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Review

Pesticide use in agriculture: The philosophy, complexities and opportunities

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Exaggerated and incompetent use of chemical pesticides in crop production can have adverse effects on human health, natural ecosystems and social capital. The potential impacts are interconnected and complicated, so the current scientific knowledge base of its understanding seems to be imperfect, and the degree of impacts could be much more; therefore the rationality of pesticide use in agriculture ought to be redefined. The paper highlights how disciplinary sciences professed and interpreted multifaceted impacts of pesticide use over time and it explores the opportunities arising from the complexities of such impacts. The opportunity is explored for Nepal as an example.

Key words: Pesticides, health and environmental impacts, complexities, interconnectedness, interdisciplinary, Nepal.

INTRODUCTION

Pesticides are chemical substances used to control harmful organisms. Its use in agriculture can adversely affect human health, environment and eco-systems. Globally, agriculture sector consumes significant amount of pesticides – approximately 85 percent of the estimated 2.9 million tones used each year (Raven et al., 2008). Pesticide use is increasing worldwide, and at a rapid rate in developing countries. The developing nations utilize only 20% of world total pesticides applied. Despite increasing application of tons of pesticides worldwide, more than 40% of all potential food production and another 20% of the harvested crop is lost to pests (Paoletti and Pimentel, 2000). For example, a 33-fold increase in pesticide use in the United States since the 1940s, crop lost due to pest have not changed significantly (Raven et al., 2008). Only a small amount of the applied pesticide actually reaches the intended target organism and the vast majority ends up elsewhere in the environ-ment (Pimentel, 2005; Pimentel and Burgess, 2012). Less than one percent of pesticides applied to the agriculture reach their target pests, and more than 99% of it adversely affects unintended targets including the public and environmental health (Pimentel, 2005). And pesticides pollute environment and ecosystems and marginalize human populace thus its use and sale is under strict control in many developed countries.

In developing countries, the mechanism for controlling pesticide use and sale are rudimentary because of many reasons. Consequently, pesticide users in developing countries, especially agricultural workers or farmers, are significantly exposed to different kinds of pesticide risks. The magnitude of exposure and associated risks for farmers in developing countries are supposed to be high. But farmers have been using such toxic chemicals in their farm to increase production and to maintain their subsistence for living, and also to increase their income. Ironically, in developing nations, farmers are under increasing pressure to use such toxic chemicals because of various social, economical, political and psychological factors. For example, subsidies in chemicals, lack of alternatives to pesticides, week enforcement of laws and regulations, low levels of education and awareness, and ease in availability are the drivers for using pesticides. Whatsoever the factors exacerbating the pesticide use in developing countries, it is well known that it’s exaggerated and incompetent use have negative impacts to human

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and ecosystems health. The areas where pesticides have negative impacts are diverse and complex. For example, bioaccumulation, biomagnifi-cations, pest resistance and resurgence (Raven et al., 2008) are the hotly discussed and threat to the human society. In addition, dumping of un-used and date-expired highly toxic chemicals into soil is also a major threat to human society (WHO, 2007). Further, few linkages among pesticide use, arctic degradation, international transport, and climate change are the newly born issues. Marla Cone's *Silent Snow* (Cone, 2006) illustrated how such dangerous chemicals are being carried to the Arctic by winds and waves. There are also probable linkages between long-term pesticide exposure and human health problems like neurological effects, endocrine disruption, reproductive health and cancer (EPA, 1999).

The current scientific knowledge on these impacts seems to be imperfect, often estimated and interpreted by a single disciplinary science, and could be much more than we believe today; therefore the rationality of its use in agricultural production ought to be redefined. The main objective of the paper is to highlight how the use of pesticides is perceived and interpreted over time and to make aware scientific communities of the opportunities arise from the complexities of such impacts.

The philosophy of pesticide impacts

Scientific enquiry into a specific subject is not merely for gaining knowledge, but also to transfer new knowledge into practical actions for the improvement of human well-being. However, while doing so, this endeavor pre-supposes knowledge of the appropriate conceptual framework, which, if originally defective will cause a malfunctioning of the system, impacting negatively on the science and the scientific knowledge (Chalmers, 1999). This is what has been observed for the pesticides knowledge. Until the early 1960s, the scientific com-munity and general public operated on the belief that pesticide use revolutionized food production and human development. They had a uniform understanding of the consequences of pesticide use to humankind, focused only on the positive aspects. The human perception, understanding, and the approach to pesticide science, as well as, methods for problem solving, instruments and techniques were all framed on the positive aspects of pesticides. However, when the book *Silent Spring* (Carson, 1962) was published, a revolutionary shift on human thinking from the benefits of pesticides to its negative consequences occurred. This new thinking was supposed to minimize pesticide use in agriculture, but in reality it did not, because shortly after, there was also a shift in agricultural practices from 'primitive' to the so-called 'green revolution'. This transformation of agri-cultural practices led further increased use of pesticides, in response to increased population growth, poverty and global demand for food, without regard for its negative externalities. The technology based 'green revolution' demands high inputs and cash investment, and also pollutes the environment and, thus, appears unsustainable for future agriculture (Wilson and Tisdell, 2001). Actually, the original paradigm of the green revolu-tion was intended to generate positive consequences like increased productivity, economy and sustainability. But now many scientists have come to the conclusion that the green revolution technology, including pesticides, has negative consequences for the environment and hence, its proper management has become a bigger challenge for maintaining human and ecosystem health, having major implications for survival and quality of life.

From the 1960s to about 1990, there were many competing theories for and against pesticide use. No single theory was widely accepted during that period, indicating a condition of turmoil. During the 1990s, a school of thought emerged with the widely accepted hypothesis that pesticide use in crop cultivation has mainly two explicit effects. The first is an income gain in the short term. The second is the negative impacts on human and ecosystem health. From 1990 to present, thousands of articles supporting a variety of aspects of the pesticide science according the established rules are available in the peer-reviewed journals, books and other literature. Most of the published articles have either supported beneficial effects of pesticides (Cooper and Dobson, 2007) like income gain, or highlighted its negative effects like environmental pollution and human health problems. In 1994, a small group of scientists proposed a new hypothesis for pesticide use that entails overall lower returns to human (Antle and Pingali, 1994; Pingali et al., 1994) in a long term. Despite much literature in favor of this hypothesis, the larger scientific community and private sector are not in favour of accepting the real consequences of pesticide use for human society. The debates are further confounded due to the as yet incomplete scientific understanding of long-term pesticide exposure on human as well as ecosystem health. Looking at the advancement of knowledge of pesticides it can be concluded that at earlier stages, pesticides were observed to be affecting only a single discipline, for example agriculture and consequent crop production. Later on, human society believed that pesticides not only do benefits but also cause negative consequences to their health. At later stage, or say currently, the use of pesticides is believed to cause multiple consequences on social health, environment and ecosystems.

Figure 1 helps to perceive changing knowledge of pesticide use with time. Its interpretation with time depends on the analytical framework of the scientific communities. The initial set of hypotheses (A_1, A_2, . .) made in the past are replaced by new ones, which result in the stepwise development of the pesticides science. Although it is not possible to claim that hypothesis or

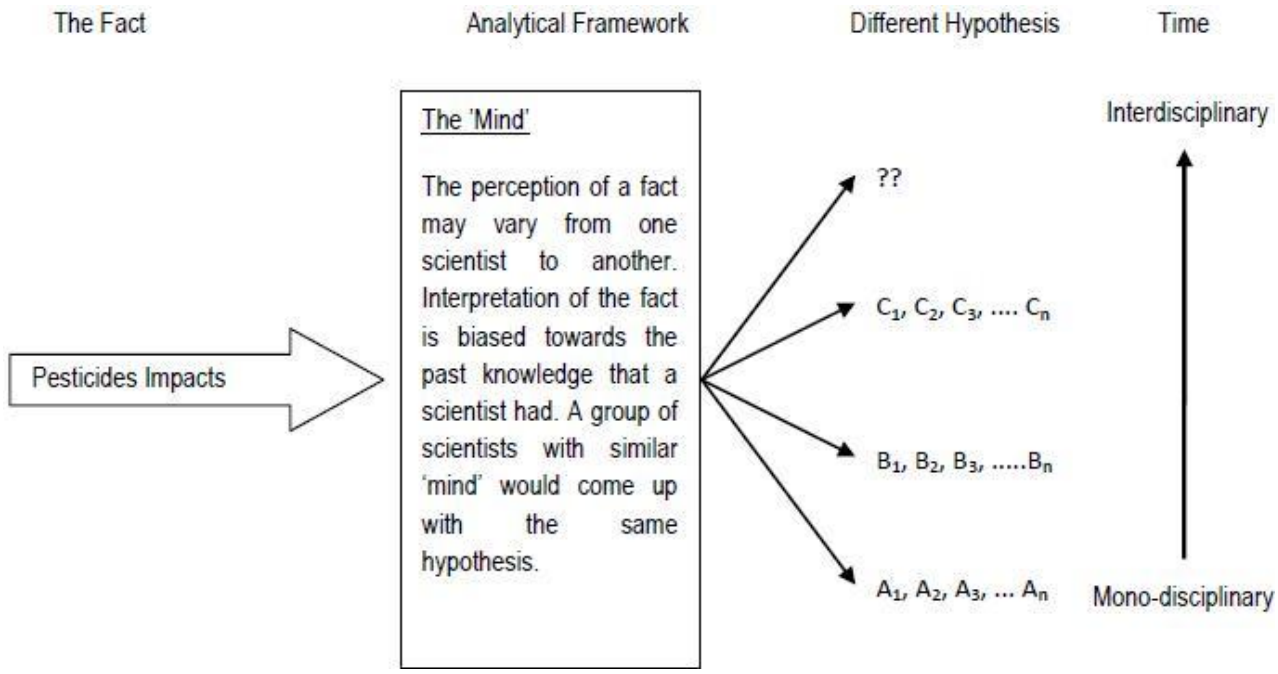

Figure 1. Interpretations of pesticide impacts depend on the analytical framework of the scientific communities and over time changing from mono-disciplinary to interdisciplinary sciences.

theory relating to pesticide use is entirely true, it is plausible to say, for example, that the set of hypotheses (C_1, C_2 . . .) in Figure 1, are closer to the truth than the previous sets (B_1, B_2, . . .) and (A_1, A_2, . . .) and as yet the set C has not been disproved based on the existing knowledge and understanding, but may be replaced in the future.

The hypotheses set C can be considered to be the best based on the current 'mind' on pesticide science, but is not the absolute truth regarding pesticide use because the 'mind' could interpret facts based on different framework in future. The 'fact' is basically constant, but our knowledge and understanding changes due to the changing 'mind', thus the dynamic nature of our 'mind' with reference to perceptions and interpretation of the facts in light of new information will enhance the pesticide knowledge. A chapter of a book (Pimentel and Lehman, 1993) entitled "*The Benefits and Risks of Pesticides: Two Views"* illustrate, for example, how a single fact is interpreted by an industrialist and environmentalist. An industrialist suggests more research on the benefits of pesticides while an environmentalist suggests just opposite. But both realize positive and negative multiple effects of pesticides. And the understandings on the pesticide impacts are shifting from single disciplinary science to multidisciplinary and interdisciplinary. Reali-zation of the multiple impacts of pesticide use either by an 'industrialist' or an 'environmentalist' not only esta-blished the interconnectedness and complexities of such impacts into their own defined disciplinary sciences, but also expanded an opportunity for these individual to scientific inquiry into its possible solutions.

The complexity - an opportunity for scientific inquiry

Use of chemical pesticides not only increases crop production and income but also negatively affects human health, pollute soil, water, air; and ultimately the ecosystems as a whole may be collapsed. Although, at the outset, the use of pesticides was believed to be beneficial for human society, it has now become amply evident that this technology may be more of a curse than a boon. The road we passed through was initially attractive (income gain for example) but it appears to be disaster in a long run. It can, some ways, be compared with the invention of nuclear weapons. Despite many positive uses of nuclear power, the two atom bombs detonated in Japan, at the end of the World War II, resulted in the immediate deaths of around 120 thousand people and eventually countless others, had been developed using the same as researched for nuclear energy production. The point here is neither to equate pesticides with nuclear weapons, nor to discount the value of nuclear power, but to illustrate that just as human still suffer from the long-term effects of radiation, agrarian societies that applied persistent chemical pesticides like DDT and BHC in the past, will continue to face health problems from exposure through conta-

minated soil, water and air. The World Health Organization

(WHO) of the United Nations has estimated that use of pesticides cause 3 million poisonings and 220 thousand deaths and about 750 thousand chronic illnesses every year worldwide (WHO, 2006).

In long-term, the benefits received by the use of pesticides could outweigh by its impacts. Therefore, pesticide use in agricultural farms cannot be viewed in part, rather should addressed the whole system. So the impacts of pesticide use estimated by the single disciplinary science at different levels are minimal and underestimated because they seldom incorporate the whole system approach. Many scientists and scholars (not all) are still working with its own defined field not even interested or willing to see how things interact in a system. It seems that the traditional structures make it hard for researchers to be interdisciplinary and much easier for people to get published in traditional disciplinary settings. However, the use of pesticides in agriculture could be a complex example where scientists may begin to look beyond their boundaries of their own disciplines and try to understand what they are seeing and experiencing. These people will find new ways of thinking and new methodological approaches to gain a better understanding of the pesticide use. As a result, much literature will be emerged in favor of inter-disciplinary science (or whole system approach) for dealing with pesticide dilemma. This is an opportunity for the current scientific world. Integration of knowledge for a complex phenomenon requires close collaboration among scholars from different disciplines. Identifying the full impacts of pesticide use on both physical and biological interacting factors is much more complicated, probably not possible with the current ‘mind’, thusthere is an opportunity to our ‘mind’ to rethink on the possible methodologies for identifying impacts. For this, (re)examination of the pesticide issues in the broader context of social, environmental, and ecological implications in alliance with many disciplinary sciences and in conjunction with local stakeholders is recommended.

Exploring opportunity- an example of Nepal

At national level, pesticides import substantially increasing in 2007 and 2008, following a general trend of decline since 2002 (Figure 2). According to the Central Bureau of Statistics (CBS, 2003), 25% of Terai land holdings use chemical pesticides, 7% of Mountain, and 9% of Mid-hills. There has been a clear trend towards the increased use of chemical pesticides, especially in semi-rural and peri-urban areas that have easy access to urban markets where a high demand for vegetables, fruits and other fresh produce exists year-round. Chemicals are readily available in the local markets now-a-days. The initial use of chemicals by a few progressive farmers has increased pressure for other farmers to also use them. Generally, pesticides in Nepal are used to control pests such as brown plant hopper, fruit flies and diseases like late blight of potato and tomato. High rates of pesticides are applied to cash crops such as potato, tomato and other vegetables. In Nepal, many studies claimed intensive use of pesticide in the market-oriented agricultural production areas with minimal pesticide use hygiene and safety precaution, but very few of them assessed the health and environmental impacts of its use. The scientific studies on pesticide use and farmers' and environmental health in Nepal are extremely few. Why? It is not an easy task to perform a good scientific study by a single ‘actor’ taking the multitude of nteracting factors, for example, health, environment, ecosystems etc. Either different areas of knowledge required for the ‘actor’ or a close collaboration among different disci-plinary ‘actors’ is needed. Both are very rare in Nepal. Neither the university degree has an interdisciplinary approach of study, nor institutional collaborations among universities, departments, (I) NGOs, etc. along with local stakeholders are established for handling such complicated problems.

Nepal Agricultural Research Council (NARC), an apex body for agricultural research in the country with ultimate goal of poverty alleviation with sustainable growth of agriculture production is still working itself on its pre-defined traditional working fields like pathology, ento-mology, soil, agronomy; there is possibility to establish new field of study to include such externalities with other disciplinary sciences. Similarly universities are delivering the same traditional disciplinary sciences over significant time. Some of the world’s universities have undergone departmental restructuring to promote interdisciplinary research and collaboration (Lok, 2008), but in Nepal no such interdisciplinary department found at Institute of Agriculture and Animal Science (http://www.iaas.edu.np/departments/index.htm) of the Tribhuvan University and Kathmandu University (http://www.ku.edu.np/departments.php) among many others. Districts agricultural offices under the Department of Agriculture control and manage pesticides issues at local levels. These district level staffs manage and report on the integrated pest management (IPM) an approach to minimize pesticide use and a complex in its nature with multiple benefits without taking care of other disciplinary individuals or public-private partnership for research and extension. In other countries, applications of IPM reduced pesticide use without reducing grain yields. For example, Peshin et al. (2009) documented a reduction in pesticide use by 68% and public health poisonings by 77% in Sweden. In Indonesia, pesticide use was reduced by 65% and increased rice yields by 12% (Oka, 1991). For Nepal, district level staffs manage and report on IPM. Therefore, a revision of the current structure of the IPM research and reporting is warranted with a clear responsibility of a collaborative institutions of the con-cerned disciplines.

The point here is neither to discount these institutions

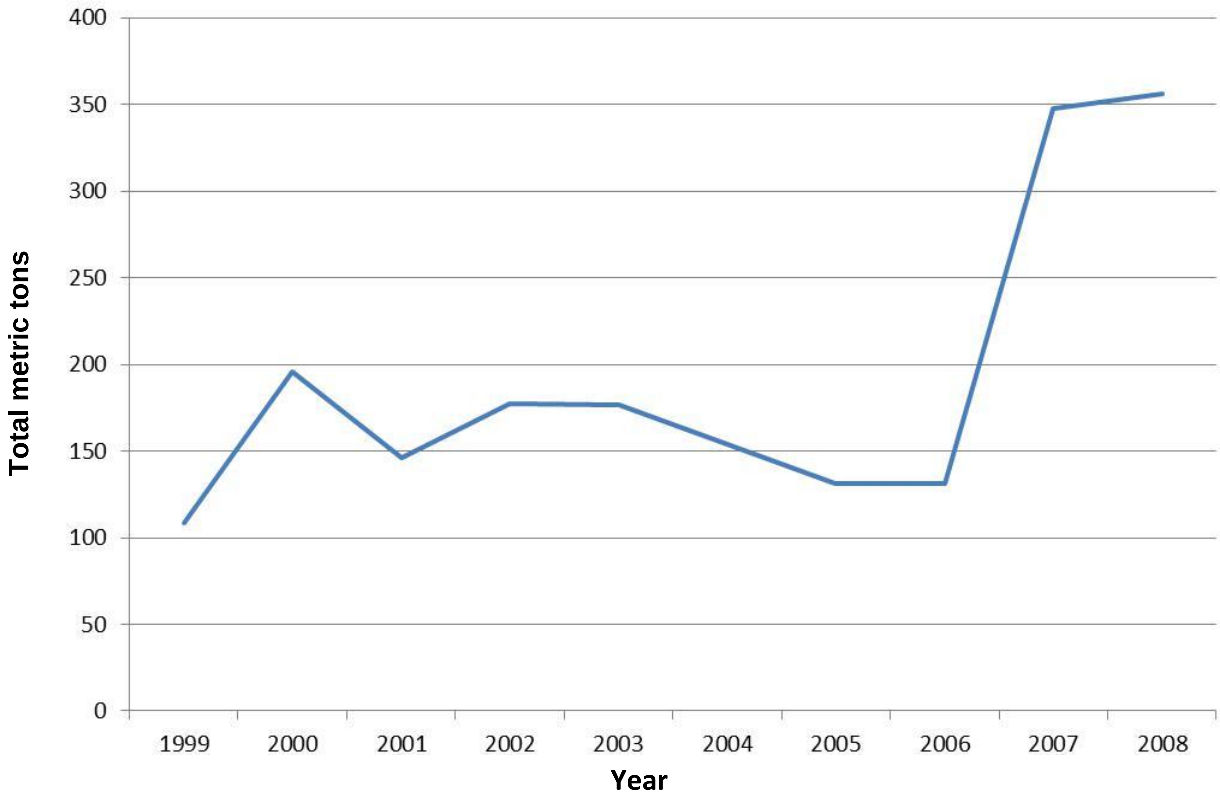

Figure 2. Total metric tons of pesticide's active ingredients import in Nepal during 1999 to 2008.

in their capabilities nor to disqualify their mono-disciplinary functions, rather to suggest incorporation of the global demand of interdisciplinary research and collaboration either by restructuring the present functional mechanisms or by introducing new departments or institutions. Individually these institutions have done number of excellent research in terms of finding impacts and recommending solutions within their disciplinary sciences but no progress be traced for pesticides dilemma because of its multifaceted impacts, and minimal cooperation among different disciplinary individuals/institutions to follow up the recommendations. Therefore, there is a tremendous opportunity to amalgamate these institutions (see Table 1) for studying complex problems like pesticide use, its impacts and management. Adding different ideas from different disciplinary sciences, and sharing knowledge among them is not only a sufficient measure for interdisciplinary approach, rather coming to a consensus through developing a well defined theoretical perspective on the problem analysis (see Table 2) by mutual professional respects and creative 'tension' is warranted.

Because of the complex nature of pesticides impacts, a simple analysis is an insufficient measure of pesticide efficacy. Interdisciplinary holistic systems analyses taking a multitude of interacting factors into account are needed.

CONCLUSION

Single disciplinary sciences seem to have dominated the assessment and evaluation of pesticide use impacts in agriculture. As the pesticides-induced impacts are complex and interconnected in natures, the global know-ledge on pesticides issues over time has been shifting from mono-disciplinary to interdisciplinary sciences. But local efforts to move into new areas of interdisciplinary science are minimal. In Nepal, intensive use of pesticides with minimal hygiene and safety precaution are known but interdisciplinary impacts assessments are extremely few. An alliance with many disciplinary sciences and with local stakeholders either by reorganizing the existing body or by reestablishing new organization/institution is recommended for (re)examine pesticide issues in the broader context of social, environmental, and ecological implications.

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Table 1. The numbers of 'actors' who ought to work together for problem solving.

1. Governmental Departments – Agriculture, Health, Education etc.
2. Universities – Tribhuvan, Kathmandu, Purbanchal, Pokhara etc.
3. Research Organization – Nepal Academy of Science and Technology (NAST), Nepal Agriculture Research Council (NARC), Nepal Health Research Council (NHRC) etc.
4. (International) non-governmental organizations (I) NGOs – WHO, FAO, ICIMOD, IUCN, Li-Bird, CEPREAD, etc.
5. Local stakeholders – Farmers, pesticide dealers, retailers, etc.

Table 2. Few areas where these 'actors' bring their ideas and knowledge for problem analyses with mutual professional respect.

1. Assessing pesticide use and its health and environmental impacts (farmers, consumers and environmental health) along with social implications.
2. Enforcing rules and regulations of pesticides use and environmental conservation (for example, Pesticides Act 1991, Regulation 1994; Environmental Protection Act 1997, Regulation 1998)
3. Controlling and banning of highly toxic and obsolete pesticides
4. Advocacy for safety precautions while handling and using pesticides
5. Designing and developing new interdisciplinary degrees at university levels to undertake complex problems like pesticides use and climate change
6. Redesigning and redeveloping curriculum of the current university degree focusing on interdisciplinary approach
7. Developing alternatives to chemical pesticides incorporating local knowledge and using local resources, for example integrated pest management
8. Developing mechanisms to inform farmers of the changes in market demands, opportunities, and threats arising from international and national rules, regulations, policies, treaties, etc

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