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Economic Evaluation of Pesticide Use Externalities in the Cotton Zones of Punjab, Pakistan

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I. INTRODUCTION

At the inception of Pakistan in 1947, there was practically no plant protection service in the country and economic soundness of plant protection measures was not even realized for a long time. The use of chemicals as preventive measures to reduce losses by insects and diseases was almost non-existent during 1960s. However, the “grow more” pressure rendered the traditional methods insufficient, to control the ever increasing pest problem from 1970s onwards. Consumption of pesticides in Pakistan has increased from 665 metric tonnes (MT) in 1980 (when subsidy was withdrawn) to 69897 MT in 2002. This colossal increase in pesticide consumption has not led necessarily to an increase in the yield of crops, as demonstrated by Poswal and Williamson (1998) and Ahmad and Poswal (2000). This indiscriminate use of pesticides has destroyed the bio-control agents in the agro-ecosystems and the populations of natural enemies of the insects and pests have declined up to 90 percent during the last decade (of the past century) especially, in cotton growing areas of the country [Hasnain (1999)].

The farmers are mainly concerned about the private cost of pesticide they have to incur to achieve desirable outputs and are least concerned about the undesirable by-products of their production processes. The pressure to maximize output is enormous especially, on low-income resource-poor small farms and the tenants. They have little

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concern for degradation of natural resources, health risks, and future productivity. It is presumed that social cost is not currently being accounted for in the prices of pesticides and as a consequence current level of pesticide use is excessive. In the past, the divergence between the private and social costs of pesticide use has been overlooked to a criminal extent and little efforts have been undertaken by the government to internalize the externalities involved. This unplanned use of chemicals has resulted in environmental pollution and sub-optimal economic returns to the society on the costly investments. Despite a rapid increase in the use of pesticides especially on cotton crop, the dominant sub-sector of Pakistan's agriculture, little research is conducted to evaluate the productivity of pesticide use or to analyze their possible adverse effects on the natural resource base of the country.

The studies conducted at the international arena have shown massive external costs, associated with the use of pesticides in agriculture, to the respective societies. Pimental, *et al.* (1992) estimated that the external cost of pesticide use for the USA amounted to \$8 billion per annum. A second attempt was made by Steiner, *et al.* (1995) who estimated a cost of externalities of the order of \$1.3 billion to \$3.6 billion for the USA economy. This was two to three time less than the externality cost estimated by Pimental and his colleagues. Waibel, *et al.* (1999) estimated an external cost of pesticide use amounting to at least 252 million DM per year for Ex Federal State of Germany. This cost accounted for 23 percent of the respective private cost actually paid by the producers.

These external costs are not paid for the impairment of health among pesticide users, reduction in biodiversity, ground water contamination, residues in food items, and so on. These costs need to be internalized by making all the stakeholders to consider it into their accounts. This study attempts at highlighting the external costs associated with pesticide use in Pakistan and to suggest appropriate guidelines for regulating the safe use of pesticides in the country. The externalities assessed in this study arise from the routine and legal use of pesticides on cotton crop in Multan and Bahawalpur, the two main cotton-producing divisions of Punjab. The estimates include the quantitative extent of adverse impacts of pesticide on human health, natural resources, food chain, production losses, and domestic animal poisoning.

II. DATA SOURCES AND METHODOLOGY

Data

Formal survey and case study methodologies were used to collect evidence on pesticide applicators' poisoning, health hazards to domestic animals, loss of biodiversity, production losses due to pest resistance, loss in wild honeybee colonies and production

loss due to reduction in pollinators. Pesticide-associated poisoning in animals and human was further substantiated through collecting evidence from local veterinary clinics and human health dispensaries and hospitals. The surveys and scientific case studies provided sufficient base to estimate external cost of pesticide in monetary terms. The secondary data from national statistics and information collected from research and extension system were used to aggregate findings of case and scientific studies.

The study also used the results of lab analyses of blood and food constituents and the cross-section information collected from pesticide dealers, manufacturers, laborers and market intermediaries. The yearly statistical books were consulted for area and production of cotton crop, vegetable crops, livestock census, and pesticide use overtime. The experimental data collected from the provincial and central cotton research institutes were used to estimate production losses that ensue due to pest problems. The vegetable market intermediaries were contacted to collect data on seasonal supplies and price variability of locally produced vegetables.

Analytical Framework

The external costs are categorized as actual and potential costs in terms of damage costs or damage abatement costs respectively Table 1. The potential costs include costs of establishment of laboratories for pesticide residue analyses, residue monitoring programmes, and training programmes on the safe use of pesticides. The loss of biodiversity, pest resistance, fatalities (animal, human, honeybee as pollinator, and birds) are the instances of actual cost born by the society. The assessment of the actual and potential external costs was required to specifically design the corrective measures in accordance to the pesticide use level and its relative impact on health, pest resistance and environment.

The procedure of the study is based on the methodology developed by the Hannover University Pesticide Policy Project (HU-PPP), which has been tested before in several countries in Asia, Africa and Latin America. The HU-PPP concept for policy analysis in crop protection has been widely recognized and is now being used by international and bilateral donor agencies.

Different economic evaluation techniques like market price and contingent evaluation approaches were used to reach at the reliable results. The scientific evidence based on lab analyses was accumulated on health hazards to women cotton pickers, contamination of food products (vegetables, fruits, edible oil and animal milk) and natural resources (soil and water). The results synthesized in this study include occupational poisoning, food residues, drinking water contamination, pest resistance, loss of bio-diversity, cost of prevention and abatement measures, and the cost of

awareness campaign.

Table 1

Damage Costs and Damage Abatement Costs Estimated in Different Areas

Externality Area/Category	Damage Cost	Damage Abatement Cost
1. Human Health		
Occupational Poisoning		
Pesticide Applicators	Fatalities, Treatment Cost	Blood Samples Monitoring Cost, Awareness Campaigns, Workdays loss
Women Cotton Pickers	Treatment Cost	Blood Samples Monitoring Cost, Awareness Campaigns, Workdays loss
Industrial Workers, Distribution, Storage and Disposal	Acute/minor ailment cost, Treatment Cost, Environmental Degradation	Blood Samples Monitoring Cost, Awareness Campaigns, Implementation of Safety Regulations, Workdays Loss
Pesticide Residues		
<i>Kharif</i> Vegetables	Potential Externality for Rejected Outputs	Residue Monitoring, Implementation of Regulations
Irrigation and Drinking-water	Contamination of Underground Water Resources	Residue Monitoring, Opportunity Cost to get Clean Water
Cottonseed-oil and Cottonseed- cake	Rejection of Contaminated Cottonseed oil and cake	Residue Monitoring, Awareness cost
2. Production Externalities		
Pest Resistance	Yield Loss	Research and Extension, more Pesticide use cost
Domestic Animal Poisoning	Production Loss, Mortality and Treatment Cost	Separate Fodder Crops, Awareness cost
Wild Honeybee Loss	Loss of Honey and Yield Loss Due to Pollinator Loss	Research to Prove and Prevent Honey Bee Losses
3. Environmental Externalities		
Wildlife and Birds	Loss of useful Misesects and birds Fauna	Ecosystem Analyses to Restore Natural Balance
Loss in Bio-diversity	Stagnating or Declining Productivity	Ecosystem Analyses to Restore Natural Balance, Increased Pesticide Use
4. Health/Environmental Monitoring		
	Health and Environmental Damages	Establishment of Regular residue Monitoring System
5. Public Awareness		
	Complexity to Develop General	Campaigns on Safe and

Campaigns**Recommendations****Judicious use of Pesticides**

The evidence on known (workdays loss, treatment cost, human and animal fatalities and pollination losses etc.); probable (rejection of contaminated products like fruits, vegetables, cottonseed oil, drinking water, loss of wildlife, birds and beneficial insects etc.); and possible external costs (monitoring, analyses, and mass media costs, etc.) were collected from the sample locations in the cotton growing divisions¹ of Multan and Bahawalpur.

III. RESULTS AND DISCUSSION

The plant protection measures in Pakistan at present are mostly limited to the use of pesticides and collectively 83 percent of the pesticides are used to control insects, pests and diseases of cotton, rice and sugarcane. In cotton production, which accounts for about 54 percent of the pesticide quantity, the indiscriminate use has provoked the development of resistance in insects/pests and the outbreak of secondary pests. This has resulted in high crop protection costs and declining cotton yields. The average number of insecticide applications on cotton increased significantly in 1990s (Figure 1).

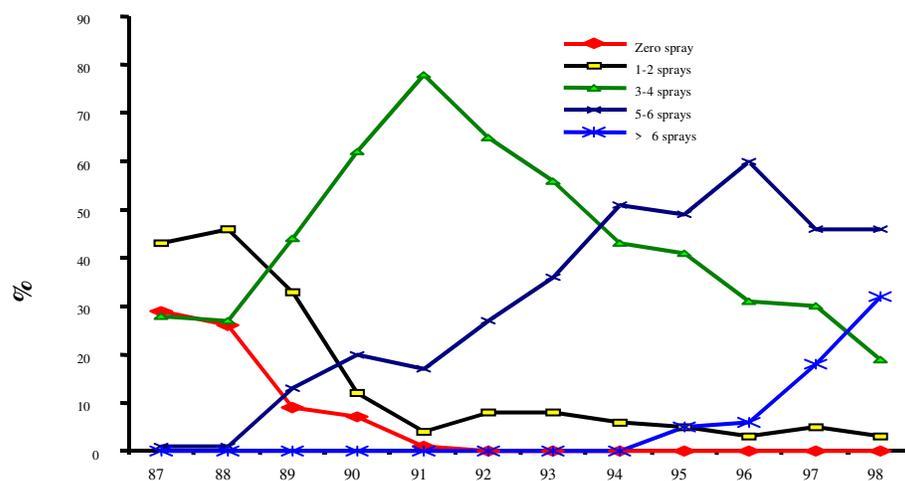


Fig. 1. Percent Cotton Growers Using Different Number of

¹The external costs were confined to the sample divisions, because: (a) these represent intensively managed 80 percent of the total cotton acreage of the Punjab; and (b) intensity of pesticide use was higher in these regions as compared with that in rest of the 20 percent cotton planted in the diversified agro-ecologies.

Sprays Over Time.

The majority of the farmers were using a minimal level of zero or 1-2 sprays during 1988 or earlier. This proportion declined considerably by 1991-92 and the percentage of cotton growers applying 3-4 sprays in a season attained its peak during 1991 and then switched over even to a higher number of 5-6 sprays in a season. The most of the cotton growers were applying six sprays to their cotton crop during 1996. In the past few years, a greater number of growers have moved towards 7 to 11 sprays. The increase in number of sprays was not mainly for yield improvements, but to avoid crop damages—mainly accruing due to the massive pest buildup and development of resistance in pests.

Besides development of resistance in insects and pests, the indiscriminate use of pesticides has also destroyed the bio-control agents in our agro-ecosystems. In fact, increased pesticide consumption has not led to increase in yields in all cases, particularly in cotton. Almost three-fold increase in pesticide consumption is observed at the expense of disproportionate improvements in the yield of cotton crop, which has consumed lion's share of pesticides (Figure 2).

The case study results demonstrated that there is a great potential for reducing over use of pesticide on cotton in Pakistan because the least efficient farmers achieve the same cotton yield while spending 70 percent more on pesticides than the best of their counterparts. It seems that an ample scope exists for encouraging a more efficient pesticide use without inflicting any economic injury to the farmers. For example, by applying an input charge (which would recover the implicit subsidies and signal the real costs of the inputs to the users) accompanied by appropriate

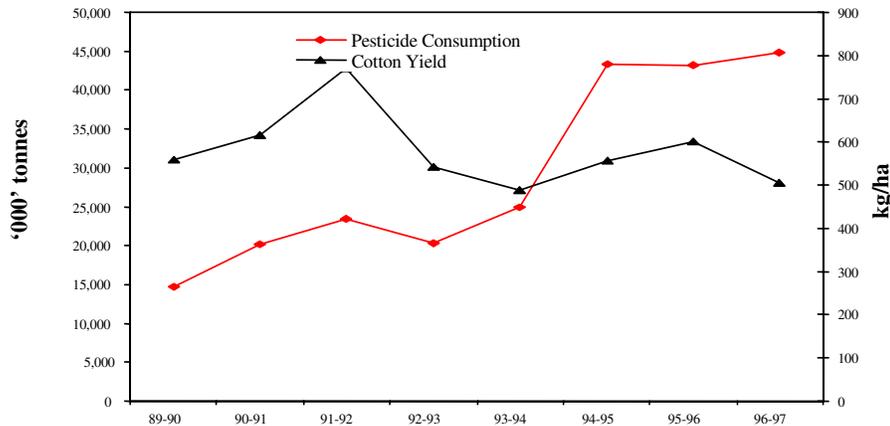


Fig. 2. Pesticide Consumption and Cotton Production.

changes in the pesticide regulatory policy.

Initially, in the 1950s pesticides were used for the first time to combat the attacks of locust. In 1954, the government imported formulated pesticides amounting to 254 metric tonnes. This was the beginning of the pesticides business in the country. Until 1980, Plant Protection Department was responsible for pesticide import and its distribution in the country through national agricultural extension network. Most of the pesticide imports were for aerial spray to control locust, pests of sugarcane, cotton, rice, tobacco, and fruit crops. The pesticides were subsidized and aerial spraying was free of cost. Thereafter, the government started to charge nominal cost of pesticides from farmers, which was then extended up to 25 percent recovery of the total pesticide application cost. The subsidy on pesticides was totally abolished during 1980 and 1982 in Punjab and Sindh, respectively.

Pakistan's crop protection policy has been focused on safeguarding the supply of affordable pesticides while maintaining standards for product registration according to internationally accepted norms. Beginning in 1980, pesticide distribution was shifted entirely from the government to the private sector. A policy for stimulating local formulation of pesticide products has been in place. The registration scheme was deregulated in 1993 to facilitate imports of generic compounds already registered under trade names and imports of pesticides that are registered and used in OECD countries or China.

The majority of pesticide products are now imported under the generics and import permission scheme as opposed to trade name registration. The Regulations for distribution, storage, use and disposal have been promulgated, but generally lack enforcement. The pesticide product quality problems and adulteration reportedly has increased after the introduction of the generic scheme. With regard to monitoring of residues in food, drinking water and the environment, a comprehensive national monitoring system is still missing.

Externalities of Pesticide Use

The environmental and social cost of pesticide use to the nation amounted to 11941 million rupees per year (Table 2). The bulk of the cost is caused through production losses due to resistance development in cotton pests and damages to domestic animals, followed by damage to human health, loss of biodiversity and monitoring costs of residues in food chain. The costs of monitoring through residue analysis and implementation of pesticide use regulations belong to the damage prevention costs.

Human Health Costs

More than one quarter of the farmers did not show much consciousness in observing basic precautions during spraying operations. The pesticide-related

Table 2

External Cost of Pesticide Use in the Major Cotton Growing Areas of Punjab

Types of External Cost	Effects Identified	Value (Million Rs)
1. Human Health		
Occupational Poisoning		
Pesticide Applicators	Fatalities, Treatment Cost, Workdays Loss	266.70
Women Cotton Pickers	Treatment Cost, Workdays Loss	765.00
Industrial Workers	Acute/Minor Ailment Cost	0.64
Distribution, Storage and Disposal	Environmental/Health Problems	NQ ^a
Pesticide Residues in Food Chain		
<i>Kharif</i> Vegetables	Potential Externality for Rejected Outputs	72.3
Drinking-water	Opportunity Cost of Labor to Get Clean Water	14.3
Cottonseed-oil and Cottonseed-cake	Potential Externality for Rejected Cottonseed-oil and Cake	23.3
2. Production Externalities		
Pest Resistance	Yield Loss and More Pesticide use Cost	5667.0
Domestic Animal Poisoning	Production Loss, Mortality and Treatment Cost	1304.5
Wild Honeybee and Sunflower Production Losses	Loss of Honey and Yield Loss Due to Pollinator Loss	63.2
3. Environmental Externalities		
Wildlife and Birds	Loss of useful Insects and Birds Fauna with Increased use of Pesticide	NQ
Loss in Bio-diversity	Increased Dependence on Pesticide use to get Stagnating or Declining Productivity	3745
4. Health/Environmental		
	Cost of Toxicity Analyses	4.8

Monitoring		
5. Public Awareness Campaigns	Cost of Public Extension Media and NGOs	14.1
Total		11,941

^aNQ= Effects yet not quantified.

illnesses are causing a considerable number of fatalities, treatment costs, and income loss especially, in the poorer sections of the rural communities. Substantial amounts of 24 million in terms of treatment, 18 million for work loss during ailments and 224 million rupees for accidental deaths are estimated as the externality costs. Total health externality of pesticide applicators adds to 267 million rupees leaving aside the partial recovery and long-term consequences to the effected individuals (Table 2).

Most of the cotton pickers were not aware of using caution (such as putting on gloves, wearing shoes and covering face) during picking. Health hazards to women cotton pickers show that about 2.23 million women got sick from their exposure to pesticide used on cotton crop and huge economic losses of 105 million rupees occur due to health treatment costs. The money value of five days work loss of 2.23 million-picker amounts to 660 million rupees that is an external cost to the lowest income strata of society (Table 2). In this way an externality of 765 million rupees is inflicted on women involved in cotton picking on field where pesticide have been applied most extensively.

Tahir, *et al.* (2001) conducted a study in Multan and Bahawalpur divisions to assess the level of poisoning among cotton pickers. The cholinesterase (ChE) activity levels measured in the blood of cotton pickers showed chronic pesticide poisoning. The results of blood analysis given in Table 3 show that the post spray season ChE activity in blood samples of only 10 percent female pickers was found to be in the normal range of 88-100 percent whereas this level was hazardous (00-50 percent) among 42 percent of the pickers.

Table 3

Proportion of Female Pickers by ChE Activity Percentage Groups during Pre-spray and Post-spray Season in 2000

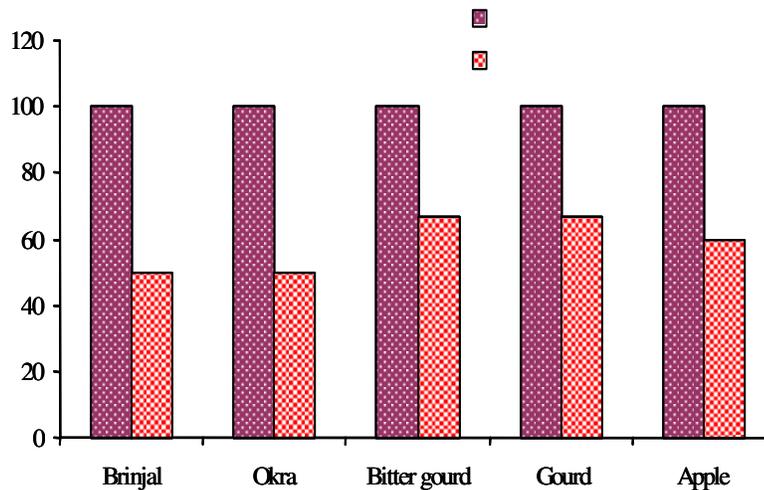
Surveys	Percent Activity of ChE				
	Normal (88–100)	Mild (76–87)	Moderate (65–75)	Considerable (51–64)	Hazards (00–50)
Pre-season	71	15	7	5	2
Post-season	10	16	13	1	42

Out of 1000 labourers working at 25 pesticide plants 500 were reported sick by

inhaling pesticide emissions. The treatment cost for ailments accounted for about 0.1 million in case of minor ailments and 0.45 million rupees for acute poisoning cases.

Pesticide Residues in Food Chain

The residual effect of pesticides applied on crops appears in the food chain. The analysis of samples of food and animal feed products produced in the high pesticide use zones showed that a high proportion of these items contain residues in



excess of standards for marketing and consumption (Figure 3). The presence of residues in food and fiber products is threatening the export opportunities to markets in foreign countries.

All the vegetable samples were found contaminated, out of which 63 percent samples were exceeding MRLs. The 51 percent of the vegetable produce that was found unsuitable for human consumption would account for 9.4 thousands metric tonnes (MT) of kharif vegetables that should either be thrown away or abandoned for human consumption. This could result into an economic loss of 72.3 million rupees if pesticide use on vegetable is not regulated. About 327 thousand MT of edible oil and 2146 thousand MT of oilseed cake produced in the Punjab would need to be abandoned for consumption purposes. The economic value of this externality amounts to 7.23 million for cottonseed oil and 16.1 million rupees for the oilseed cake.

Brinjal Okra Bitter ground Ground Apple

Fig. 3. Status of Pesticide Residues in Vegetables and Fruits during 2000.

Animal and Honeybee Poisoning

The use of pesticide on crops is also resulting in the poisoning of domestic animals through various ways. The common sources of animal poisoning are: (a) feeding fodders carrying sprayed chemicals; (b) chemicals residues in the cotton seed cake; and (c) chemicals residues in the wheat straw. Animal succumbed to acute poisoning if fed accidentally with poisoned fodder. Major consequences of poisoning on animal health include loss in milk productivity (40 percent), loss in vigor (36 percent) and mortality (18 percent). The money value of externality of animal poisoning incidences amounts to 1304 million rupees, when aggregated over the total population of small and large ruminants and poultry birds in the study zone. The increased pesticide use has severely affected the wild honeybee colonies in the area and has deprived the farming communities of sizeable direct and indirect benefits. The direct annual loss of 9.91 million rupees is accrued on account of a loss of 5661 MT of honey. The indirect loss is through probable reduced yield of pollinated crops due to decline in population of the honeybees. There is no scientific evidence available in Pakistan, to directly relate sunflower yield losses to depletion in pollinators' population. Piemetal, *et al.* (1993) estimated honeybees related pollination losses of about 10 percent for pollinated crops. Assuming a conservative 10 percent loss in sunflower production due to reduction in honeybees as pollinator would result in a net annual loss of 6.55 million rupees in the selected 9 districts of the cotton zone.

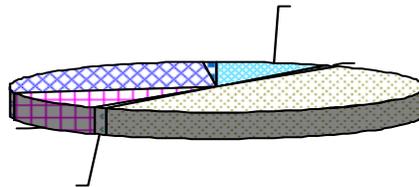
Pest Resistance, Resurgence, and Biodiversity Loss

The greatest concern is now also being shown to the question that how the use of pesticides effect biodiversity. Pearce and Tinch (1998) indicated that yet this is the subject about which least appears to be known. Irshad (1999) has classified a comprehensive review on pest resistance problems in Pakistan. He improved upon his predecessors Matin and Jabbar (1988) and Jabbar (1988), who reported preliminary information on the pest resistance issues. The development of pesticide resistance in pest population is resulting in additional applications of pesticides to maintain the crop yields. This becomes more obvious during pest flare-ups, which cause serious setbacks² to our cotton crop. The additional cost of increased pesticide application, due to pesticide resistance developed in the pests, is about 11000 rupees per hectare. This amounts to 5667 million rupees when extrapolated to 1.7 million

²The farmers of the area reported the occurrence of at least 3 such setbacks to cotton crop during the last decade.

hectares of cotton grown in the study area. Similarly, a loss of 374 million rupees per annum is estimated occurring due the loss of biodiversity resulting from pesticide use.

The structure of external costs of pesticide use in our agricultural production systems is shown in Figure 4. About 49 percent external cost can be attributed to the pest resistance problem, while loss in biodiversity and human and animal health damages respectively accounted for 29 and 20 percent of the total external costs. The



damage prevention cost on residue monitoring and public awareness is less than 2 percent.

This shows that what a meager amount we are spending on damage prevention strategies against the damages caused by pesticide use, human health, animal fatalities, production losses, additional pesticide use, and residues in food chain.

The Cost Benefit Analysis of Pesticide Use

The benefit costs were estimated separately using private costs as well as social costs associated with pesticide use and are reported in Table 4. Potential yield

Fig. 4. Percent Share of Different External Costs in Total Pesticide Use.

conditions. The production loss estimates are based on the results presented in the annual reports (1992-1999) of Central Cotton Research Institute, Multan. About 272 kg per hectare increase in the yield of seed-cotton was estimated with pesticide use. The actual gross benefit of pest control was calculated as 8069 million rupees by multiplying incremental yield with price of seed-cotton (Rs 17.5/kg) and the total cotton area of 9 districts (1.7 million hectare). In order to calculate benefit cost ratio, the private costs of pesticides were added to the producer rent yielding the gross value added from this input

factor.

Table 4

Benefit-cost Ratio of Pesticide Use in the Cotton Zone of Pakistan's Punjab

Total Costs per Year	18611 Million Rupees
Pesticide Costs (Chemical + Spray)	7044 Million Rupees
External Costs	11567 Million Rupees
Benefit	8069 Million Rupees
Benefit-cost Ratio without External Cost	1.14
Benefit-cost Ratio with External Cost	0.43

The social cost (private plus the external cost) resulted into a benefit-cost ratio of about 0.43. This shows that benefit cost ratio of 1.14 reduced significantly when external cost was added in the total cost. However, the ratio of external costs to the private cost of pesticide use is quite high (1.64), which shows other tradeoffs involving environmental quality, irreversible damages to agro-ecosystem and human health problems.

An overall economic evaluation of the externalities of current pesticide use levels show that the external costs are quite higher than the currently paid price at the farm gate level. This means that the true cost of pesticides for the national economy are currently grossly understated since they are more than twice as high as assumed by the participants in the pesticide market. If externalities are incorporated in the market price of pesticide products, there will be an incentive to reduce inefficient use and related external effects, which subsequently benefits the national economy. From a strictly cost benefit approach, it appears that pesticide use is not beneficial (Table 4).

IV. CONCLUSIONS AND RECOMMENDATIONS

The present study conducted in the cotton growing belt of Pakistan provide evidence which shows significant impacts of pesticides on society and strongly recommends the promotion of precautionary approaches towards the use of pesticides in agriculture. The reduced reliance on crop protection products seems inevitable for sustainable and healthy crop production. The basic structure of the external costs of pesticide use established in this study help to draw important conclusion to introduce economic instrument for regulating the pesticide use.

Imposition of access on import of pesticides and raw materials is recommended for investment of the proceeds in health care, residue monitoring, research and extension. The emphasis needs now to be shifted from sheer plant

protection to total crop management for sustainable and healthy crop production. Similarly, other steps to discourage cheap availability of pesticide to users and strict enforcement of regulatory measures are also suggested. The major future strategy components to promote rational use of pesticides are given here as under.

Policy Regulations

The government of Pakistan should review mechanism for the enforcement of existing legislation in pesticide for import, registration, formulation, distribution, advertising, usage and disposal. The legislation should be amended in cases where human health and the environment are endangered to an un-necessarily high degree. Proper taxing of pesticides is required as an instrument of Integrated Pest Management (IPM) policy. The financing of monitoring and control may be assured by a targeted cess on pesticide products. The government should be giving increased emphasis to provide an incentive system including the use of economic instruments in reducing uneconomic pesticide use and promotion of market mechanisms for the production of food and fiber with reduced pesticide use and safety measures or risk reduction.

Public Awareness on True Cost of Pesticide Use

The true costs including external costs of pesticides must be made explicit to everybody for the benefit of the common people and the economy. Hiding such information will cause unnecessary risks for the Pakistani people and endanger the competitiveness of Pakistan's exports in the international markets.

Institutional Reforms

The government of Pakistan may create an enabling environment for transforming the existing pesticide market into a market for crop protection information. In this regard the role of extension staff and NGOs in farm level extension work has to be strengthened. The government should set targets for environmental quality and human health related to pesticides use in collaboration with ministries of Agriculture, Environment, and Health. A proper national monitoring and surveillance system also needs to be established.

Capacity Building

The government should support capacity building in economic analyses of pesticide use and assessment of externalities. IPM may be taken as a farming system approach rather than a commodity approach. Instead of having a centralized research

system, IPM research should agree on a common ecological framework in support of local decision-making. The national IPM Programme (Nat-IPM) may be strengthened. Substantial increases in the allocation of financial resources to promote IPM methods in crop protection need immediate attention at planning and policy levels. Implementation of farmer-led IPM approach could help in achieving the production, income, health, environment, and equity goals.

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