amount of pesticide transport from catchments to water bodies and calculation of rating index. The estimation of total load of pesticides can be done by multiplying the values such as rate of application (kg/liter per ha), frequency of application, fraction of active ingredient and area of catchment (ha) and total transport can be estimated by the summation of transports of pesticides through direct runoff, soil erosion and spray drift. On the other hand, Rating Index can be found from the ratio of total transport and toxic limit of pesticides for any definite ecological indicator species. The pathways for pesticide transport from the site of application to surface water bodies are complex and site as well as compound specific. Pesticides may reach water bodies through runoff, eroding soil colloids, spray drift during application, volatilization or with dust particles. The volatilization and dust particle pathways are of lower importance relative to the other pathways mentioned because the impacts are assessed for use in rice field. In PIRI, the transport factor to surface water is partitioned among runoff water, soil erosion, and spray drift out of the target area being sprayed. These are quite separate pathways, although there will be a high correlation between the surface runoff and the soil erosion pathways.

4.4.2 Transport due to direct runoff

The amount of pesticides in runoff water depends on the fraction of water input leaving the farm as runoff, sorption and persistence properties of pesticides. The sorption of pesticides (K_d) is specific to both the soil and the pesticide and can be approximated by the product of absorption coefficient (K_{oc}) and factor of organic carbon (f_{oc}). A pesticide with a low absorption coefficient (K_{oc}) that has been deposited on a plant or soil surface can subsequently be washed off in rain or irrigation and be transported to surface or groundwater.

The equation of pesticide transport through direct runoff is given as (OECD, 1998; Kookana et al., 1998):

$$T_{\text{Direct run-off}} = a \left\{ \left(\frac{Rf_1}{P} \times \frac{1}{1+Kd}\right)\left(\exp\left(-t\frac{\ln 2}{t_{\frac{1}{2}}}\right)\right) \right\} \tag{4.1}$$

where R is the amount of water that runs off the site (mm) and P represents the near worst-case scenario of runoff (here P is assumed to be 66 mm from a 100 mm rainfall event in a clayey soil with high soil moisture), a is the upper bound of pesticide loss, representing the combination of high soil loss and high sorption and the persistence of a pesticide. The maximum value of a in case of pesticide loss through direct runoff was assumed to be 10% of the amount applied (Leonard, 1990). The terms t and $t_{\frac{1}{2}}$ in equation (4.1) represent the time elapsed between application of pesticides in fields and runoff generation and half lives of pesticides respectively. Equation (4.1) is essentially based on the model of Lutz (1984) and Maniak (1992), as developed by the OECD (1998) and used by Verro et al. (2002). The correction factor f_1 corrects for the effect of slope on runoff of water from the site. In this model, the value of R is dependent on the amount of rainfall, the amount of irrigation and site conditions, soil type, surface cover and soil moisture content. While the presence of buffer strip can help reduce the sediment transport, it does not have a significant effect in reduction of dissolved phase of pesticides. Therefore, unlike OECD (1998), the correction in R due to the presence of buffer zone was not included in Equation (4.1). For direct runoff, the worst case of pesticide loss would be represented when a persistent pesticide with low K_{oc} is available for transport to the surface water by runoff in heavy rain or irrigation soon after the application of the pesticide.

4.2.3 Transport due to soil erosion

Pesticides transported with soil colloids through erosion depend on the magnitude of soil loss and the amount of pesticides attached to soil colloids. The loss of pesticide through soil erosion requires a function that is initially zero for no soil loss and which asymptotes to the maximum proportion of the applied mass of the pesticide that is likely to be lost under a near worst case scenario (a). Depending on the nature of the pesticide, the degree of soil loss and management control structures such as buffer strips, the loss will be lower than a. A suitable function is:

$T_{Erosion} = a \times$ (Soil Loss Factor ×Buffer Factor ×Sorption Factor ×Persistence Factor)

Mathematically,

$$T_{Erosion} = a \left\{ \frac{Soil \text{ loss factor} \times f_2}{1 + \frac{1}{bK_d}} \right) \exp\left(-t \; \frac{\ln 2}{t_{\frac{1}{2}}}\right)\} \tag{4.2}$$

where the coefficient a is the upper bound of pesticide loss, representing the combination of high soil loss and high sorption and the persistence of a pesticide. Based on literature data, the maximum fraction of pesticide that is likely to be lost due to erosion (a) was assumed to be 0.10 of the amount applied (Leonard, 1990). On the other hand, b is a correlation factor between K_{oc} and loss of soil of pesticides with soil colloids.

The "Soil Loss Factor" is simply a ratio of actual soil loss (t/ha) at a site with an expected maximum soil loss, varying from 0 to 1. A soil loss factor of 1 represents a worst-case scenario of transport of pesticides with soil colloids. The buffer correction factor f_2 in Equation (4.2) also varies from 0 to 1, and depends on the width of a buffer zone (WBZ). f_2 is defined by OECD (1998) as f 2 =0.83 WBZ. As a guide, where there is a densely grassed 10 m buffer strip free of rills, f_2 is given a rating of 0.16.

The "Persistence Factor" is the fraction of pesticide residue calculated from the pesticide degradation rate (μ) and time t elapsed since the last application of it, as shown in Equation (4.2). Figure 4.1 shows the effect of K_{oc} on loss of pesticides. It can be seen from the figure that for the "Sorption Factor" function to asymptote to 0.1, using a pesticide with Koc >5000, b in Equation (4.2) was required to be 0.3. From Equation (4.2), it can also be found that a worst-case scenario of pesticide loss through colloid transport would be when a pesticide with high sorption affinity for soil is used (i.e. the "Sorption Factor" approaching 1) under high soil erosion conditions (i.e. the "Soil Loss Factor" approaching 1), and the erosion event occurs soon after the application of pesticide allowing little time for pesticide degradation (i.e. the "Persistence Factor" approaching 1) and where there is no protection through management options such as buffer strips.

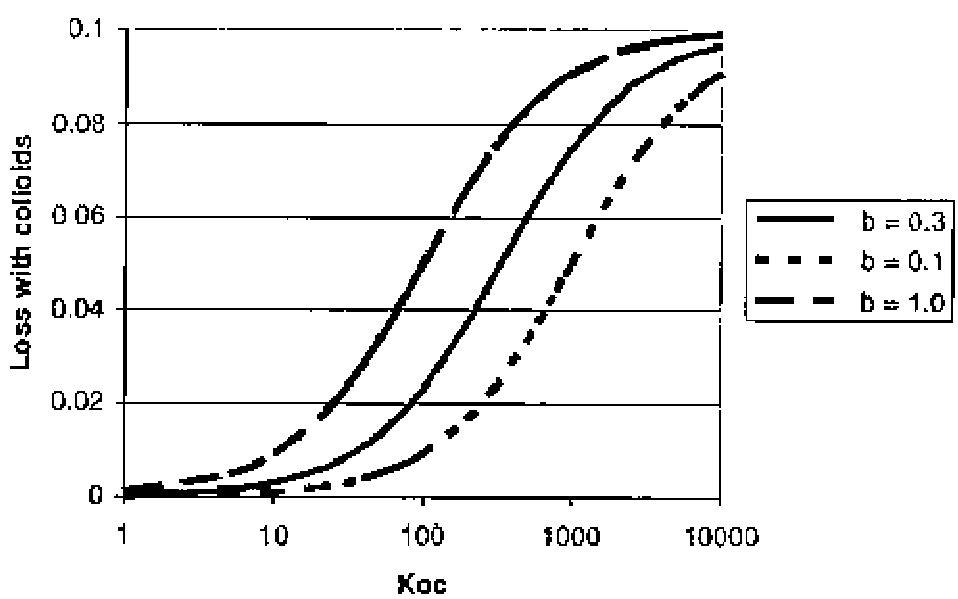

Figure 4.1: Effect of increasing K_{oc} on the maximum pesticide loss due to erosion for varying values of the parameter b (Kookana et al., 1998)

4.2.4 Transport through spray drift

Pesticides sprayed through aerial and ground-based applications have a potential of drifting off target through droplet drift, volatilization and dust transport. This transport pathway is complex, is affected by several factors (such as application method, local wind and humidity conditions, and proximity to a receiving water body) and is therefore difficult to quantify accurately. The complexity of this process makes accurate predictions from even comprehensive models quite challenging, despite when local conditions are well known. The multitude of factors affecting atmospheric transport and the complexity of the processes involved preclude a comprehensive inclusion of this transport component in PIRI, without sacrificing its practicability. However, considering the major importance of droplet size in determining the extent and amount of downwind drift during spray. only the effect of this parameter has been included in PIRI (Raupach et al., 2001).

The center of a very large field would receive the intended amount because the amount lost to drift would be compensated by gains from other parts of the field. However, near the edge of the field, the losses due to drift would not necessarily be compensated by drift from other parts of the field. Beyond the boundary, the amount of spray deposition due to drift decreases, and a convenient way to quantify the effect of drift at a given point is to define the drift deposition fraction (f_{Drift}) as the ratio of the amount of spray falling at a given point compared to the intended rate.

T_{Drift} is related to spray droplet size and the distance downwind of the water body from the downwind edge of the sprayed area, with a decrease in the amount of spray drift with increasing distance. The relationships between droplet size and the drift at a given point (f_{Drift}) are shown in Figure 4.2. However no adjustment has been made in PIRI for field width, wind speed or release height. The actual amount of deposition for a distance interval from the field can be found by integrating over that distance. In practice, the integration is estimated from across the width of the water body using the trapezoidal rule. This requires the input of the distance to the water body and the width of the water body, together with the deposition fractions for some points in that interval. Using this. the fraction of the pesticide applied to the field that is deposited on the water body can be estimated. Due to the limitations of the data that the user can supply, the minimum distance from the crop to the water body has been used in PIRI. It has been assumed that the pesticide has had no time to break down (i.e. a worst case scenario has been assumed in PIRI).

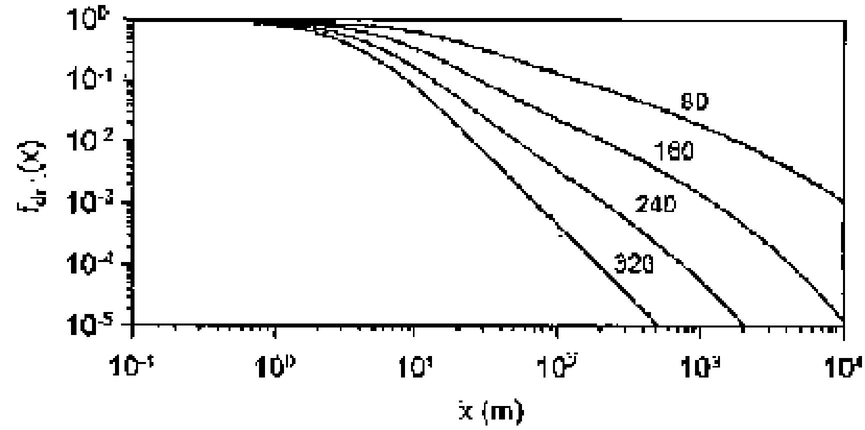

Figure 4.2: Model simulated spray deposition downwind (Raupach et al., 2001)

Knowing the size of the water body and its distance from the crop being sprayed, the value of T_{Drift} was calculated by

$$T_{drift} = \int_{X}^{X+W} f_{Drift}\,(\text{droplet size, distance and size of the water body})$$

where, the water body of width w (m) is located at distance x (m) from the edge of field.

4.2.5 Selection of indicator species

PIRI assesses the impact of any pesticide on the ecological resources by considering some indicators as representative of total ecosystem (Kookana et al., 1998). The selection of indicator species is a complex work and needed in depth knowledge about local and regional ecosystem. This work was done mainly on the basis of literature review. The basic guidelines for the selection of indicator species for the Arial Beel were found from USEPA (2000). Other important literatures which were reviewed in this regards are: Fu-Liu et al. (1999), Belnap (1998), Hansaker and Carpenter (1990). From the review of these literatures it was found that other three ecological indicator species suggested in PIRI except Rainbow Trout (Table 4.1) can be adopted in Bangladesh as they represent those specific levels of freshwater ecology which are almost universal. But selection of indicator species for direct impact of pesticide on fishes. it is necessary to have knowledge on the richness of fish species in the study area. In this regard, a reconnaissance survey was conducted during May 2008 and it was found that the Indian catfish as the most endangered fish species in the Arial Beel. So rainbow trout of PIRI was replaced with the Indian catfish. Table 4.1 shows the name of the selected indicator species and their ecological role.

Table 4.1: Indicator species and their representing trophic level

Name of the Indicator species	Representing Organism/ Function	Ecological Role of Selected Indicator Species
Indian Catfish/Catfish	Freshwater fish	Secondary consumer
Daphnia	Freshwater invertebrate	Primary consumer
Algae	Freshwater food chain	Primary producer
Rat	Mammals	Predators control/ Top level consumers

4.2.6 Digitization of rating index

A qualitative value such as very low, low, medium, high, very high and extremely high is usually found from the PIRI model as output. These values denote the magnitude of the impacts of that pesticide on a specific indicator. But for analytical purpose it is necessary to have a numerical value which can be easily averaged or added to get cumulative impacts on the total ecological resources. So digitization of the magnitude of PIRI output was done in this study. The digitization process was done considering a value for each magnitude of impacts such as for very low the value is 0-0.99, for low 1-1.99, for medium 2-2.99, for high 3-3.99, for very high 4-4.99 and for extremely high 5-6. This work was done by placing the PIRI bar chart into a synthetic scale. The scale was created by forming a table with six columns. Each column is then divided into 5 cells by splitting the columns into five equal cells. The value of each cell was marked at 0.2 distances. As for example in Figure 4.3 two output from PIRI are placed into the synthetic scale formed for this study (the bottom horizontal bar) and found that the impact of Carbaryl and Diazinon are low and very high respectively which contain values between 1-2 and 4-5 respectively. From eye measurement they can be read as about 1.9 and 4.6 respectively.

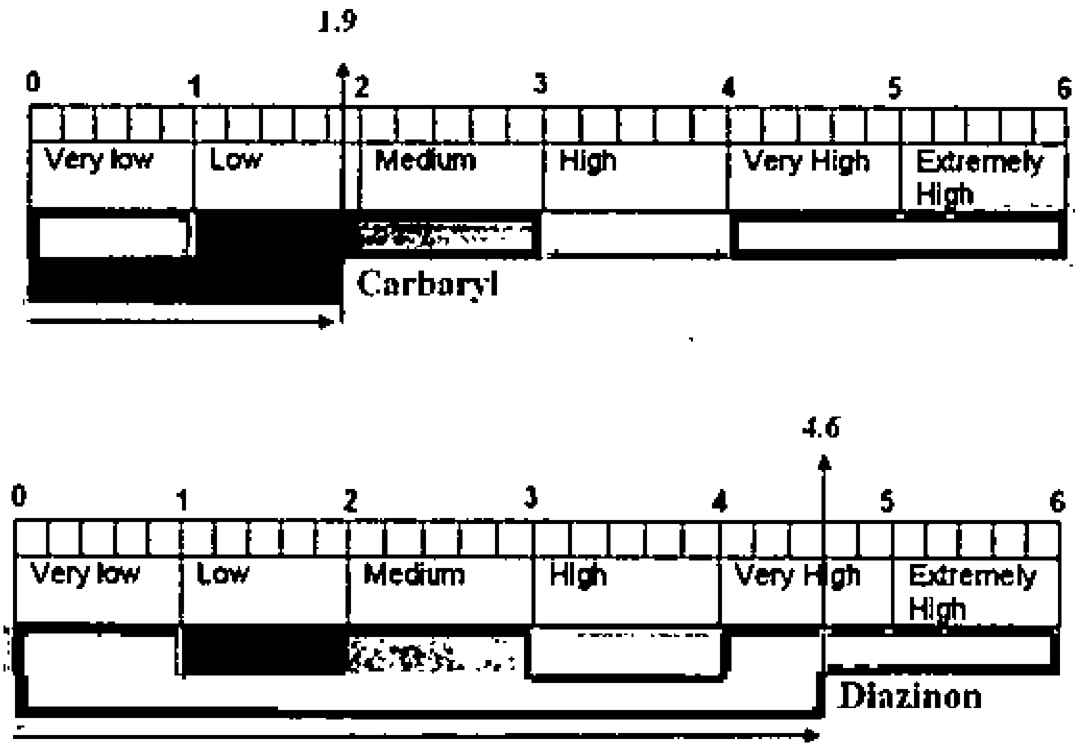

Figure 4.3: Placement of PIRI output in synthetic measuring scale

4.3 Data Requirement

Offsite impact of any pesticide mainly depends on its chemical, physical as well as toxic properties. Besides these, frequency of application, application procedure, etc. influence the impact. As offsite impact is a function of pesticide migration to nearby water bodies, climatological characteristics of the concern area as well as land and topographic conditions are the most important factors based on which PIRI assesses the impacts. All the data needed for the assessment of pesticide impact through PIRI are arranged in Table 4.2. From the table it can be seen that the data were collected by measurement, group discussion as well as from the secondary sources.

Table 4.2: Data requirements in the PIRI software and collection procedure

PIRI Interface	Required Data	Collection Method
Land Use Interface	Land Use Types	Field Observation
	Soil Texture	Soil Map
	Target Species	Literature Review and Baseline Survey
	Moisture Condition of the Soil	Field Observation
	Starting Month of the Season	Field Observation
	Ending Month of the Season	Field Observation
	Soil Organic Matter Content	Soil Map
	Diameter of the Nearest Water Body	Field Measurement
	Distance of Water Body from the Edge of the Land	Field Measurement
	Slope of Land to Water Body	Land Elevation Map
	Width of Buffer Zone	Field Measurement
	Estimated Average Soil Loss	Universal Soil Loss Equation
	Total Rainfall During a Season	Bangladesh Meteorological Department
	Total Irrigation During the Season	Field Flow Measurement
	Average Minimum Air Temperature	Bangladesh Meteorological Department
	Average Maximum Air Temperature	Bangladesh Meteorological Department
	Minimum Number of Days from the Application of Pesticides to the First Rainfall	Bangladesh Meteorological Department
Pesticides Application Interface	Name of the Pesticide	Group Discussion
	Chemical Type of Pesticide	Online Database of Pesticides
	Rate of Application of Pesticide	Group Discussion

	Frequency of Application	Group Discussion
	Pesticide Spray Type	Group Discussion
	Half Life of Pesticide	Online Database of Pesticides
	Adsorption Coefficient (Koc)	Online Database of Pesticides
	LC_{50} for Catfish	Online Database of Pesticides
	LC_{50} for Daphnia	Online Database of Pesticides
	LC_{50} for Algae	Online Database of Pesticides
	LD_{50} for Rat	Online Database of Pesticides
Catchment Characteristics Interface	Area of Catement	Google Earth Software

4.4 Data Collection

Data collection was done by following different methodologies. Some of the required primary data (e.g. distance of a definite pond from the edge of its catchment) were collected through field measurement whereas some other data such as the names of the pesticides used by the farmers and their rate and frequency of application were collected through Focus Discussions. Some other primary data like active ingredient of applied pesticides were collected from the label of the pesticide packets. Like primary data secondary data were also collected by following different methodologies. As for example, climatic data of the study area were collected from Bangladesh Meteorological Department (BMD), textural classes of soils of the selected catchments were collected from Bangladesh Agricultural Research Council (BARC) and data on persistency and toxicity of pesticide were collected from the websites of pesticide regulation and information networks like EXTOXNET and USEPA (www.extoxnet.orst.edu and www.usepa.org; accessed on 7 October 2008)

4.4.1 Selection of ponds and separation of catchments

The selection of ponds was done by the help of Google Earth software (version-Google Earth-Win-plus-5.0.113). From the software, the hydrological characteristics and land use practices around the ponds of the Arial Beel were observed and total number of ponds was counted. A total of 147 ponds were identified from the software. Fifteen ponds (10% of total ponds) were selected on the basis of three major criteria such as: i) The ponds are very close to rice field and ii) receive agricultural runoff from four sides iii) are small in size and not protected with high bank. The global position (longitude and latitude) of each pond (Table 4.3) was also noted from the software. After selection of ponds, a print screen image of each pond was taken. The print screen images of the ponds were used to identify those ponds in the beel with the help of Cell Phone Global Positioning System (C-GPS, model – Toshiba TGI 3G GPS). After identification of ponds in the beel, their catchments were separated by monitoring the runoff. The runoff monitoring was done during June-July 2008. The areas of the catchments of selected ponds (Figure 4.4) were also calculated with the help of Google Earth software. The approximate locations of the selected ponds in the beel are given in Figure 4.5.

The naming of the selected ponds was done by using two letters of upazilla name (e.g. DO for Dohar, NW for Nawabgonj, SR for Sreenagar, SI for Sirajdikhan) and with a numerical value as a subscript. The numerical value was given by considering the distance from the reference point. The point from where the field measurement process started was set as a reference point. As for example, the name DO_1 denotes a pond which is located at Dohar Upazilla and it is the nearest pond from Dhaka-Dohar Road.

Table 4.3: Global positions of selected ponds

District	Upazilla	Name of the Pond	Latitude	Longitude
Dhaka	Dohar	DO_1	23⁰46'07"N	90⁰08'11"E
		DO_2	23⁰45'48" N	90⁰12'23" E
		DO_3	23⁰43'56" N	90⁰09'58" E
	Nawabgonj	NW_1	23⁰42'09" N	90⁰12'07" E
		NW_2	23⁰43'59" N	90⁰13'22" E
		NW_3	23⁰41'16" N	90⁰14'08" E
		NW_4	23⁰37'36" N	90⁰13'55" E
Munshigonj	Sreenagar	SR_1	23⁰36'10" N	90⁰11'2" E
		SR_2	23⁰34'48" N	90⁰16'11" E
		SR_3	23⁰37'52" N	90⁰17'51" E
		SR_4	23⁰36'41" N	90⁰18'52" E
	Sirajdikhan	SI_1	23⁰41'08" N	90⁰17'07" E
		SI_2	23⁰41'56" N	90⁰19'01" E
		SI_3	23⁰41'29" N	90⁰21'58" E
		SI_4	23⁰36'19" N	90⁰22'05" E

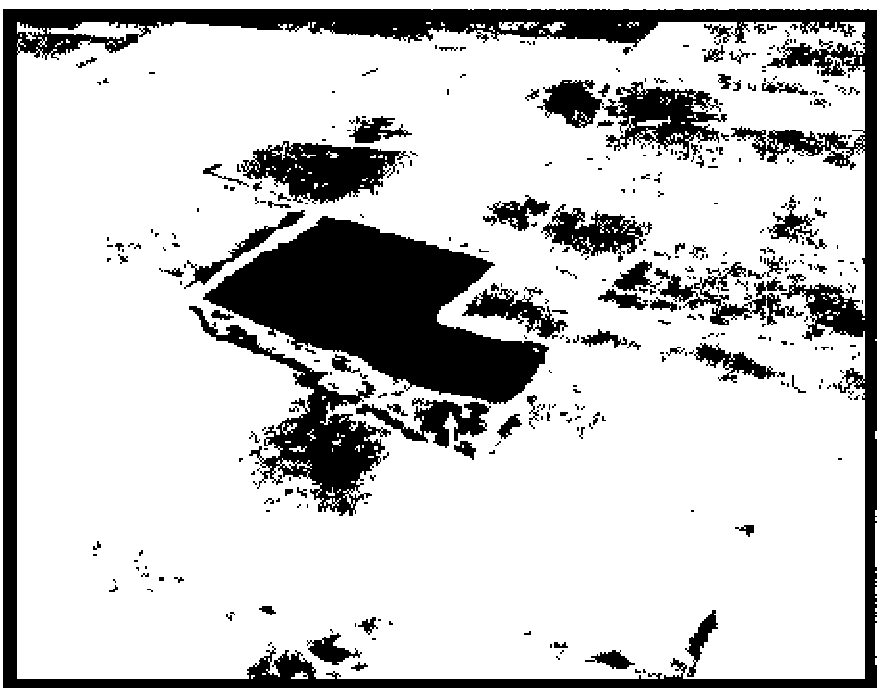

Figure 4.4: Catchment of a selected pond of the Arial Beel

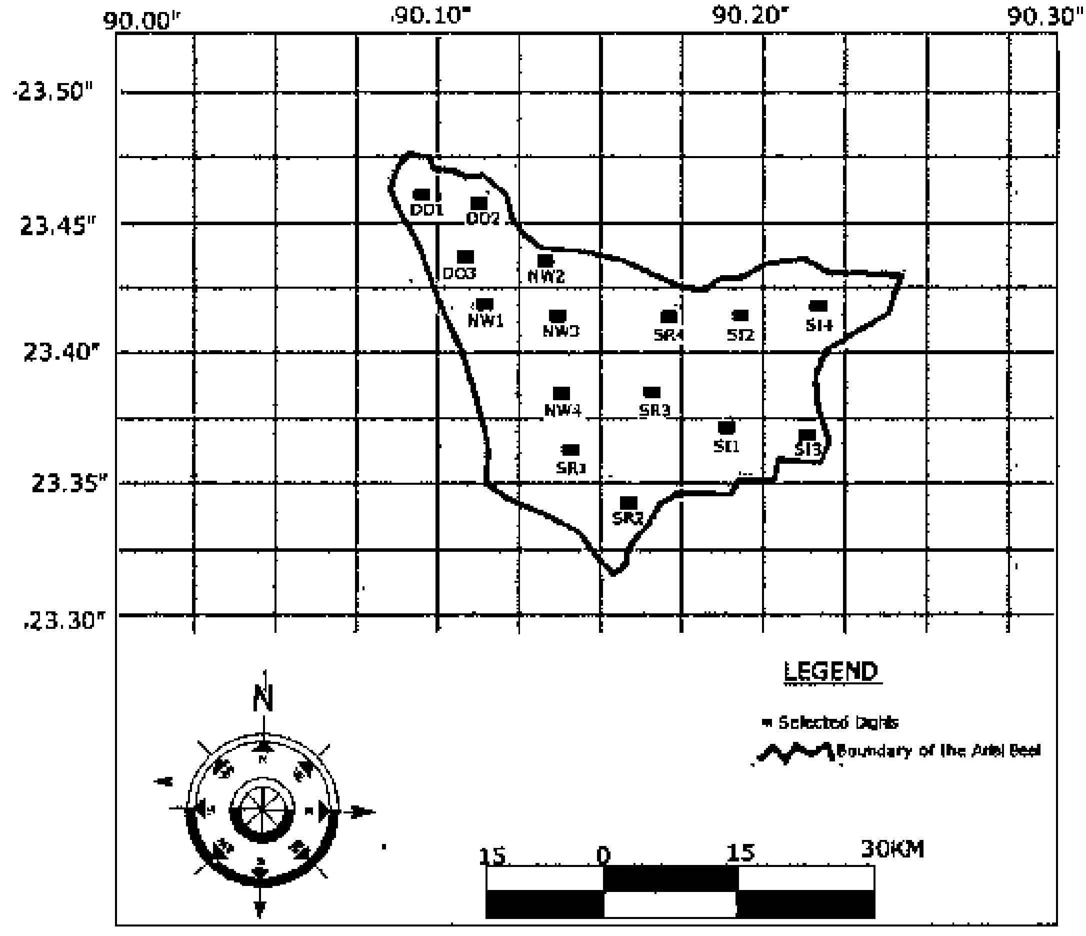

Figure 4.5: Approximate positions of selected ponds in the Arial Beel

4.4.2 Measurement of field slope and distance

For assessment of impact of pesticides on ecological resources by using the PIRI model, a number of field data are needed. Some important of them are the distance of a field where pesticides are applied from the edge of the selected pond and diameter or width of the pond. These measurements were done by using a measuring tape (Photo 4.1). As all data needed in PIRI should be measured in M.K.S. system, the distance was measured in meter (m). Besides this, the slope of lands to the ponds was measured by using Goggle Earth software where elevation of each field from the mean sea level is found. The slope calculation was done in percent as per the requirement of PIRI.

Photo 4.1: Measurement of distance between a selected pond and the field

4.4.3 Measurement of pond size and water depth

Length and width of the ponds were measured for the rectangular ponds and diameters were measured for circular ponds. The measurements were done by using a measuring tape as reported earlier. All the measurements were taken in M.K.S. system. Water depth was measured by using a measuring stick which was prepared by marking a bamboo stick with colour pen. For getting the effective water depth, depth of bottom clay was subtracted from the measured value. The depth of clay materials were found to be 0.15 m which was obtained from the average of several measurements. To get an average effective water depth, water depth of five sample points of each pond were taken and then averaged.

4.4.4 Estimation of average seasonal soil loss

Estimation of average seasonal soil loss from the fields of the Arial Beel was done by using the Universal Soil Loss Equation (USLE) which predicts the average seasonal rate of erosion on a field. The estimation was done on the basis of rainfall, soil type, topography, crop system and management practices. USLE only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that occur from gully, wind or tillage erosion. This erosion model was created for use in selected cropping and management systems (http://www.omafra.gov.on.ca/english/engineer/facts/00-001.htm#tab2, last accessed on 4 October 2008).

Five major factors were used to calculate the soil loss for the Arial Beel. Each factor was the numerical estimate of a specific condition that affects the severity of soil erosion at a particular location. The erosion values reflected by these factors can vary considerably due to varying weather conditions. Therefore, the values obtained from the USLE are representative long-term averages. The equation is given below:

$$A = R \times K \times LS \times C \times P \qquad (4.3)$$

where A represents the potential seasonal soil loss in tons per ha, R is the rainfall and runoff factor by geographic location, K is the soil erodibility factor, which is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff, LS is the slope length-gradient factor, C is the crop/vegetation and management factor. It is used to determine the relative effectiveness of soil and crop management systems in terms of preventing soil loss, and P is the support practice factor. The field verification of USLE result was also done by using the following steps:

- Collection of one liter sample from the point of runoff.
- Filtering the water to get the soil.
- Air drying of soil to get the dry weight of eroded soil.
- Estimation of seasonal runoff and
- Calculation of seasonal soil loss and comparison with USLE output.

4.4.5 Observation of rainfall events

The offsite impact of pesticide depends on its transportation to the nearby water bodies. In this case identification of minimum number of days between application of pesticides and first rainfall is an important factor. To find this number, observation of rainfall event during 20 March-07 April was done. This time schedule was found from group discussions with the farmers and field observations. The rainfall observation was done both in 2008 and 2009. Only those rainfall events which were able to generate runoff from field to nearby pond were considered.

4.4.6 Availability of fish per catch

To verify the PIRI result, field data on the availabilities of some local freshwater fish species were collected. This was done by counting the number of fish caught in a dry season catch by a professional fisherman. This counting was done by selecting some points where fish availability was more than the other parts of the beel. The information on time of catching fish and expert fishermen were collected from local key informants such as local school teachers. The selected fish species for this study were walking fish, climbing fish, catfish, scorpion fish, etc.

4.4.7 Data collected through group discussions

In the present study, a number of group discussions were conducted with the farmers and the fishermen. This was done to collect necessary information on names of pesticides used in the rice field, rate and frequency of application of pesticides, etc., from the farmers of the study area. To verify the impacts of pesticides in actual condition, the information about the availabilities of fish were collected from the fishermen. The discussions were carried out during the Boro and Aman seasons. In this regard about twelve field trips were made and each trip was two days long. The field trips were done during the February 2008 to March 2009. The discussions were conducted in the 40 spots of the beel area. The selection of the spots and the farmers and fishermen groups were random with the help of local peoples and key informants.

Chapter V
RESULTS AND DISCUSSIONS

5.1 Introduction

Assessment of the impacts of pesticide use in agricultural land on the ecological resources of the Arial Beel was done by using a linear model known as PIRI. For the assessment, four ecological indicators were used. From the PIRI assessment, intensity of the impact caused by each pesticide were found which is then converted to numerical value for statistical analysis. The numerical values were also used to identify the seasonal variation of the impacts of all six pesticides. A ranking of pesticides based on their impacts were also done in this study. Moreover numerical values were used to find out the cumulative impacts of all six pesticides in the actual field condition which were verified by the field data.

5.2 Characteristics of the Catchments of the Selected Ponds

Some characteristics of pesticides applied fields and selected ponds were colleted. This work was mainly done by collecting secondary data from the relevant organizations as well as through direct field measurements. Detailed methodologies of the field measurements were given in Chapter IV. Some important data which were obtained from direct field measurement were: distance of a pond from the edge of its catchment, slope of lands to ponds, average soil loss during the period of interest, diameter of the selected ponds (in case of circular ponds) or width of the selected ponds (in case of rectangular ponds). The term 'period of interest' means the season for which impacts of pesticides were evaluated. The details about the period of interest were given in Chapter IV. Table 5.1 shows the major characteristics of the catchments of the selected ponds which were needed to evaluate the impacts of pesticides by using the PIRI software. From the table it can be seen that most of the selected ponds were very close to their catchments and the maximum distance was found in this case was 9.60 m. Slopes of lands to ponds were found to be variable and not so steep. The maximum slope was found only 3.00% for a pond located in Nawabgonj upazilla (NW_1). Table 5.1 also shows that the soil textures of Dohar and Nawabgonj upazillas were mainly silty clay whereas those in Sreenagar and Sirajdikhan upazillas were mainly clay and most of these soils belong to the deepest portion of the beel where flooding depth varies from 1.83 m to 3.05 m. In case of organic matter content of soil, it can be found that the catchments of the selected ponds of Sreenagar upazilla contain the highest amount (2.65%) of organic matter which is followed by Nawabgonj upazilla (2.50%). On the other hand, the catchments of the ponds of Sirajdikhan upazilla contain the least amount of organic matter (2.30%) and it is followed by the catchments of Dohar upazilla (2.36%). The loss of soils from agricultural land is directly related to the organic matter content of soil as organic matter acts as a cementing agent to form soil aggregates. As the catchments of the selected ponds of Sreenagar upazilla contain the highest amount of organic matter, the soil loss is minimum there (0.17 t/ha) and the same was found to be maximum (0.35 t/ha) in Sirajdikhan upazilla where organic matter content was found to be minimum (2.30%). Pesticides transport from fields to the water bodies by soil erosion. One of the most important for transport of pesticides from the field to water bodies is the soil erosion. Organic matter aggregates the soil particle and hence less erosion for which less transport occur. Besides this complex compound of organic matter also fix the pesticides molecule which also restrict the transport of pesticides to the water bodies by direct runoff. The assessment was done for rice field where 100% of the land was covered with foliage and the soils of the fields remained wet during the time of application of pesticides (period of interest).

Table 5.1: Characteristics of the catchments of the selected ponds

Upazilla	Pond No.	Field Cover	Soil Texture	Organic Matter Content (%)	Average Soil Loss (t/ha)	Distance of Pond from the Edge of Its Catchment (m)	Average Slope of Land to Pond (%)	Moisture Condition of Soils	Catchment Area (ha)
Dohar	DO_1	Covered Ground	Silty Clay	2.36	0.20	7.00	1.80	Wet	2.5
	DO_2	Covered Ground	Silty Clay	2.36	0.25	9.50	2.50	Wet	5.2
	DO_3	Covered Ground	Silty Clay	2.36	0.23	2.60	2.00	Wet	5
Nawabgonj	NW_1	Covered Ground	Silty Clay	2.50	0.28	3.80	3.00	Wet	4.5
	NW_2	Covered Ground	Silty Clay	2.50	0.28	2.90	0.80	Wet	3.8
	NW_3	Covered Ground	Silty Clay	2.50	0.28	3.00	1.25	Wet	14.5
	NW_4	Covered Ground	Silty Clay	2.50	0.35	4.8	2.60	Wet	10
Sreenagar	SR_1	Covered Ground	Clay	2.65	0.17	3.8	0.65	Wet	13
	SR_2	Covered Ground	Clay	2.65	0.17	1.28	0.85	Wet	8
	SR_3	Covered Ground	Clay	2.65	0.17	0.80	2.10	Wet	1.5
	SR_4	Covered Ground	Clay	2.65	0.17	0.75	2.56	Wet	2.1
Sirajdikhan	SI_1	Covered Ground	Clay	2.30	0.35	1.30	1.50	Wet	1.5
	SI_2	Covered Ground	Clay	2.30	0.35	1.25	2.30	Wet	3.2
	SI_3	Covered Ground	Clay	2.30	0.35	9.60	1.50	Wet	1.5
	SI_4	Covered Ground	Clay	2.30	0.35	2.30	2.30	Wet	1.8

5.3 Characteristics of the Selected Ponds

The characteristics of the selected ponds were found from the field measurements. The results of the field measurements are given in Table 5.2. From the table it can be found that most of the selected ponds (13 nos.) were rectangular in shape and only 2 ponds were circular in shape (SR_1 and SI_3). Almost all the ponds were small in size and the maximum length (58.60 m) was found for a pond of Dohar upazilla (DO_2) and the minimum length (6.90 m) was found for a pond of Sreenagr upazilla (SR_3). The diameters of the two circular ponds (SR_1 and SI_3) were 8.50 m and 15.36 m respectively. The dry season water depth among the ponds varied from 0.58 m to 2.10 meter. The maximum water depth was found for a pond located in Nawabgonj upazilla (NW_4) whereas the minimum was found for a pond of Sirajdikhan upazilla (SI_2).

Table 5.2: Characteristics of the selected ponds

Pond No.	Shape	Length (m)	Width (m)	Diameter (m)	Average Dry Season Water Depth (m) (November.-December)
DO_1	Rectangular	25.80	7.50	-	1.30
DO_2	Rectangular	58.60	22.60	-	1.40
DO_3	Rectangular	16.80	7.50	-	1.62
NW_1	Rectangular	9.60	5.20	-	1.45
NW_2	Rectangular	18.90	12.60	-	1.26
NW_3	Rectangular	21.00	9.80	-	1.29
NW_4	Rectangular	11.25	5.60	-	2.10
SR_1	Circular	-	-	8.50	1.95
SR_2	Rectangular	8.50	6.30	-	1.45
SR_3	Rectangular	6.90	2.65	-	0.98
SR_4	Rectangular	28.60	17.40	-	1.25
SI_1	Rectangular	12.50	6.50	-	1.00
SI_2	Rectangular	11.80	7.60	-	0.58
SI_3	Circular	-	-	15.36	1.20
SI_4	Rectangular	7.80	3.50	-	0.85

5.4 Meteorological Characteristics of the Arial Beel Area

Pesticide Impact Rating Index (PIRI) evaluates the impacts of a pesticide on ecological resources by considering the transport of that pesticide into the nearby water bodies by processes like runoff, soil erosion and spray drift. Transport of any pesticide from the field where it was applied to the nearby water body depends on meteorological characteristics of the site. Important meteorological parameters needed for this study were: maximum temperature, minimum temperature, total rainfall and minimum number of days from the application of pesticide to the first rainfall. From the discussions with the farmers of the Arial Beel, it was found that Boro season starts in the Arial Beel at approximately 5-15 February ends at 15-25 May, whereas the Aman season starts at 5-15 July and ends at 15-25 October. So daily temperature (maximum and minimum) and rainfall data of Dhaka and Munshigonj meteorological stations from February 2008 to October 2008 were collected from Bangladesh Meteorological Department (BMD). Minimum number of days between the application of pesticides and the first rainfall were collected from the observation of rainfall events during 20 March to 7 April in the year of 2008. All of the above mentioned data are given in Table 5.3 which shows that about 325 mm of rainfall occurred during the Boro season at Dhaka district, whereas in Munshigonj district the rainfall was about 498 mm. In Aman season 1250 mm of rainfall occurred in 2008 at Dhaka, whereas in Munshigonj rainfall was 1340 mm. In case of maximum temperature, it was found that maximum temperature in Boro season was 30.8^0C in Dhaka and 29.7^0C in Munshigonj. Minimum temperature in Boro season was 19.2^0C and 16.5^0C in Dhaka and Munshigonj districts respectively, whereas in Aman season it was 18.7^0C and 17.4^0C respectively. Average minimum number of days between the applications of pesticides to the first rainfall to be observed 8 days at Dhaka district and 6 days at Munshigonj district.

Table 5.3: Meteorological characteristics of the Arial Beel area at Boro and Aman Seasons

Parameter	Dhaka		Munshigonj	
	Boro	Aman	Boro	Aman
Average Maximum Air Temperature (^0C)	30.8	23.8	29.7	22.4
Average Minimum Air Temperature (^0C)	19.2	18.7	16.5	17.4
Total Rainfall (mm)	325	1250	498	1340

Source of Data: Bangladesh Meteorological Department

5.5 Pesticides Used By Farmers in Rice Fields of the Arial Beel

Field surveys were conducted at 40 points of the Arial Beel during March-April 2008 (for Boro season) and July-August 2008 (for Aman season) to collect information on the use of pesticides in rice fields. The surveys were conducted on 115 farmers and agricultural labourers. As pest attack occurs mainly in the vegetative stage of rice plant, pesticides were usually used by the farmers 30-45 days after transplantation and surveys were conducted during that time. The list of pesticides used by the farmers of the Arial Beel which was obtained from the surveys is given in Table 5.4. It is seen from the table that Basudin, a carbamate pesticide, was the most popular pesticide to the farmers and the largest portion of farmers (44%) used this pesticide to control steam borer, gall midge plant hopper and green leaf hopper of rice. Other pesticides which were used by the farmers were: Furadan (15%), Sumithion (14%), Ripcord (12%) and Malathion (10%). Only a fewer portions of farmers (5%) were found to use Sevin for managing steam borer, grass hopper and rice bug in their fields. From the field survey, it was also found that most of the farmers did not have any specific choice of pesticides and in most cases they used pesticides based on the availabilities to the local distributors whereas the local distributors used to sell those pesticides which are more profitable. In some cases, it was found that the farmers used pesticides according to the advice of the block supervisors of the local agriculture office or neighbourer farmers.

Table 5.4: Pesticides used by the farmers in the Arial Beel and their purposes of use

Name of the Pesticide	Purpose of Use	Percent of Farmers Used
Basudin	Steam borer, Gall midge plant hopper, Green leaf hopper	44%
Furadan	Steam borer, Grass hopper, Rice bug	15%
Sumithion	Leaf roller, Rice hipsa	14%
Ripcord	Rice hipsa, Green leaf hopper, Steam borer	12%
Malathion	Green leaf hopper, Steam borer, Thrips, Rice bug	10%
Sevin	Steam borer, Grass hopper. Rice bug	5%

5.6 Application of Pesticides and the Characteristics of Applied Pesticides

The off site impacts of a pesticide depend on the method of its application in the field as well as on the physical state of the pesticide. For this study, the methods of application of pesticides were collected through group discussions with the farmers and agricultural labourers. From the group discussions, it was found that most of the farmers of the beel area used back pack air pumping spray method for pesticide application and they mainly did this work in the morning time usually from 10.00 AM to 12.30 PM.

In case of frequency of application, it was found that most of the farmers of the study area used pesticides just for one time and in some cases two times. The decision on the use of pesticides depended on the evidence of pest attack. The rate of application of pesticides varied from 8.27 kg/ha (Basudin) to 0.96 liters/ha (Ripcord) (Table 5.5). Usually farmers used pesticides according to the recommendation of pesticides vendors and block supervisors of local agricultural office. From the group discussions, it was found that in most cases farmers used pesticides during the vegetative stage of the plant, i.e. 30-45 days after transplantation of rice as pest attack occurs usually during this time.

The physical and chemical properties of these pesticides were gathered from various pesticide information database networks. Active ingredients present in the pesticides were collected from the labels of pesticide packets. The most commonly used pesticide was the Basudin which belongs to the common group Diazinon (Table 5.5). The trade name of this pesticide is Basudin 10G. The trade name of any pesticide expresses its physical state as well as the percent of active ingredient. So from the trade name of Basudin 10G it can be said that it is a granular pesticide which contains 10% active ingredient. Another pesticide of same chemical group but of different trade name (Diazinon 10G) was found to be used in some parts of the Arial beel. All properties of the applied pesticides, including the trade name, common name, chemical group, physical state, percent of active ingredient and adsorption coefficient, needed in PIRI are given in Table 5.5. From the table it can be found that most of the pesticides used by the farmers in the Arial Beel belong to the chemical group Organophosphate (Furadan, Ripcord, Malathion), whereas others belong to the Carbamate (Basudin and Sevin) and Pyrethroid (Sumithion) groups. Active ingredient varies from 5% (Furadan) to 57% (Malathion) and adsorption coefficient (Koc) varies from 22 liters/kg (Furadan) to 100,000 liters/kg (Ripcord). The frequency of application of all pesticides except Basudin is 1 and for Basudin it was 2. The frequency of application of pesticides in Aman season was lower than that of Boro season.

Toxicity of any pesticide is also a function of its persistency in the environment which is expressed as half life ($t_{1/2}$) of that pesticide. Half life usually varies with the pH of the medium. The variation of persistency of pesticides in the environment with pH is not a linear relation and varies greatly with the chemical nature of pesticides. The persistency of Organophosphate pesticides increases with the increase of pH, but for Carbamate it decreases with the increase of pH. A correction factor was introduced in this study to adjust this variation. From the Table 5.5 it can seen that Furadan has the longest persistency in the environment (50 days) which is followed by Ripcord (45 days) and Basudin has the shortest persistency in the environment (16 days).

Table 5.5: Properties of the applied pesticides in the Arial Beel and their frequency and rate of application

Pesticide Name	Trade Name	Common Name	Chemical Group	Physical State	Active Ingredient (%)	K_{OC} (liters/kg)	Persistency in Environment (Days)	Frequency of Application	Rate of Application (kg or l/ha)
Basudin	Basudin 10 G	Diazinon	Carbamate	Granular	10	332	16	2	8.27
Furadan	Furadan 5 G	Carbofuran	Organophosphate	Granular	5	22	50	1	4.89
Sevin	Sevin 50 WDP	Carbaryl	Carbamate	Crystalline Powder	50	3000	20	1	2.56
Sumithion	Sumithion 50 EC	Cypermathrin	Pyrethroid	Liquid	50	2000	45	1	5.83
Ripcord	Ripcord 10 EC	Fenitrothion	Organophosphate	Liquid	10	100000	17.5	1	0.96
Malathion	Malathion 57 EC	Malathion	Organophosphate	Liquid	57	1800	14	1	4.38

Sources: Extension Ecological Network (EXTOXNET) and United States Environmental Protection Agency (USEAP)

5.7 Toxicological Properties of the Applied Pesticides

Impact of any pesticide on ecological resources is dependent on the toxicological properties of that pesticide which is again dependent on its chemical nature. For expressing the toxicity of a pesticide several terms are widely used such as Lethal Concentration 50 or LC_{50} and Lethal Dose 50 or LD_{50}. LD_{50} is a dose in which 50% of experimental animal/plant die within a definite time. LC_{50} is a concentration in which 50% of experimental animal/plant die within a definite time. The term LC_{50} is used to denote the toxicity of a pesticide to aquatic organisms, whereas the term LD_{50} is used for terrestrial animals for oral intake. LD_{50} and LC_{50} values are specific to plants and animals and have different values for each of them according to their physiological condition and biochemical reaction of pesticides with enzymes. In this study LD_{50} and LC_{50} of all pesticides for selected indicator species were collected from some pesticides information support networks, such as Extension Ecological Network (EXONET), United States Environmental Protection Agency (USEPA) pesticide wing, etc. Table 5.6 shows the values of major toxicological parameters of applied pesticides for rice pest management in the Arial Beel area from where it can be found that daphnia is very much sensitive to almost all pesticides used in the Arial Beel and LC_{50} value for daphnia varies from 0.00015 mg/l (Ripcord) to 0.015 mg/l (Furadan). On the other hand, oral LD_{50} value for rat varies from 8 mg/kg (Furadan) to 2200 mg/kg (Ripcord).

Table 5.6: Toxicological characteristics of pesticides used by the farmer in the Arial Beel

Name of Pesticide	LC50 (mg/l)			LD50 (mg/kg)
	Cat Fish	Daphnia	Algae	Rat
Basudin	2.90	0.096	0.001	1250
Furadan	0.30	0.015	0.060	8
Sumithion	1.30	0.086	0.013	1700
Ripcord	0.00069	0.00015	0.001	2200
Sevin	1.30	0.006	0.001	675
Malathion	3.50	0.071	0.0080	450

Sources: EXTOXNET and USEPA, Note: Both LC_{50} and LD_{50} values are taken for 48 hours experimental time.

5.8 Assessment of Pesticide Impacts

5.8.1 Qualitative assessment

In this study, fifteen unprotected ponds were randomly selected to assess the magnitude of impacts of pesticide use on ecological resources. Only those ponds were selected whose catchments occupy rice farms. Impacts of applied pesticides on the ecological resources of those fifteen ponds were assessed by PIRI. The impacts of each pesticide on ponds of all four upazillas are given in Tables 5.7- 5.10. The notations used in the tables are: VL=Very Low, L=Low, M=Medium, H=High, VH=Very High, and EH=Extremely High.

Table 5.7 shows the impacts of pesticides on catfish at different upazillas. From the table it can be seen that the impacts of Basudin on catfish at Boro season were Extremely High in eight ponds and in the rest seven ponds the impacts were Very High. The impacts of Furdan on catfish in Boro season were Extremely High in two ponds, Very High in four ponds and High in nine ponds. Sumithion, Ripcord, Sevin and Malathion showed variable impacts on catfish. The minimum impacts (Very Low) were found for Sumithion in two ponds.

Table 5.8 shows the impacts of pesticides on daphnia at different upazillas. From the table it can be seen that daphnia is very much sensitive to Basudin and Extremely High impacts were found in twelve ponds at Boro season. Three ponds were found to be Extremely High sensitive to Furadan and three ponds were found to be Very High sensitive. The impacts of other pesticides were not very severe on daphnia.

Table 5.9 shows the impacts of pesticides on algae at different upazillas. From the table it can be found that the impacts of Basudin on algae at Boro season were Extremely High in only one pond, Very High in six ponds and High in the rest eight ponds. The impacts of Furdan, Sumithion. Ripcord, Sevin and Malathion on algae was found to be lower at Boro season than those of Basudin. Extremely High impacts were not found for these pesticides in any pond of the beel.

Table 5.10 shows the impacts of pesticides on rat at different upazillas. From the table it can be seen that the impacts of pesticides on rat were relatively lower that those on other indicator species. For rat, the maximum impacts were found Very High only in one pond (NW_1) and in other ponds the impacts varies from Very Low to Medium.

Most of the lands of the Arial Beel remain as fallow land in Aman season and rice was found to be cultivated only in the higher lands. So pesticides were found to be used only in two ponds (DO_3 and NW_4), out of fifteen, in Aman season. As the present study calculated the total load of pesticides from the summation of the amount of pesticides applied in the fields of a catchment, comparatively lower load of pesticides were found in Aman season. From the tables 5.7-5.10, it can be found that the impacts of all pesticides in Aman season were comparatively lower than those in Boro season. Medium impacts were found for Furdan, Sevin and Malathion on catfish in both ponds. For Ripcord Low impacts on catfish were found for both ponds and for Basudin Medium impacts on catfish were found in DO_3 and Very High impacts in NW_4. The impacts on another indicator species were found to be variable and in most cases those were Medium to Low.

Table 5.7: Qualitative impacts of pesticides on catfish at different upazillas

Pond No.	Basudin		Furadan		Sumithion		Ripcord		Sevin		Malathion	
	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman
DO_1	EH	-	H	-	M	-	M	-	L	-	L	-
DO_2	VH	-	H	-	M	-	M	-	L	-	L	-
DO_3	EH	M	H	M	L	L	M	L	L	M	M	M
NW_1	EH	-	VH	-	M	-	H	-	H	-	M	-
NW_2	VH	-	VH	-	VL	-	VH	-	M	-	H	-
NW_3	VH	-	H	-	L	-	H	-	M	-	VH	-
NW_4	EH	VH	H	M	VL	H	M	L	M	M	H	M
SR_1	EH	-	VH	-	M	-	M	-	M	-	M	-
SR_2	VH	-	H	-	H	-	H	-	H	-	H	-
SR_3	VH	-	EH	-	M	-	M	-	M	-	M	-
SR_4	EH	-	H	-	L	-	L	-	L	-	L	-
SI_1	EH	-	VH	-	M	-	M	-	M	-	M	-
SI_2	VH	-	H	-	H	-	H	-	H	-	H	-
SI_3	VH	-	EH	-	M	-	M	-	M	-	M	-
SI_4	EH	-	H	-	L	-	L	-	L	-	L	-

Table 5.8: Qualitative impacts of pesticides on daphnia at different upazillas

Pond No.	Basudin		Furadan		Sumithion		Ripcord		Sevin		Malathion	
	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman
DO_1	EH	-	H	-	M	-	M	-	M	-	L	-
DO_2	EH	-	H	-	M	-	H	-	H	-	L	-
DO_3	EH	M	H	M	L	L	VH	L	H	M	M	M
NW_1	EH	-	EH	-	H	-	H	-	EH	-	M	-
NW_2	EH	-	VH	-	EH	-	VH	-	M	-	H	-
NW_3	EH	-	H	-	M	-	H	-	H	-	VH	-
NW_4	VH	VH	H	M	H	VH	M	L	M	H	H	L
SR_1	EH	-	EH	-	H	-	H	-	EH	-	M	-
SR_2	EH	-	VH	-	EH	-	VH	-	M	-	H	-
SR_3	EH	-	H	-	M	-	H	-	H	-	VH	-
SR_4	VH	-	H	-	H	-	M	-	M	-	H	-
SI_1	EH	-	EH	-	H	-	H	-	EH	-	M	-
SI_2	EH	-	VH	-	EH	-	VH	-	M	-	H	-
SI_3	EH	-	H	-	M	-	H	-	H	-	VH	-
SI_4	VH	-	H	-	H	-	M	-	M	-	H	-

Table 5.9: Qualitative impacts of pesticides on algae at different upazillas

Pond No.	Basudin		Furadan		Sumithion		Ripcord		Sevin		Malathion	
	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman
DO_1	EH	-	H	-	M	-	M	-	M	-	L	-
DO_2	H	-	H	-	L	-	H	-	VH	-	M	-
DO_3	H	M	H	M	M	L	M	L	M	M	M	M
NW_1	VH	-	VH	-	M	-	H	-	H	-	M	-
NW_2	H	-	VH	-	VL	-	VH	-	M	-	H	-
NW_3	VH	-	H	-	L	-	M	-	M	-	VH	-
NW_4	H	VH	H	M	L	VH	M	M	VH	H	H	M
SR_1	VH	-	H	-	M	-	H	-	M	-	VL	-
SR_2	VH	-	VH	-	L	-	M	-	VL	-	L	-
SR_3	H	-	VH	-	VL	-	L	-	M	-	L	-
SR_4	H	-	H	-	L	-	M	-	L	-	VL	-
SI_1	VH	-	H	-	M	-	H	-	M	-	VL	-
SI_2	VH	-	VH	-	L	-	M	-	VL	-	L	-
SI_3	H	-	VH	-	VL	-	L	-	M	-	L	-
SI_4	H	-	H	-	L	-	M	-	L	-	VL	-

Table 5.10: Qualitative impacts of pesticides on rat at different upazilas

Pond No.	Basudin		Furadan		Sumithion		Ripcord		Sevin		Malathion	
	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman
DO_1	H	-	H	-	H	-	M	-	L	-	L	-
DO_2	H	-	M	-	H	-	M	-	L	-	L	-
DO_3	H	L	H	M	M	L	M	L	L	M	M	M
NW_1	VH	-	H	-	M	-	H	-	H	-	M	-
NW_2	H	-	VH	-	L	-	H	-	M	-	H	-
NW_3	H	-	H	-	L	-	H	-	M	-	VH	-
NW_4	H	H	H	M	VL	VH	M	L	M	M	H	M
SR_1	H	-	M	-	L	-	L	-	VL	-	L	-
SR_2	H	-	H	-	VL	-	VL	-	M	-	VL	-
SR_3	M	-	H	-	VL	-	M	-	M	-	M	-
SR_4	M	-	M	-	L	-	M	-	L	-	M	-
SI_1	H	-	M	-	L	-	L	-	VL	-	L	-
SI_2	H	-	H	-	VL	-	VL	-	M	-	VL	-
SI_3	M	-	H	-	VL	-	M	-	M	-	M	-
SI_4	M	-	M	-	L	-	M	-	L	-	M	-

5.8.2 Quantitative assessment

To obtain a cumulative impact of pesticides on the total ecological resources of the Arial Beel, it is necessary to get the impact of a pesticide on a pond in numerical scale so that the impacts from different ponds can be averaged to get an average impact or added to get a cumulative impact. So the qualitative impact values were converted into quantitative numerical values. The processes of quantification of impacts were described in Chapter IV. Tables 5.11-5.14 show the quantitative impacts of Basudin, Furadan, Sumithion, Ripcord, Sevin and Malathion on catfish, daphnia, algae and rat as well as average values of such impacts in each upazilla. From the tables it can be found that the impact of Basudin varies from 5.80 (NW_4) to 4.20 (NW_3) at Boro season and 4.60 (NW_4) to 2.60 (DO_3) in Aman season. The impact of Furadan on catfish at Boro season varies from 4.80 (NW_1) to 3.20(DO_3) and from 3.8(NW_4) to 2.8 (DO_3) at Aman season. The impacts of Sumithion, Ripcord, Sevin and Malathion on catfish were comparatively lower than those of Basudin and Furadan both at Boro and Aman seasons. The impact of Basudin on daphnia were the maximum (5.90) among all ponds as well as all indicator species.

The average quantitative impacts of Basudin on catfish for ponds of Dohar upazilla are the maximum (5.26) which is followed by Nawabgonj upazilla (5.05). The impact is minimum at Sreenagar and Sirajdikhan upazillas (4.92). The tables also show that for daphnia the average quantitative impact is the maximum (5.60) for all ponds of Nawabgonj, Sreenagar and Sirjadikhan upazillas. It can also be seen from the tables that the average impacts of Basudin for all ponds of Dohar upazilla on catfish, daphnia, algae and rat were 5.26, 5.46, 4.26 and 3.60 respectively in Boro season, in Aman season the average impacts were 0.86, 0.93, 0.93 and 0.40 respectively. On the other hand, the average impacts of Furadan for the same ponds on the same indicator species were found to be 3.46, 3.60, 3.73, and 3.33 for Boro season and 0.93, 0.80, 0.93 and 0.93 for Aman season respectively. The minimum average impact (1.40) was found for Sevin in all ponds of Dohar Upazilla and the maximum (5.46) was found for Basudin in the same upazilla. Like qualitative impacts, the quantitative impacts in Boro season were comparatively higher than those of Aman season because in Aman season pesticides were found to be used in a few fields of the catchments of the only two ponds (DO_1 and NW_4).

Table 5.11: Quantitative impacts of pesticides on catfish at different upazillas

Pond No	Basudin		Furadan		Sumithion		Kipcord		Sevin		Malathion	
	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman
DO_1	5.40	-	3.40	-	2.40	-	3.40	-	1.80	-	1.60	-
DO_2	4.80	-	3.80	-	2.60	-	3.80	-	1.60	-	1.20	-
DO_3	5.60	2.60	3.20	2.8	1.60	1.80	3.20	1.80	1.80	2.60	2.60	2.20
Average	**5.26**	**0.86**	**3.46**	**0.93**	**2.20**	**0.60**	**3.46**	**0.60**	**1.40**	**0.86**	**1.46**	**0.73**
NW_1	5.40	-	4.80	-	2.80	-	3.80	-	3.80	-	2.80	-
NW_2	4.20	-	4.80	-	0.80	-	4.20	-	2.80	-	3.00	-
NW_3	4.80	-	3.60	-	1.20	-	3.80	-	2.20	-	4.20	-
NW_4	5.80	4.60	3.20	3.8	0.60	4.20	2.60	1.60	2.60	2.60	3.80	2.20
Average	**5.05**	**1.15**	**4.10**	**0.95**	**1.35**	**1.05**	**3.60**	**0.40**	**2.85**	**0.65**	**3.45**	**0.55**
SR_1	5.10	-	4.70	-	2.40	-	2.50	-	2.50	-	2.80	-
SR_2	4.60	-	3.50	-	3.20	-	3.00	-	3.30	-	3.50	-
SR_3	4.60	-	4.20	-	2.80	-	2.50	-	2.70	-	2.10	-
SR_4	5.40	-	3.80	-	1.80	-	1.80	-	1.90	-	1.90	-
Average	**4.92**	-	**4.05**	-	**2.55**	-	**2.45**	-	**2.60**	-	**2.57**	-
SI_1	5.10	-	4.70	-	2.40	-	2.50	-	2.50	-	2.80	-
SI_2	4.60	-	3.50	-	3.20	-	3.00	-	3.30	-	3.50	-
SI_3	4.60	-	4.20	-	2.80	-	2.50	-	2.70	-	2.10	-
SI_1	5.40	-	3.80	-	1.80	-	1.80	-	1.90	-	1.90	-
Average	**4.92**	-	**4.05**	-	**2.55**	-	**2.45**	-	**2.60**	-	**2.57**	-

Table 5.12: Quantitative impacts of pesticide on daphnia at different upazillas

Pond No.	Basudin		Furadan		Sumithion		Ripcord		Sevin		Malathion	
	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman
DO_1	5.40	-	3.60	-	2.60	-	2.80	-	2.40	-	1.60	-
DO_2	5.20	-	3.40	-	2.80	-	3.60	-	3 60	-	1.80	-
DO_3	5.80	2.80	3 80	2.40	1.60	1.20	4.20	1.8	3 40	2.40	2.40	2.40
Average	**5.46**	**0.93**	**3.60**	**0.80**	**2.33**	**0.40**	**3.53**	**0.6**	**3.13**	**0.80**	**1.93**	**0.80**
NW_1	5 80	-	5.80	-	3.80	-	3.60	-	5 80	-	2.80	-
NW_2	5.80	-	4.40	-	5 40	-	4.80	-	2.30	-	3.00	-
NW_3	6 00	-	3.80	-	2.40	-	3.50	-	3 30	-	4.50	-
NW_4	4.80	3.80	3.60	2.80	3 40	4.60	2.70	1.9	2.60	3.40	3.40	1.50
Average	**5.60**	**0.95**	**4.40**	**0.70**	**3.75**	**1.15**	**3.65**	**0.47**	**3.50**	**0.85**	**3.45**	**0.37**
SR_1	5.80	-	5.40	-	3.30	-	3.20	-	5.10	-	2.90	-
SR_2	5.80	-	4.90	-	5.10	-	4.10	-	2.90	-	3.00	-
SR_3	5 90	-	3.70	-	2.90	-	3.10	-	3.10	-	4.00	-
SR_4	4 90	-	3.90	-	3.00	-	2.90	-	2.90	-	3.10	-
Average	**5.60**	-	**4.47**	-	**3.57**	-	**3.32**	-	**3.50**	-	**3.25**	-
SI_1	5 80	-	5.40	-	3.30	-	3.20	-	5.10	-	2.90	-
SI_2	5 80	-	4.90	-	5.10	-	4.10	-	2.90	-	3.00	-
SI_3	5 90	-	3.70	-	2.90	-	3.10	-	3.10	-	4.00	-
SI_4	4.90	-	3.90	-	3.00	-	2.90	-	2.90	-	3 10	-
Average	**5.60**	-	**4.47**	-	**3.57**	-	**3.32**	-	**3.50**	-	**3.25**	-

Table 5.13: Quantitative impacts of pesticides on algae at different upazillas

Pond No.	Basudin		Furadan		Sumithion		Ripcord		Sevin		Malathion	
	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman
DO_1	5.40	-	3.60	-	2.80	-	2.80	-	2.60	-	1.80	-
DO_2	3.60	-	3.80	-	1.60	-	3.40	-	4.60	-	2.40	-
DO_3	3.80	2.80	3.80	2.80	2.20	1.80	2.40	2.20	2.40	2.60	2.60	1.80
Average	**4.26**	**0.93**	**3.73**	**0.93**	**2.20**	**0.60**	**2.86**	**0.73**	**3.20**	**0.86**	**2.26**	**0.60**
NW_1	4.30	-	4.80	-	2.80	-	3.60	-	3.60	-	2.60	-
NW_2	3 80	-	4.70	-	0.70	-	4.50	-	2.80	-	3.80	-
NW_3	4.50	-	3.60	-	1.10	-	2.80	-	2.60	-	5 40	-
NW_4	3.60	4.90	3.50	3.30	1.20	4.50	2.20	2.60	5.40	3.70	3.20	2.80
Average	**4.05**	**1.25**	**4.15**	**0.82**	**1.45**	**1.12**	**3.27**	**0.65**	**3.60**	**0.92**	**3.75**	**0.70**
SR_1	4.10	-	3.90	-	2.80	-	3.10	-	2.20	-	0.80	-
SR_2	4 00	-	4.00	-	1.90	-	2.90	-	0.90	-	1.20	-
SR_3	3.90	-	4.20	-	0.90	-	1.90	-	2.00	-	1.00	-
SR_4	3.90	-	3.70	-	1.10	-	2.00	-	1.20	-	0.70	-
Average	**3.97**	-	**3.95**	-	**1.67**	-	**2.47**	-	**1.57**	-	**0.92**	-
SI_1	4.10	-	3.90	-	2.80	-	3.10	-	2.20	-	0.80	-
SI_2	4.00	-	4.00	-	1.90	-	2.90	-	0.90	-	1.20	-
SI_3	3.90	-	4.20	-	0.90	-	1.90	-	2.00	-	1.00	-
SI_4	3.90	-	3.70	-	1.10	-	2.00	-	1.20	-	0.70	-
Average	**3.97**	-	**3.95**	-	**1.67**	-	**2.47**	-	**1.57**	-	**0.92**	-

Table 5.14: Quantitative impacts of pesticide on rat at different upazillas

Pond No.	Basudin		Furadan		Sumithion		Ripcord		Sevin		Malathion	
	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman
DO_1	3.60	-	3.60	-	3.20	-	2.20	-	1.80	-	1.80	-
DO_2	3.80	-	2.80	-	3.00	-	2.00	-	1.20	-	1.20	-
DO_3	3.40	1.20	3.60	2.80	2.20	1.00	2.00	1.80	1.60	2.40	2.40	2.80
Average	**3.60**	**0.40**	**3.33**	**0.93**	**2.80**	**0.33**	**2.06**	**0.60**	**1.86**	**0.80**	**1.80**	**0.93**
NW_1	4.50	-	3.50	-	2.60	-	3.50	-	3.00	-	2.90	-
NW_2	3.60	-	4.40	-	1.40	-	3.60	-	2.00	-	3.10	-
NW_3	3.30	-	3.40	-	1.30	-	3.00	-	2.00	-	4.10	-
NW_4	3.80	3.30	3.80	2.60	0.80	4.60	2.50	1.60	2.00	2.20	3.30	2.90
Average	**3.80**	**0.82**	**3.77**	**0.65**	**1.52**	**1.15**	**3.15**	**0.40**	**2.25**	**0.55**	**3.35**	**0.72**
SR_1	3.20	-	2.50	-	1.10	-	1.30	-	0.80	-	1.20	-
SR_2	3.20	-	3.00	-	0.90	-	0.90	-	2.10	-	0.70	-
SR_3	2.90	-	3.00	-	0.80	-	2.10	-	2.00	-	2.10	-
SR_4	2.80	-	2.70	-	1.00	-	2.00	-	1.90	-	2.00	-
Average	**3.02**	-	**2.80**	-	**0.95**	-	**1.57**	-	**1.70**	-	**1.50**	-
SI_1	3.20	-	2.50	-	1.10	-	1.30	-	0.80	-	1.20	-
SI_2	3.20	-	3.00	-	0.90	-	0.90	-	2.10	-	0.70	-
SI_3	2.90	-	3.00	-	0.80	-	2.10	-	2.00	-	2.10	-
SI_4	2.80	-	2.70	-	1.00	-	2.00	-	1.90	-	2.00	-
Average	**3.02**	-	**2.80**	-	**0.95**	-	**1.57**	-	**1.70**	-	**1.50**	-

5.8.3 Average impacts of different pesticides

In this study, impacts of six pesticides on fifteen selected small ponds were evaluated. To get a picture of the impacts of these pesticides on total beel ecology, simple mathematical averaging was done. Table 5.15 shows the average impacts of Basudin, Furadan, Sumithion, Ripcord, Sevin and Malathion on catfish, daphnia, algae and rat. From the table it can be found that the average impact values of Basudin on catfish were 5.03 for Boro season and 0.50 for Aman season. For daphnia, the average impacts of Basudin were 5.56 and 0.47 for Boro and Aman season respectively. As in Aman season pesticides were applied only in one or two fields of the catchment, the average impact was found to be very negligible. The maximum average impact (5.56) was found for Basudin on daphnia in Boro season and the minimum (1.55) was found for Sumithion on rat in the same season.

The comparative picture of average impacts of Basudin, Furadan, Sumithion, Ripcord, Sevin and Malathion is shown in Figure 5.1. From the figure it can be clearly seen that Basudin has the highest impacts on catfish, daphnia, algae and rat which is followed by Furdan. On the other hand, Sumithion has the least impacts on all the indicator species.

Table 5.15: Average and cumulative impacts of pesticide on indicator species

Pesticide Name	Catfish		Daphnia		Algae		Rat		Average Ecological Impacts	
	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman	Boro	Aman
Basudin	5.03	0.50	5.56	0.47	4.06	0.54	3.36	0.30	4.50	0.45
Furadan	3.91	0.47	4.23	0.37	3.94	0.43	3.16	0.39	3.81	0.41
Sumithion	2.16	0.41	3.30	0.38	1.74	0.43	1.55	0.37	2.18	0.39
Ripcord	2.99	0.25	3.45	0.26	2.76	0.34	2.08	0.28	2.82	0.28
Sevin	2.36	0.37	3.40	0.41	2.48	0.44	1.89	0.33	2.53	0.38
Malathion	2.51	0.32	2.97	0.29	1.96	0.32	2.03	0.41	2.36	0.33
Average Impacts of Pesticide	3.16	0.38	3.81	0.36	2.82	0.41	2.34	0.34	-	-
Cumulative Impacts									3.03	0.73

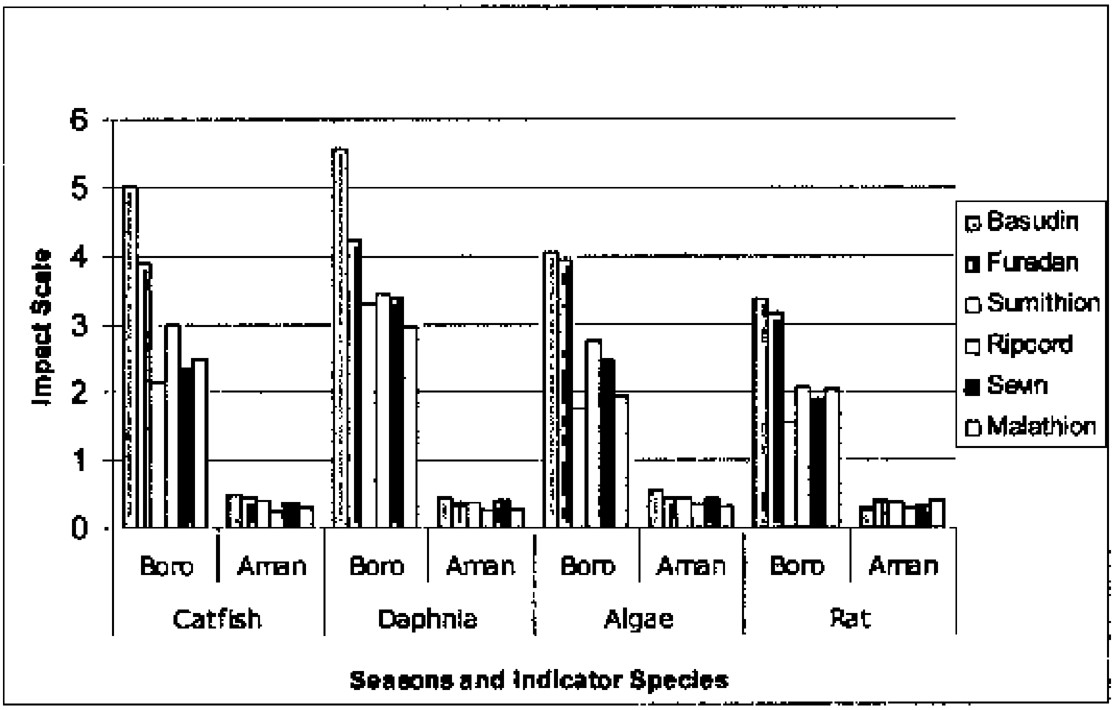

Figure 5.1: Comparative impact of pesticides on indicator species

5.8.4 Seasonal variation of pesticide impacts

The present study also assessed the impacts of pesticides in both Boro and Aman seasons. The seasonal variation of impact of pesticides on ecological resources of the Arial Beel are shown by bar diagram in Figures 5.2, 5.3, 5.4, 5.5, 5.6 and 5.7 for Basndin, Furadan, Ripcord, Sumithion, Ripcord, Sevin and Malthion, respectively, on catfish, daphnia, algae and rat. From the figures it can be clearly seen that the impact of Basndin on almost all indicator species is several times higher in Boro season than that in Aman season. The similar differences in impacts can also be found for Furdan, Sumithion, Ripcord, Sevin and Malathion.

It was found that most of the beel area is low land where flooding depth is about 1.53-3.05 m (Table 3.2) and the deeper portion of the beel remains fallow during the Aman season (Table-3.9). So the impacts of pesticides on ecological resources in the Aman season were found to be almost negligible. Although transplanted Aman is cultivated in the upper parts of the beel and pesticides are used, the impact is not much. However pesticide use in the Boro season was found to have an adverse impact on the beel ecosystem.

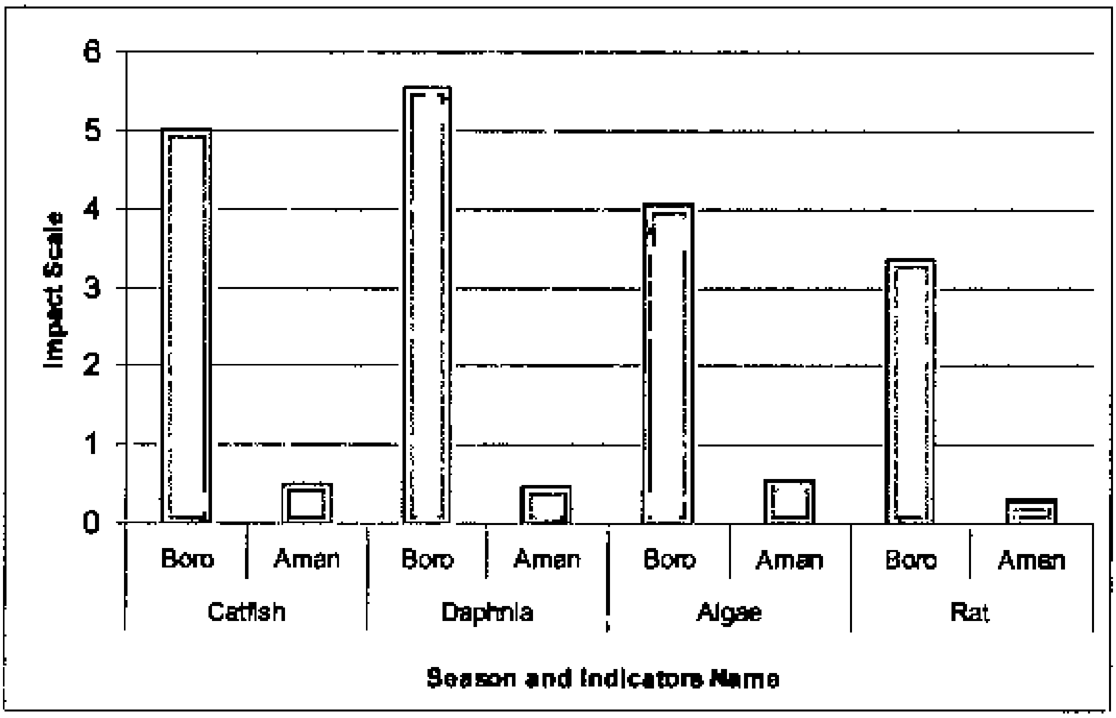

Figure 5.2: Comparative impacts of Basudin in Boro and Aman seasons

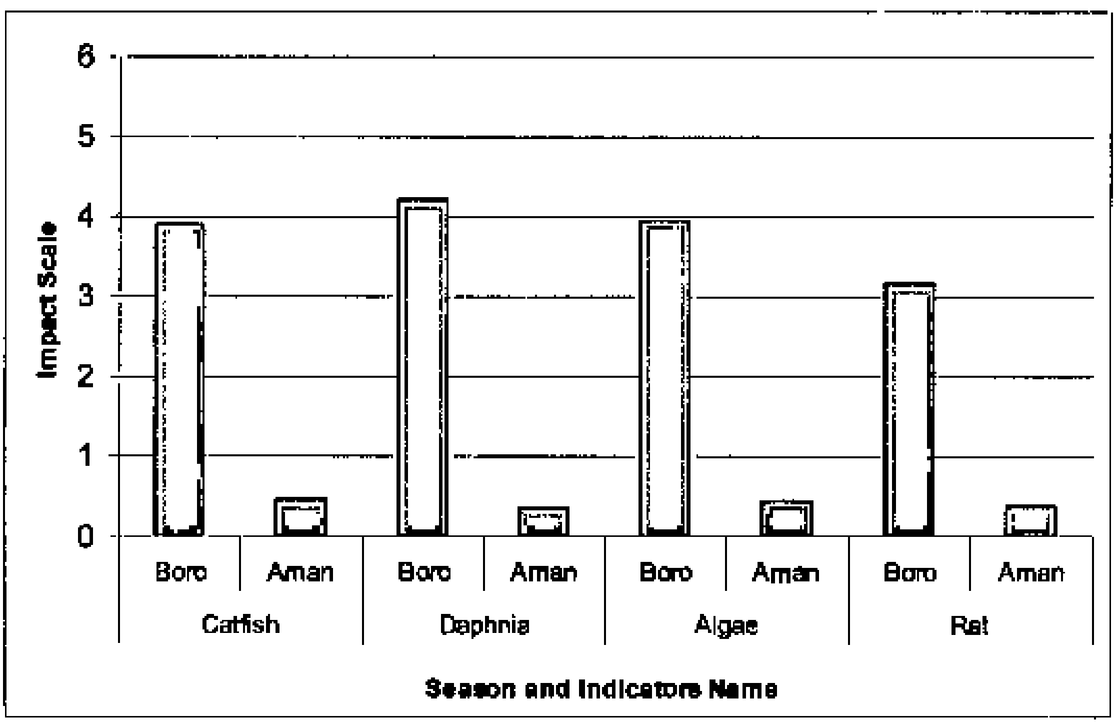

Figure 5.3: Comparative impacts of Furadan in Boro and Aman seasons

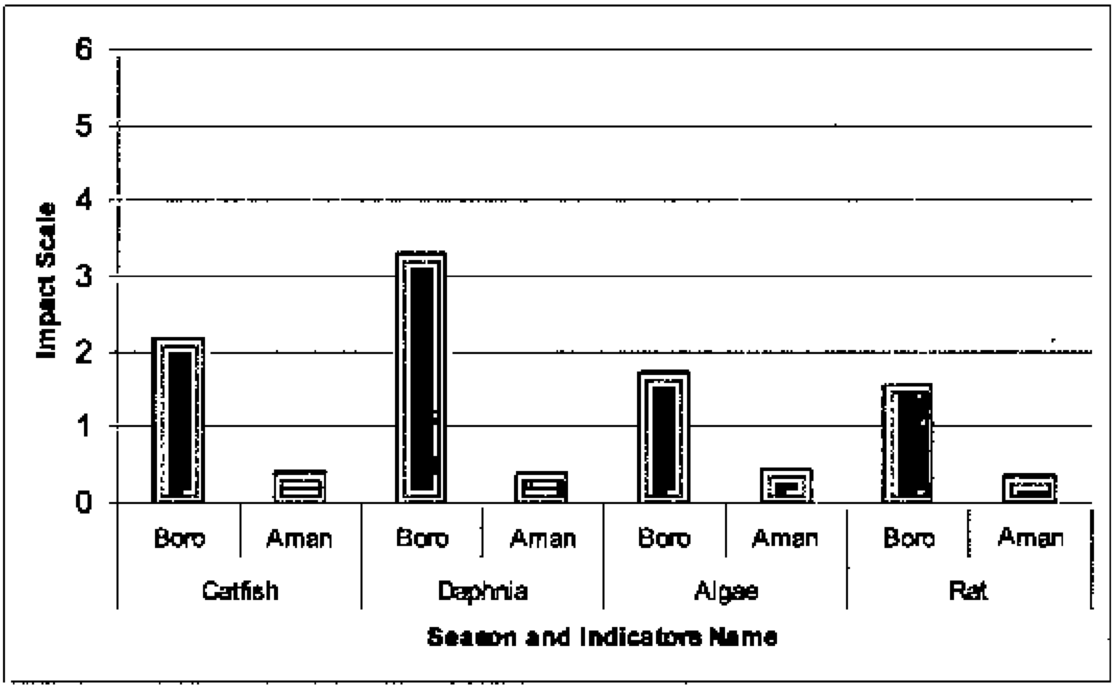

Figure 5.4: Comparative Impacts of Sumithion in Boro and Aman seasons

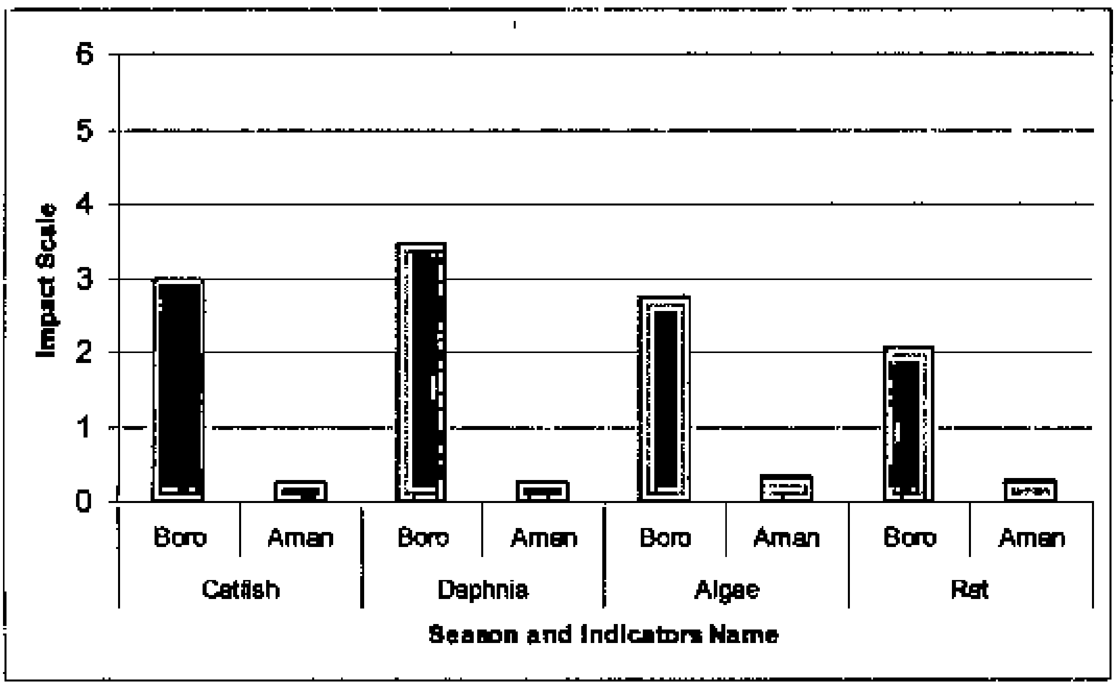

Figure 5.5: Comparative impacts of Ripcord in Boro and Aman seasons

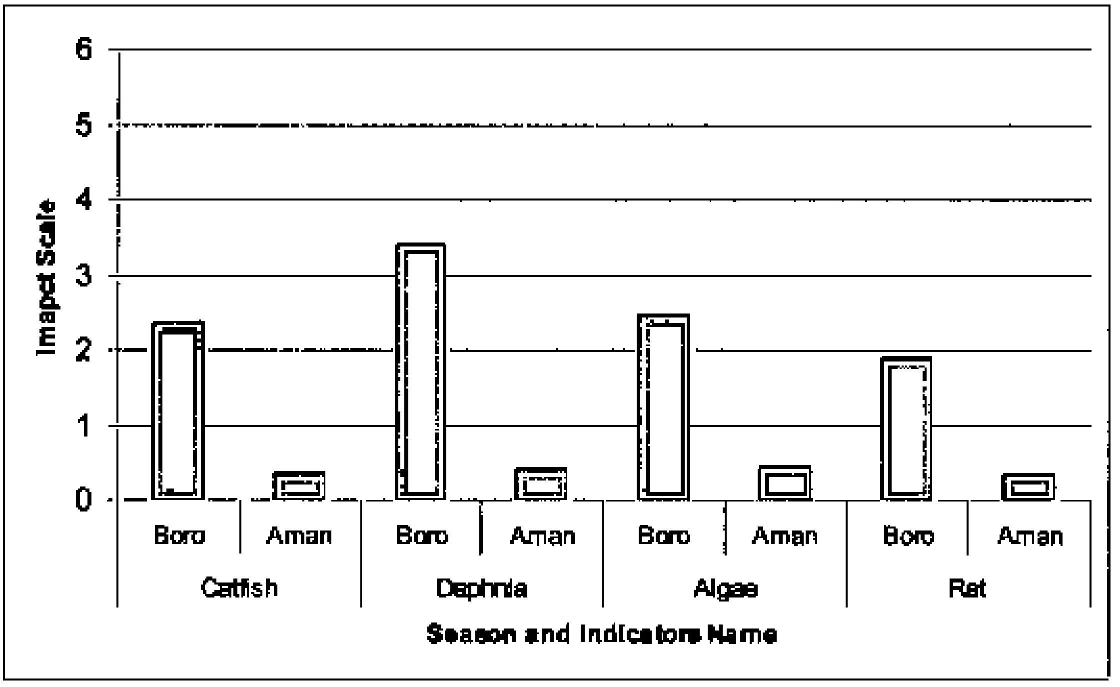

Figure 5.6: Comparative impacts of Sevin in Boro and Aman seasons

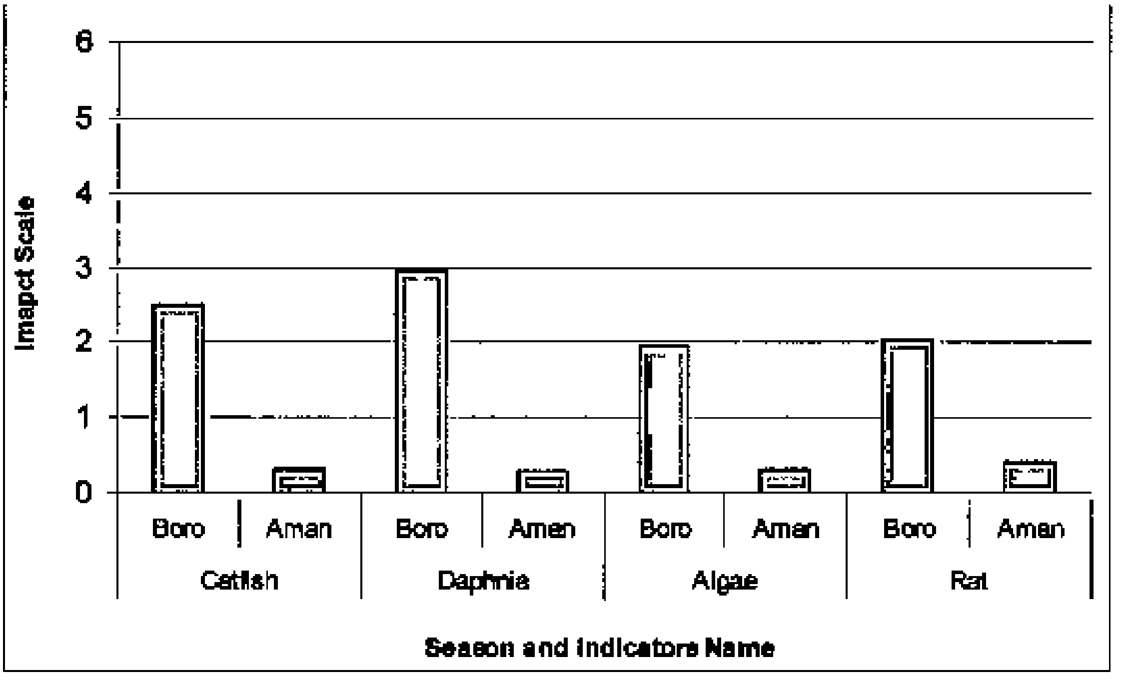

Figure 5.7: Comparative impacts of Malathion in Boro and Aman seasons

5.8.5 Ranking of pesticides based on their impacts

Ranking of pesticides is an important task for ecological management of wetland ecosystem. Based on such ranking, the use of more harmful pesticides can be discouraged or banned. The ranking of pesticides used by the farmers in the Arial Beel was done on the basis of their impacts. This ranking procedure is known as hazardousness ranking (Kookana et al., 1998). Ranking was done from the mathematical average impacts of pesticides in Boro and Aman Seasons.

The ranking of pesticides based on their impacts is shown in Figure 5.8 by bar diagram. From the figure it can be seen that Basudin has the highest rank based on its impacts on ecological indicator species. Furadan attains the second position and Ripcord, the third. From the figure, it can also be found that the rank of Sevin, Malathion and Sumithion are very close to each other and Sumithion is in the last position. The figure also shows that the impact of Basudin can be marked as 'Very High' and Furadan as 'High'. On the other hand, the impacts of Ripcord, Sevin, Malathion and Sumithion can be marked as 'Medium' though there are some differences among the values of their impacts.

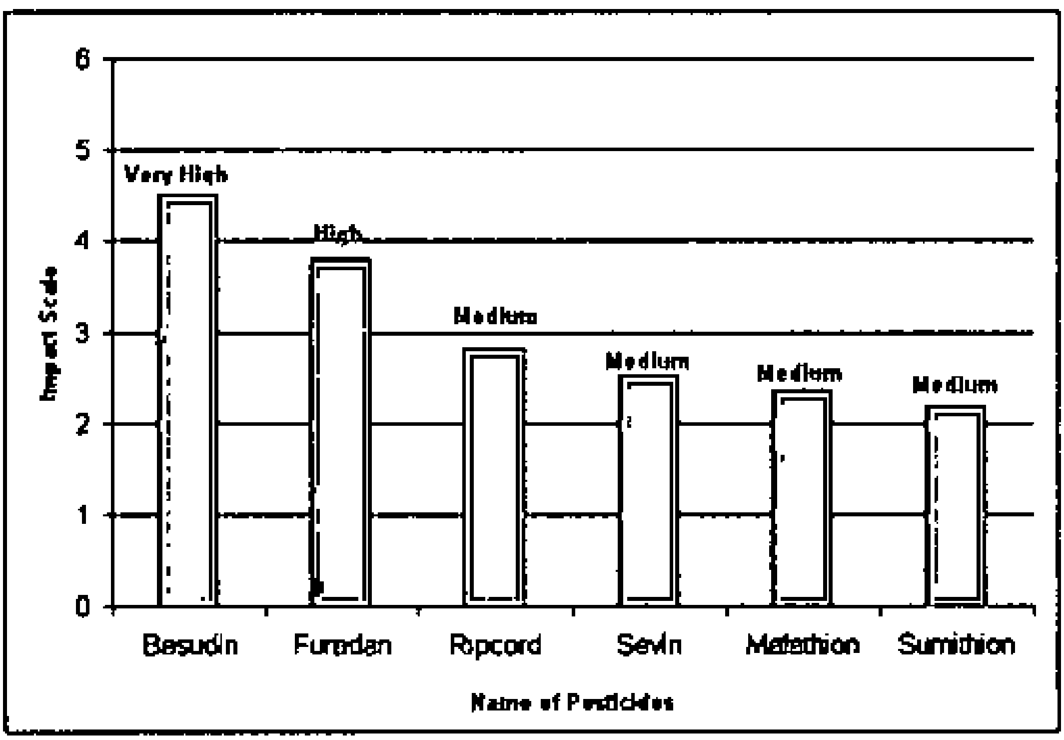

Figure 5.8: Ranking of pesticide based on their impacts

5.8.6 Cumulative impacts of pesticides and field observations

The assessment of impact of pesticides on ecological resources reported earlier was done by considering the use of the same pesticide for whole catachment of a particular pond. But in reality the same pesticide is certainly not used in the whole catchment, rather a variety of pesticides are used. So the cumulative impact was evaluated considering the actual use of six pesticides in the catchments of all fifteen ponds. In that case, for Boro season the impact score was found to be 3.03 (Table 5.15) which can be marked as 'High' according hazardousness marking of PIRI. The value 3.03 means that approximately 50% of the indicator species will die if rainfall occurs within 13.5 days (average half life of all six pesticides used in the Arial Beel) from the date of application of pesticides in the fields.

Boro season starts in the Arial Beel during 5-15 February and in most cases pest attack occurs in vegetative stage of the rice plant which is approximately from 20 March- 7 April. Most of the farmers of the Arial Beel use pesticides during that time. Rainfall events of the Arial Beel area during the time of application of pesticides (20 March - 7 April) were observed in 2008 and 2009. The rainfall events which can create run-off to the ponds were only considered. Table 5.16 shows the number of rainfalls that occurred during 20 March to 7 April in 2008 and 2009.

Table 5.16: Number of rainfall events occurred during 20 March to 07 April 2008 and 2009

Year	Number of Rainfalls	Date of Occurrence	Amount of Rainfall
2008	2	30 March & 4 April	112 mm and 87 mm
2009	3	26 March, 30 March & 2 April	65 mm, 78 mm and 95 mm

Fish mortality was found to occur after all of the above mentioned rainfall events but the most dangerous thing happened was in 2008 at a number of ponds in Sreenagar upazilla. On 29 March 2008, three farmers of the Arial Beel area used pesticides in their fields and on 30 March 2008 heavy rainfall occurred in the area which caused a huge run-off to a number of ponds and severe fish mortality (Photo 5.1) occurred in some ponds which received mostly Basudin runoff from their catchments.

Photo 5.1: Fish mortality in a pond of the Arial Beel

This was seen during the field visit on 30 March 2008. Almost 100% species of the affected ponds had died. Table 5.15 shows that the average score of impacts of Basudin on total ecology is 4.50 which means that 75% of the total species will die if minimum number of days between the application of pesticide and the first rainfall is 7 days (average). Though we find a 75% decrease in the total ecological resources of a pond if it receives runoff contaminated with Basudin, the actual effect may be more dangerous if rainfall occurs earlier. However, this event was a particular case and cannot be considered as a regular event. On the basis of this phenomenon, a survey was conducted on 31 March 2009 to find out the changes in fish availabilities over 2008. Fish catches of some freshwater wetland fishes such as catfish, walking fish, scorpion fish, etc. with standard fishing gear such as cast net was observed. The observation was done in 20 points of the beel and the numbers of catcher were assumed same in 2008 and 2009. Table 5.17 shows the result of the survey. From the table it can be seen that the availabilities of almost all fishes had decreased in 2009 compared to 2008 and the highest decrease was for the scorpion fish.

Table 5.17: Change of availabilities of common fish species from 2008 to 2009

Name of the Fish	Number of Fishes/Catch		Change in Availability
	2008	2009	(%)
Climbing fish	5	4	20
Walking fish	3	2	33.33
Cat fish	6	4	33.33
Sheat fish	2	1	50
Scorpion Fish	3	0	100
Average Change in Fish Availability			47.37

Table 5.15 shows that the cumulative impact score of the pesticides used by the farmers in the Arial Beel is 3.03 which mean approximately 50% of the target specicies will die if the time interval between the application of pesticides and the first rainfall is 13.5 days (average half life of six pesticides) and Table 5.17 shows that, availabilities of common fish specices in the beel area had decreased by 47.37% which verify the PIRI result. However, if only Sumithion was used in the whole catchment the fish mortality would have been approximately 36% with other parameters remain the same. So it can be said that all chemical pesticides have adverse impact on freshwater ecology though some can be less hazardous than others.

5.9 Identification of Convenient Pest Management Options

5.9.1 Introduction

To minimize the impacts of pesticides on ecological resources, it is necessary to identify the most convenient pest management options for the Arial Beel. This work was done by following a three step methodology. In the first step, literature review was done to find out some sustainable pest management options. The second step was to assess the acceptance of such pest management options to the farmers and the third step was to identify the ways to implement the most acceptable option.

5.9.2 Sustainable pest management options

A number of literatures were reviewed to find the way for minimization of impacts of pesticides in the Arial Beel. Feder et al. (2004), Fakih et al. (2003). Altieri et al. (1999), and Farah (1994) suggested a number of eco friendly pest management options as well as approaches which were adapted and practiced in many countries of the world including Bangladesh. Some of the most important of them are:

(a) Adaptation of integrated pest management (IPM) technique

There are many definitions of IPM. The FAO definition of IPM is "A pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economic injury". In the context of Bangladesh, the term IPM includes elements contributing to an effective, safe, sustainable and economically sound crop protection system. Major components of IPM are the use of bio pesticides, optimization of active ingredient in pesticides, adjustment of the application of pesticides with the rainfall etc. The use one or more options of the above mentioned techniques could minimize the adverse impact of pesticides on environment. The benefits of IPM over chemical control of pests are:

- Increases self-reliance of farmers by promoting locally developed and adapted crop management practices;
- Reduces the risks to farmers, general public and the environment: these include the risks of crop loss and all risks related to the use of pesticides;
- Brings enormous savings by reducing the use of farm chemicals;
- Reduces use of pesticides at the national level;
- Improves the field conditions for beneficial insects and generates extra income as well as nutritious food for the farmers; and
- Promotes community activities and the formation of farmer groups (e.g. IPM clubs) and facilitates empowerment of both female and male farmers.

(b) Development of bio/herbal pesticides

Biopesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals. For example, canola oil and baking soda have pesticidal applications and are considered biopesticides. At the end of 2005, there were approximately 195 registered biopesticide active ingredients and 780 products. Biopesticides fall into three major classes (Feder et al. (2004) :

1. Microbial pesticides consist of a microorganism (e.g., a bacterium, fungus, virus or protozoan) as the active ingredient. Microbial pesticides can control many different kinds of pests, although each separate active ingredient is relatively specific for its target pests. For example, there are some fungi that control certain weeds, and some ther fungi that kill specific insects. The most widely used microbial pesticides are subspecies and strains of Bacillus Thuringiensis, or BT. Each strain of this bacterium produces a different mix of proteins, and specifically kills one or a few related species of insect larvae. While some BTs control moth larvae found on plants, other BTs are specific for larvae of flies and mosquitoes. The target insect species are determined by whether the particular BT produces a protein that can bind to a larval gut receptor, thereby causing the insect larvae to starve.
2. Plant-Incorporated-Protectants (PIPs) are pesticidal substances that plants produce from genetic material that has been added to the plant. For example, scientists can take the gene for the BT pesticidal protein, and introduce the gene into the plant's own genetic material. Then the plant, instead of the BT bacterium, manufactures the substance that destroys the pest. The protein and its genetic material, but not the plant itself, are regulated by EPA.

3. Biochemical pesticides are naturally occurring substances that control pests by non-toxic mechanisms. Conventional pesticides, by contrast, are generally synthetic materials that directly kill or inactivate the pest. Biochemical pesticides include substances. such as insect sex pheromones, that interfere with mating, as well as various scented plant extracts like Neem extraction.

Benefits of biopesticides over chemical pesticides are:

- Biopesticides are usually inherently less toxic than conventional pesticides.
- Biopesticides generally affect only the target pest and closely related organisms, in contrast to conventional pesticides that may affect a broad spectrum of organisms as different as birds, insects, and mammals.
- Biopesticides often are effective in very small quantities and often decompose quickly, thereby resulting in lower exposures and largely avoiding the pollution problems caused by conventional pesticides.
- When used as a component of Integrated Pest Management (IPM) programs, biopesticides can greatly decrease the use of conventional pesticides, while crop yields remain high.
- To use biopesticides effectively, however, users need to know a great deal about managing pests.

(c) Optimization of active ingredients in formulated pesticides

The functional chemical compound present in a pesticide is known as the active ingredient of that pesticide and the rest is known as the inert ingredient. Lack of appropriate guidelines and monitoring practices in Bangladesh, the so called formulation industry does not consider environmental safe factor during formulation of pesticides. In most cases, it was found that the fractions of active ingredients are several times higher than those of developed countries (Karim, 1998). This may cause the economical as well as environmental loss. So optimization of active ingredient in formulated pesticides can maximize the economic benefit including the conservation of ecological resources.

(d) Adjustment of timing of pesticide application with rainfall events

Rainfall induced runoff is an important process for migration of pesticides from fields to water bodies. Prediction of rainfall occurrence during a crop season can be done by the analysis of meteorological data of the concerned area. From the field survey in the study area it was found that if the Boro season of the Arial Beel area can be started 10 days earlier, substantial protection of ecological resources can be ensured. So attempts can be made to motivate the farmers to use pesticides in a safe time. This adjustment of timing can also play a vital role in the maximization of economic benefit.

(e) Regulatory approach to prevent the use of proscribed pesticides

Farmers of the study area were found to be certainly aware about the offsite migration of pesticides. They usually use those types of pesticides which are economically cheap and can be collected easily. However, it was found that most of the pesticides which are cheaper in price have already been banned by government. There is no regulatory action regarding the use of these banned pesticides impacts of these pesticides are more severe. So legal actions against import, formulation, distribution, sell and use of proscribe pesticides can play a vital role in minimizing the adverse impacts of pesticides.

5.9.3 Existing pest management practices

Eight nos. FGDs were conducted during March-April 2008 to find out the existing pest management practices in the Arial Beel. The results of FGDs are given in Figure 5.9. It can be seen from the figure that the greatest portion of the farmers (86%) were habituated with the use of chemical pesticides for rice pest management and only 8% of the total farmers used IPM in this regard. Only 3% of the farmers of the Arial Beel use biopesticides like Neem extract for controlling rice pests and the rest 3% farmers used some others miscellaneous pest management techniques.

5.9.4 Farmers' awareness about sustainable pest management options

Another attempt was taken to know the farmers' perceptions regarding sustainable pest management options. In this case, those options that were found from literature reviews (Section 5.10.2) as sustainable pest management options were discussed with the farmers and they were asked to inform whether they were conversant with those options or not? The discussion was held with 85 farmers. It was found that only 40-45% farmers were conversant with one or more options of the sustainable pest management and most of the farmers have no idea about such options (Figure 5.10).

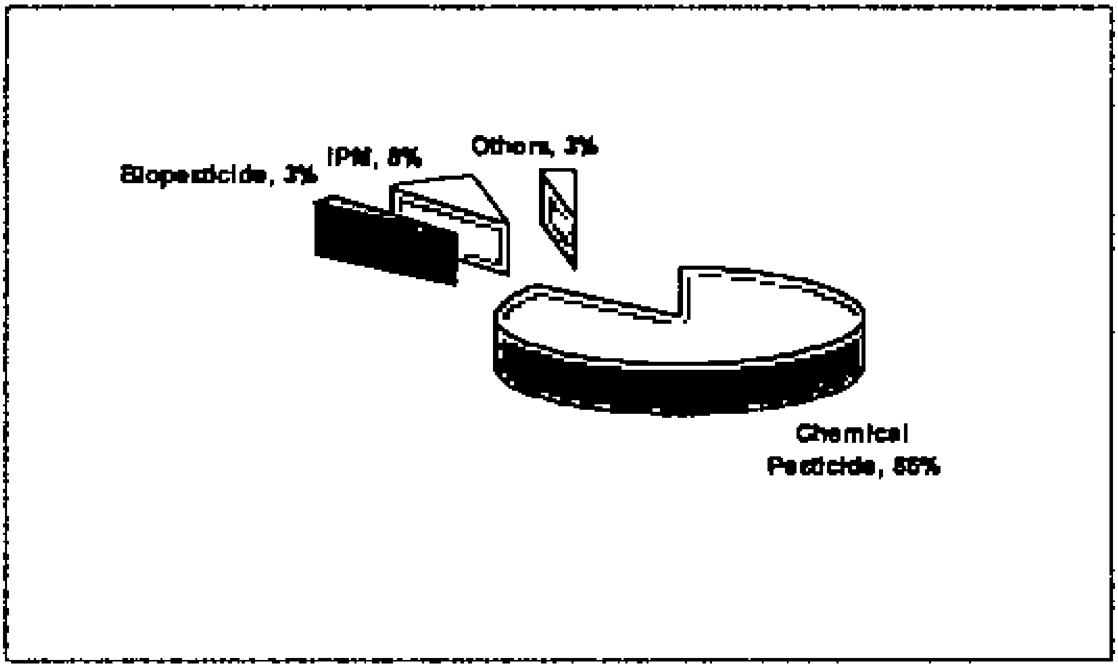

Figure 5.9: Existing pest management practices in the Arial Beel

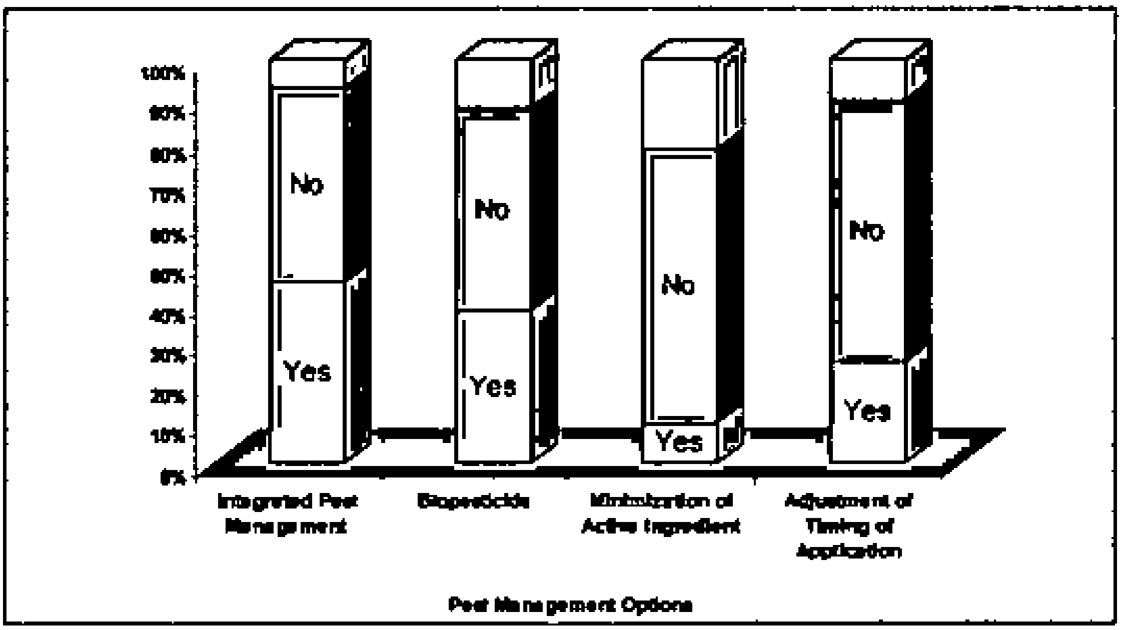

Figure 5.10: Farmers' perception on sustainable pest management options

5.9.5 Level of acceptance of sustainable pest management techniques by farmers'

Assessment of the farmers' level acceptance of different sustainable pest management options was done by FGDs. About seven nos. FGDs were conducted for this purpose. Almost all farmers who participated in the discussions believed that the use of chemical pesticides was the main reason for a decrease of fishes in the beel area. Moreover, though the farmers were not well conversant with the sustainable pest management, they were some how implementing IPM to manage pests up to a certain level. In some fields, bamboo sticks which were found to be used to support the birds to consume harmful pests (Photo 5.2).

When the farmers were asked about suitable pest management techniques, 36 % of the farmers (Figure 5.11) respond that the use of natural/indigenous techniques like IPM is the most suitable way of pest management. Some farmers also quoted their childhood experiences as examples and informed that there were no pesticides in that time but they controlled pests at that time by using some products like Neem extraction. 15% of the farmers respond that optimization of active ingredient in formulated pesticides can minimize the adverse impact and 10% of the farmers respond that bio/herbal pesticides can be used as a sustainable pest management technique. Only 12% of the farmers agreed and believed that the adjustment of the time of application of the pesticides with rainfall events can minimize the adverse impacts while others thought that this technique can be adapted as pesticides are used immediately when its application is necessary to stop the pest attack and it may not be possible to wait further. However a large portion of farmers (27%) of the farmers believes that the regulatory approach can play a vital role in minimizing the adverse impacts. On based on farmers' view, it can be concluded that IPM is one of the most suitable pest management options which can be adapted to minimize the offsite impacts.

Photo 5.2: Photo showing the use of an indigenous technique (bamboo stick) for pest control

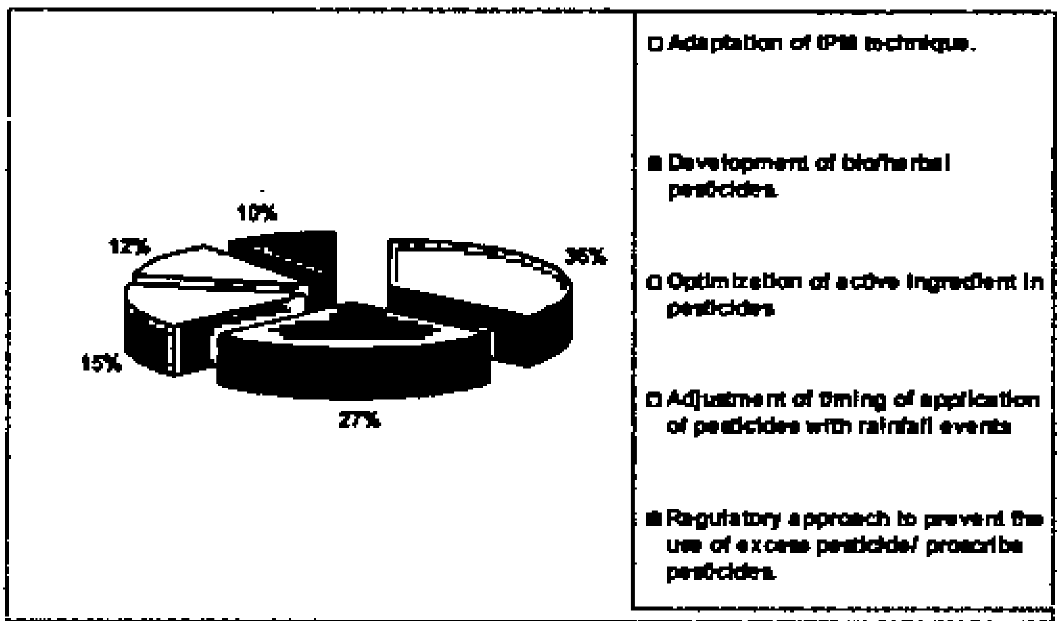

Figure 5.11: Farmers' opinion regarding suitability of sustainable pest management options

5.9.6 Development of IPM Guidelines

A guideline for implementation of IPM in the Arial Beel is developed from the review of Stern et al. (1959), Matthews (2000), Naranjo (2001), Berg (2004), Mansfield et al.

(2006), Koul et al. (2008) and Romeis et al. (2008). The guideline has three major steps- avoidance, surveillance and control. Figure 5.12 shows the three steps in a pyramid form. The description of each step is given bellow:

1. **Avoidance of pests:** The avoidance of pest can be done by the proper management of landscape, cultural control of pests, conservation of natural enemies of pests, development of resistance of host plants and bio-control of pests.
2. **Development of surveillance:** The development of surveillance for sustainable pest management can be done by monitoring the pest as well as the crops. Proper monitoring of pests and crops is an important pre-requisite for action threshold.
3. **Control of pests:** If management of pests cannot be done by adapting the above mentioned two techniques, actions can be taken to control pests. The control measures in IPM includes development of genetically modified pest resistant plant species, development of less harmful chemical pesticides by considering the mode of action of pesticides, control of active ingredient in pesticides during the time of formulation and control of migration of pesticides from fields to water bodies by optimizing the time and rate of application.

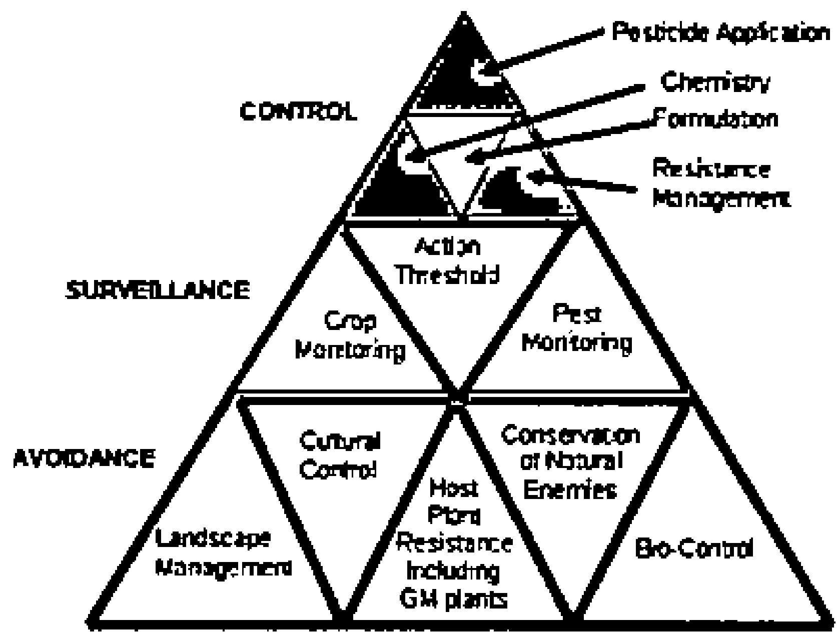

Figure 5.12: Steps of Integrated Pest Management (IPM)

Meetings were held with the elite persons of union level like UP chairman and members, and political leaders of different parties for identifying the suitable ways for implementation of IPM techniques in the beel area for pest management in rice fields. From those meetings following options came out:

1. Upazilla agriculture office can take necessary steps to train the farmers on IPM and can form a cell to monitor its implementation by the farmers.
2. Non government organizations can play a vital role in this sector. They can take projects to create awareness on adverse impacts of pesticides on environment and farmers health.
3. Government can take initiative to award the for most successful IPM users to inspire the farmers on IPM practices.

5.10 Discussions

The Arial Beel is one of the major wetlands of Dhaka and Munshingonj districts. There is a great social, economical and ecological value of the beel. It provides a huge support to the livelihoods of local poor community. Fish is one of the most important resources of the beel. The poorest community of the beel area is the fisherman community who directly depends on the availabilities of fish in the beel. But the extensive use of pesticides in rice fields has caused a degradation of natural resources including the fishes. As a consequence of the resources degradation, beel dependent fishermen had lost their profession which lead them to get involved in illegal works like catching of fish from government leased large ponds.

This study was conducted to assess the impacts of pesticides use in rice field on the ecological resources of the Arial Beel. The assessment was conducted by selecting four ecological indicators such as catfish, daphnia, algae and rat. One species of each of the four trophic levels was taken in such assessment. As the productivity of any ecosystem depends on the food chain of that system, the assessment was done by considering the above mentioned four indicator species. The availabilities of the fish in the Arial Beel will be affected if ecological functions of any of the four indicator species are affected. For example, some pesticides were not affect the fish directly, but they affect the fish indirectly by affecting the growth of algae. In this case, the food chain of fish is affected as the availabilities of foods for small fishes are decreased and ultimately fish production of the beel is decreased. However in the present study it is found that almost all pesticides have medium to high impact in the Boro season on almost all indicator species. In this case, the fish production of the beel is greatly affected.

Fish availabilities in a wetland system depend on so many factors that are interlinked with each other. For this reason the total production of a wetland system is affected if any one of the factors affects the growth. In the present study, the impact of pesticides on fish were assessed by PIRI and the result was tested and verified by the field data of change of fish availabilities of some common freshwater fishes like scorpion fish, sheet fish, walking fish, climbing fish, etc. Here, it was considered that the number of catcher was the same in both years of 2008 and 2009. From the discussion with the farmers it was found that in actual cases, the number of professional fisherman is decreasing day by day because it is not possible to lead life by fishing these days. For a fisherman it has now become a hard task to manage a family only by fishing, so most of the fishermen of the beel area have already given up the fishing. But population in the beel area is increasing day by day. By considering these factors, the number of catcher can be taken as the same. Considering the number of catchers the same in the consecutive years, the study revealed that a great change (47.37% decreases) of fish availabilities had occurred. Though it cannot be said that total decrease of the fish availabilities was occurred only for pesticides, it can be easily said that unwise use of pesticides is one of the most important factors in this reduction.

HYV rice cultivated in the Boro season usually requires a huge agricultural input like fertilizers and pesticides. In this study, medium to high impacts on indicator species were found for almost all such pesticides. On the other hand, in the Aman season, traditional varieties were found to be cultivated which were almost nature dependent and farmers were found to have used less agricultural inputs. Moreover in the Aman season, huge rainfall generate surface overflow on land and for this reason farmers do not like to use pesticides. In the Aman season there exists no boundary of any field, all remain under water. The local varieties are most pest resistance than the HYV rice and hence comparatively low amount of pesticides is needed. Pesticides were found to be used only in some fields, which were located in a relatively higher topography. As the amount of pesticides applied in the Aman season is negligible in comparison with the Boro season, the impact was found to be very low.

Farmers usually try to grow more food to ensure their food security. In this case, they always try to use agricultural input like pesticides and fertilizer as much as possible and do not consider the effect of this use on environment. However, the farmers are willing to accept those techniques which will reduce their production cost as well as ensure better yield. By taking appropriate initiative to make the farmers understand about the economic benefits of using Integrated Pest Management (IPM), the farmers may start using IPM techniques. Chemical pesticides never bring good to farmers. It decreases the pest resistancy of the crops but increases the resistancy of pest. It was found in the study that it became hard to control the old pests by using pesticides. Use of pesticides is also not economical. It increases the production cost of the famers because for the use of pesticides. the productivity of field decreases gradually and more fertilizers are needed to get expected production. The use of pesticides hampers the activities of soil microbes, so decomposition of organic matter cannot be done smoothly in the field.

There is a number of traditional pest management systems which were found to used in the Arial Beel area. Some farmers were found to use neem plant extraction for pest management in the vegetative stage of rice. They prepare the neem extraction by boiling the old leaves with water and then by filtering the solution. Some farmers were also found to use some bamboo sticks in their fields to support the birds to sit in the fields. These birds consume the larvae of pests and control the pests. Some farmers were found to collect the pest larvae by net to damage those. It appears that, the components of IPM are not new concepts to the beel people rather they do not know the name only. Some important components of IPM which were described in this study are: development of bio or harval pesticides, adjustment of timing of application of pesticides with rainfall, control of active ingredient in formulated pesticides, etc. The total sequences of IPM implementation were described as a three step IPM guideline. A stepwise implementation of such guideline could be very useful for sustainable pest management in the beel area.

Chapter VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the findings of the present study, the following conclusions are drawn:

- The farmers of the Arial beel used a number of pesticides for management of rice pests. Most of the farmers (44%) used Basudin (a carbamate pesticide) and a significant fraction of farmers (15%) used Furadan (an organophosphate pesticide). Other pesticides, which were frequently used by the farmers, are Ripcord, Sevin, Malathion and Sumithion.
- Almost all of the pesticides used by the farmers during the Boro season have very high to medium impacts on the indicator species such as catfish, daphnia, algae and rat. However, two widely used pesticides (Basudin and Furandan) have very high and high impacts, respectively, on the ecological indicators.
- Qualitative assessment revealed that Basudin has the highest impacts score of 4.5 which means that if the first rainfall occurs within 7 days of application of this pesticide, 75% of the indicator species will be affected.
- The cumulative impact score for all of the pesticides used by the farmers in the Arial Beel is found to be 3.03 which indicate that approximately 50% of the total ecological resources will be degraded if time interval between the application of pesticides and the first rainfall is less than 13.5 days.
- A ranking of pesticides was done on the basis of impacts found in the study. Based on the severity of impacts, the pesticides can be ranked as: Basudin> Furadan> Ripcord> Sevin> Malathion >Sumithion.
- The impacts of pesticide in Aman season were comparatively very low and it was found that in Aman season pesticides were used only in the catchments of those ponds which were located in relatively higher topography.
- As much as 36% of the total farmers think that Integrated Pest Management (IPM) technique is the most suitable pest management technique.

- If Boro season of the Arial Beel area can be started 10 days earlier, substantial protection of ecological resources can be ensured by minimizing rainfall induced migration of pesticides from rice fields to ponds.
- Farmers' suggestions regarding the implementation of IPM techniques in the beel area are to organize training for farmers on IPM.
- Government and non-government organizations can take projects in the beel area to create awareness on harmful impacts of pesticides on environment and to train the farmers about various technical sides of IPM.

6.2 Recommendations

From the findings of the present study following recommendations can be proposed:

- Government should take necessary measures to ban the ecologically hazardous pesticides as well as legal action should be taken to control the import, supply and use of unauthorized pesticides in the country.
- For popularizing IPM techniques at farmers' level, government and non-government organization should take initiatives.
- Local agricultural office should help the farmers to find the right time for pesticide application to minimize the off site impacts.
- Before importing of a pesticide in the country, government authority should assess the possible impacts of that pesticide on ecology and farmers' health.
- In this study impact assessment was based on the use of a liner model PIRI, developed by CSIRO, Land and Water, Australia. Many data required in the model were available from the secondary sources. No direct measurements of pesticide residues in the pond water were made due to budgetary and laboratory constraints. In future, further application of the model can be made suing more primary data.

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