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Evolution of global agriculture and modern usage of agrochemicals: An analysis based on environmental and social impact in Sri Lanka

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Abstract

The history of agriculture records the domestication of plants and animals and the development and dissemination of techniques for raising them productively. Agriculture began independently in different parts of the globe, and included a diverse range. Agriculture has played a key role in the development of human civilization. Until the Industrial Revolution, the vast majority of the human population labored in agriculture. Development of agricultural techniques has steadily increased agricultural productivity, and the widespread diffusion of these techniques during a time period is often called an agricultural revolution. A remarkable shift in agricultural practices has occurred over the past century in response to new technologies. In particular, the Haber-Bosch method for synthesizing ammonium nitrate made the traditional practice of recycling nutrients with crop rotation and animal manure less necessary. Synthetic nitrogen, along with mined rock phosphate, pesticides and mechanization, have greatly increased crop yields in the early 20th century. Increased supply of grains has led to cheaper livestock as well. Further, global yield increases were experienced later in the 20th century when high-yield varieties of common staple grains such as rice, wheat, and corn (maize) were introduced as a part of the Green Revolution. The Green Revolution exported the technologies (including pesticides and synthetic nitrogen) of the developed world out to the developing world.

Keywords: agricultural productivity, green revolution, agricultural practices

Introduction

Many governments have subsidized agriculture to ensure an adequate food supply. These agricultural subsidies are often linked to the production of certain commodities such as wheat, corn (maize), rice, soybeans, and milk. These subsidies, especially prevalent in developed countries have been noted as protectionist, inefficient, and environmentally damaging. Proponents of organic farming such as Sir Albert Howard argued in the early 1900s that the over use of pesticides and synthetic fertilizers damages the long-term fertility of the soil. While this argument lay dormant for decades, as environmental awareness has increased in the 2000s there has been a shift towards sustainable agriculture by some farmers, policymakers and other interested parties.

Agriculture was developed at least 10,000 years ago, and it has undergone significant developments since the time of the earliest cultivation. Evidence points to the Fertile Crescent of the Middle East as the site of the earliest planned sowing and harvesting of plants that had previously been gathered in the wild. Independent development of agriculture is also believed to have occurred in northern and southern China, Africa's Sahel, New Guinea and several regions of the Americas.

Agricultural practices such as irrigation, crop rotation, fertilizers, and pesticides were developed long ago but have made great strides in the past century. The Haber-Bosch method for synthesizing ammonium nitrate represented a major breakthrough and allowed crop yields to overcome previous constraints. The recent history of agriculture has been closely tied with a range of political issues including water pollution, biofuels, genetically modified organisms, tariffs, and farm subsidies. In recent years, there has been a backlash against the external environmental effects of mechanized agriculture, and increasing support for the organic movement and sustainable agriculture.

Discussion

Evolution of Agriculture - Ancient Origins

The Fertile Crescent of the Middle East was the site of the earliest planned sowing and harvesting of plants that had previously been gathered in the wild. Independent development of agriculture occurred in northern and southern China, Africa's Sahel, New Guinea and several regions of the Americas. Barley has been found in archeological sites in Levant, and east of the Zagros Mountains in Iran.

The eight so-called Neolithic founder crops of agriculture appear: first emmer wheat and einkorn wheat, then hulled barley, peas, lentils, bitter vetch, chick peas and flax. Bitter vetch and lentils along with almonds and pistachios appear in Franchthi Cave Greece simultaneously, about 9,000 BC. Neither are native to Greece, and they appeared 2,000 years prior to domesticated wheat in the same location. This suggests that the cultivation of legumes and nuts preceded that of grain in some Neolithic cultures.

By 7000 BC, small-scale agriculture reached Egypt. From at least 7000 BC the Indian subcontinent saw farming of wheat and barley, as attested by archaeological excavation at Mehrgarh in Balochistan. By 6000 BC, mid-scale farming was entrenched on the banks of the Nile. About this time, agriculture was developed independently in the Far East, with rice, rather than wheat, as the primary crop. Chinese and Indonesian farmers went on to domesticate taro and beans including mung, soy and azuki. To complement these new sources of carbohydrates, highly organized net fishing of rivers, lakes and ocean shores in these areas brought in great volumes of essential protein. Collectively, these new methods of farming and fishing inaugurated a human population boom dwarfing all previous expansions, and is one that continues today.

By 5000 BC, the Sumerians had developed core agricultural techniques including large scale intensive cultivation of land, mono-cropping, organized irrigation, and use of a specialized labour force, particularly along the waterway now known as the Shatt al-Arab, from its Persian Gulf delta to the confluence of the Tigris and Euphrates. Domestication of wild aurochs and mouflon into cattle and sheep, respectively, ushered in the large-scale use of animals for food/fiber and as beasts of burden. The shepherd joined the farmer as an essential provider for sedentary and semi-nomadic societies. Maize, manioc, and arrowroot were first domesticated in the Americas as far back as 5200 BC.

The potato, tomato, pepper, squash, several varieties of bean, tobacco, and several other plants were also developed in the New World, as was extensive terracing of steep hillsides in much of Andean South America. The Greeks and Romans built on techniques pioneered by the Sumerians but made few fundamentally new advances. Southern Greeks struggled with very poor soils, yet managed to become a dominant society for years. The Romans were noted for an emphasis on the cultivation of crops for trade.

Middle Ages

During the middle Ages, Muslim farmers in North Africa and the Near East developed and disseminated agricultural technologies including irrigation systems based on hydraulic and hydrostatic principles, the use of machines such as norias, and the use of water raising machines, dams, and reservoirs. They also wrote location-specific farming manuals, and were instrumental in the wider adoption of crops including sugar cane, rice, citrus fruit, apricots, cotton, artichokes, aborigines, and saffron. Muslims also brought lemons, oranges, cotton, almonds, figs and sub-tropical crops such as bananas to Spain. The invention of a three field system of crop rotation during the middle Ages, and the importation of the Chinese-invented moldboard plow, vastly improved agricultural efficiency. Another important development towards the end of this period was the discovery and subsequent cultivation of fodder crops which allowed over-wintering of livestock.

Modern Era

After 1492, a global exchange of previously local crops and livestock breeds occurred. Key crops involved in this exchange included the tomato, maize, potato, cocoa and tobacco going from the New World to the Old, and several varieties of wheat, spices, coffee, and sugar cane going from the Old World to the New. The most important animal exportations from the Old World to the New were those of the horse and dog (dogs were already present in the pre-Columbian Americas but not in the numbers and breeds suited to farm work). Although not usually food animals, the horse (including donkeys and ponies) and dog quickly filled essential production roles on western hemisphere farms.

By the early 1800s, agricultural techniques, implements, seed stocks and cultivated plants selected and given a unique name because of its decorative or useful characteristics had so improved that yield per land unit was many times that seen in the Middle Ages. With the rapid rise of mechanization in the late 19th and 20th centuries, particularly in the form of the tractor, farming tasks could be done with a speed and on a scale previously impossible. These advances have led to efficiencies enabling certain modern farms in the United States, Argentina, Israel, Germany, and a few other nations to output volumes of high quality produce per land unit at what may be the practical limit.

The Haber-Bosch method for synthesizing ammonium nitrate represented a major breakthrough and allowed crop yields to overcome previous constraints. In recent years there has been a backlash against the external environmental effects of conventional agriculture, resulting in the organic movement.

The global agriculture which developed gradually was faced with major threats during the past 200 years. Industrialization. Urbanization, commercialization and rapid increase in transportation were among the leading factors of this change. The traditional agriculture pattern was stagnated until the industrialization in the 18th century and the Green Revolution in the 20th century.

Impact related to agrochemical usage

Many agrochemicals are toxic, and agrochemicals in bulk storage may pose significant environmental and/or health risks, particularly in the event of accidental spills. In many countries, use of agrichemicals is highly regulated. Government-issued permits for purchase and use of approved agrichemicals may be required. Significant penalties can result from misuse, including improper storage resulting in spillage. On farms, proper storage facilities and labeling, emergency clean-up equipment and procedures, and safety equipment and procedures for handling, application and disposal are often subject to mandatory standards and regulations. Usually, the regulations are carried out through the registration process. The amount of toxic dose is calculated by Lethal Dose (LD50) (Ministry of Agriculture 2006) and it is the amount of an ingested substance that kills 50 percent of a test sample. It is expressed in mg/kg, or milligrams of substance per kilogram of body weight. According to LD 50 scale toxic chemicals can be classified as follows.

Table 1: Agrochemical classification (Ministry of Agriculture 2006)

Category	Color	Impact
1 A highly toxic	red	hazardous
IIB toxic 5- 50	red	hazardous
II C medium range Toxic 5- 500	yellow	dangerous
III normal toxic 500 – 5000	blue	cautious
IV less toxic 5000 - 15000	green	cautious

People should be cautious about the color line of the label when purchasing pesticides. If it is possible to purchase only the products marked with green and blue the impact will be less.

Effects of agrochemicals on environment

Many important benefits are achieved by the use of agrochemicals. These are largely associated with increased yields of plant and animal crops, and less spoilage during storage. These benefits are substantial. In combination with genetically improved varieties of crop species, agrochemicals have made important contributions to the successes of the "Green Revolution." This has helped to increase the food supply for the rapidly increasing population of humans on earth.

However, the use of certain agrochemicals has also been associated with some important environmental and ecological damages. Excessive use of fertilizers, for example, can lead to the contamination of groundwater with nitrate, rendering it unfit for consumption by humans or livestock. Water containing large concentrations of nitrate can poison animals by immobilizing some of the hemoglobin in blood, reducing the ability to transport oxygen. In addition, the run-off of agricultural fertilizer into streams, lakes, and other surface waters can cause an increased productivity of those aquatic ecosystems, a problem known as eutrophication. The ecological effects of eutrophication can include an extensive mortality of fish and other aquatic animals, along with excessive growth of nuisance algae, and an off-taste of drinking water.

Pollution caused by agrochemicals

The impact of agrochemicals consists of the effects of pesticides on non-target species. Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, because they are sprayed or spread across the entire agricultural fields. Runoff can carry pesticides into aquatic environments while the wind can carry them to other fields, grazing areas, human settlements and undeveloped areas, potentially affecting other species. Other problems emerge from poor production, transport and storage practices. Over time, repeated application increases pest resistance, while its effects on other species can facilitate the pest resurgence.

Each pesticide or pesticide class comes with a specific set of environmental concerns. Such undesirable effects have led many pesticides to be banned, while regulations have limited and/or reduced the use of others. Over time, pesticides have generally become less persistent and more species-specific, reducing their environmental footprint. In addition the amounts of pesticides applied per hectare have declined, in some cases by 99%. However, the global spread of pesticide use, including the use of older/obsolete pesticides that have been banned in some jurisdictions, has increased overall

Air

Pesticides can contribute to air pollution. Pesticide drift occurs when pesticides suspended in the air as particles are carried by wind to other areas, potentially contaminating them. Pesticides that are applied to crops can volatilize and may be blown by winds into nearby areas, potentially posing a threat to wildlife. Weather conditions at the time of application as well as temperature and relative humidity change the spread of the pesticide in the air. As wind velocity increases so does the spray drift and exposure. Low relative humidity and high temperature result in more spray evaporating. The amount of inhalable pesticides in the outdoor environment is therefore often dependent on the season. Also, droplets of sprayed pesticides or particles from pesticides applied as dusts may travel on the wind to other areas, or pesticides may adhere to particles that blow in the wind, such as dust particles.

Pesticides that are sprayed on to fields and used to fumigate soil can give off chemicals called volatile organic compounds, which can react with other chemicals and form a pollutant called tropospheric ozone. Pesticide use accounts for about 6 percent of total tropospheric ozone levels.

Water

In many countries around the world pesticides were found to pollute every stream and over 90% of wells sampled in a study by the US Geological Survey. Pesticide residues have also been found in rain and groundwater. Studies by the UK government showed that pesticide concentrations exceeded those allowable for drinking water in some samples of river water and groundwater.

Pesticide impacts on aquatic systems are often studied using a hydrology transport model to study movement and fate of chemicals in rivers and streams. As early as the 1970s quantitative analysis of pesticide runoff was conducted in order to predict amounts of pesticide that would reach surface waters.

There are four major routes through which pesticides reach the water: it may drift outside of the intended area when it is sprayed, it may percolate, or leach, through the soil, it may be carried to the water as runoff, or it may be spilled, for example accidentally or through neglect. They may also be carried to water by eroding soil. Factors that affect a pesticide's ability to contaminate water include its water solubility, the distance from an application site to a body of water, weather, soil type, presence of a growing crop, and the method used to apply the chemical.

Social and economic impact on humans

People in our country are being addicted to yield a maximum harvest within a short span of time. To achieve that target they now largely use various chemical fertilizers, pesticides and other chemicals. Using agrochemicals instead of natural control methods and scientific ways had caused many issues.

Pesticide among agrochemicals causes the major impact. The use of pesticides and nitrogen fertilizers in agriculture has grown dramatically over the past 30 years. Currently, approximately 600 active pesticide ingredients are used, but adequate toxicological data are available for only approximately 100 of these. Environmental exposure of humans to agrochemicals is common and results in both acute and chronic health effects, including acute and chronic neurotoxicity (insecticides, fungicides, fumigants), lung damage (paraquat), chemical burns (anhydrous ammonia), and infant methemoglobinemia (nitrate in groundwater). A variety of cancers also have been linked to exposure to various pesticides, particularly hematopoietic cancers. Immunologic abnormalities and adverse reproductive and developmental effects due to pesticides also have been reported. The health effects associated with pesticides do not appear to be restricted to only a few chemical classes. Therefore, enhanced efforts are needed to control or eliminate human exposures to agrochmicals wherever possible. Research also is needed to better characterize and quantitative the adverse effects of agrichemicals on human health.

Pesticide exposure can cause a range of neurological health effects such as memory loss, loss of coordination, reduced speed of response to stimuli, reduced visual ability, altered or uncontrollable mood and general behavior, and reduced motor skills. These symptoms are often very subtle and may not be recognized by the medical community as a clinical effect. Other possible health effects include asthma, allergies, and hypersensitivity, and pesticide exposure is also linked with cancer, hormone disruption, and problems with reproduction and fetal development.

Pesticide formulations contain both "active" and "inert" ingredients. Active ingredients are what kill the pest, and inert ingredients help the active ingredients to work more effectively. These "inert" ingredients may not be tested as thoroughly as active ingredients and are seldom disclosed on product labels. Solvents, which are inert ingredients in many pesticide formulations, may be toxic if inhaled or absorbed by the skin.

Children are at greater risk from exposure to pesticides because of their small size: relative to their size, children eat, drink, and breathe more than adults. Their bodies and organs are growing rapidly, which also makes them more susceptible; in fact, children may be exposed to pesticides even while in the womb.

People in low- and middle-income countries (LMICs), such as Sri Lanka, often experience acute exposure alongside chronic exposure due to the widespread and largely unregulated use of pesticides. The level of chronic pesticide exposure in LMICs is likely to be higher than in high-income countries, as a large proportion of rural families in Sri Lanka live close to agricultural fields and are not only exposed to pesticides when the fields are being sprayed but also have sustained exposure through their food and drink and through air particles. In addition, villagers in rural Sri Lanka often use the irrigation canals, rivers and lakes as a free source of bathing water. This water source is likely to be heavily contaminated with pesticides, not only due to run-off but also as a direct consequence of the practices of pesticide sprayers.

National Toxic Information Center affiliated to Ministry of Health is operational in Sri Lanka. Every information related to toxic are being collected by them. According to them between year 1992 and 2001 a total of 15,458have died due to agrochemical intoxication. During this period 265,524have been hospitalized.

The percentage of agrochemical intoxication is 20% to the total. This was revealed in a limited survey carried out by the Ministry of Health in 2000 – 2013. Their statistics show 12.5% deaths due to pesticide intoxication and 21.5% deaths due to negligence. According to the information center 10000 – 20000 people are hospitalized due to pesticide intoxication. (Ministry of Agriculture 2014)

Impact of agrochemicals

Table 2

Year	No of patients hospitalized	No of deaths
2000	20226	1843
2001	19081	1717
2002	17364	1437
2003	19055	1310
2004	16644	1281
2005	16110	1270
2006	17518	1240
2007	17727	1152
2008	18033	911
2009	18110	910
2010	20460	759
2011	22872	606
2012	21133	502
2013	21011	520
Total	265524	15458

Source: Medical statistical Division, Ministry of Health - 2014

These numbers have increased since 2000. These information contain suicides, suicide attempts also.

Table 3

District	No of patients admitted to hospitals	No of deaths
Kurunegala	4310	310
Anuradhapura	3103	115
Badulla	1510	119

Source: Medical statistical Division, Ministry of Health -2014

Kurunagala and Anuradhapura are the heavily affected districts. In both districts recorded the highest number of kidney patients in the country in year 2013. According to World Health Organization report in 2013 the number of kidney patients in Sri Lanka has surpasses 64000. It says15% of the population between year 15 – 70 in North and Uva provinces have become victims of the disease. Similarly, there is a high tendency among year 40 years to be affected.

Recommendation

The success of a crop is imperative for a farmer’s livelihood in rural Sri Lanka. This need, coupled with heavy marketing of pesticides has led to a nearly ubiquitous use of pesticides on crops. It is not clear whether this heavy use, resulting in high levels of both acute and chronic exposure, has any long-term detrimental health effects. The difficulty in assessing this arises because of challenges in the measurement of long-term pesticide exposure. Traditional biological samples, like blood and urine, are difficult to collect and only capture short-term pesticide exposure.

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