Agroecosystem Management for Improved Human Health: Applying principles of integrated pest management to people

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Abstract

During the past century, both the agricultural and health sciences have become compartmentalized making great technical advances in relatively specialized technologies that generated significant increases in food production and reductions in human diseases. Although the primary purpose of agriculture is to maintain human health and human health depends upon agriculture, there have been few efforts to integrate the two. At a time when both realms of study are questioning the sustainability of their respective achievements, the concept is emerging that effective agroecosystem management may provide a cost-effective approach to improving human health. This hypothesis builds on an enhanced understanding of how the state and condition of agroecosystems links to human health. Experience gained by the International Development Research Centre (IDRC) reveals a number of essential methodological elements required to support research intended to test this hypothesis. It suggests that the principles of integrated pest management that have been successful developed and applied in agriculture may be applicable to improving human health in the context of agroecosystems.

Introduction

WHO (World Health Organization, 1976) adopted a broad view defining human health as "a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity." Without food, good health is not possible. Although traditionally emphasizing the production and distribution of food, the ultimate overall goal of agriculture must be the maintenance of human health and well-being. Surprisingly, there is little evidence that most agricultural and health researchers and practitioners consciously accept this view. In spite of hundreds of thousands of research papers available in both fields of study, a search of recent research literature conducted by the International Development Research Centre (IDRC) resulted in only six "hits" identifying papers that contained both "agroecosystems" and "human health" as key words. Although fine tuning using additional and related key words revealed other relevant publications, the gap in our knowledge of the links between human health and agriculture systems is evident. Closing this gap requires shareholders to recognize that agriculture is in fact agroecosystem management (Nielsen, 1998). By design, people are an integral component of all agroecosystems. It follows that both the condition and management of agroecosystems have a direct influence on the health of people. The purpose of this paper is to outline some of the fundamental concepts essential to using agroecosystem management as a tool for improving human health and to describe IDRC's program to encourage collaborative research that can make this possible.

Agroecosystems

"An agroecosystem is a conceptual construct used to describe ageographically and functionally coherent domain of agricultural activity. It includes all living and nonliving components and the interactions among them" (Agro-ecosystem Health Project, 1996). Researchers often consider the farm as the basic unit of an agroecosystem, but this concept may not be relevant in extensive grazing systems. The precise geographic scale can vary from a system involving a single farm to communities and watersheds composed of many farms and even beyond that to large eco-regions. The definition is context-specific, and in each case it is somewhat arbitrary. Regardless of the scale, agroecosystems are not closed systems. It is normal that agroecosystems are characterized by driving variables or inputs that include immigration and inflows of capital, information, energy, fertilizers, chemicals, and human infrastructure and knowledge. Natural driving variables or inputs include solar radiation, rain, wind and water. Most agroecosystems also experience losses or outflows from the system such as water, and emigration. Nutrient losses caused by leaching and the export of crops and livestock are common.

Agroecosystems cover 30% of the world's land area (Elliot and Cole, 1989). Farmers manage more land area than any other group of people. During the last 50 years, scientific progress (the green revolution) in plant and animal breeding, irrigation, pest and disease control, labour-saving technologies, and food processing enabled food production to keep pace the demands of a growing human population (Borlaug, 1995). Without these technological breakthroughs and compared to 1961, three times more land in China and the United States and two times more in India would have to be under cultivation in order to achieve the food production levels obtained in 1995 (Borlaug, 1995). To meet the demand caused by the continuing increase in population and the increasing demand for animal products in the developing countries, food production must double over the next 30 years.

During the past century, agricultural sciences became compartmentalized or divided into many specialties that enabled the green revolution to happen. The apparent success of production agriculture depended on the exploitation of the world's capital held in the form of soil organic matter and nutrients. One unintended outcome of production oriented agriculture is recent global degradation of soil and water resources and the consequent loss of biodiversity (Srivastava *et al.*, 1996). High yielding production systems accelerated the "mining" of soil capital (Sanchez *et al.*, 1977). Replenishment of soil nutrients by dependence on chemical fertilizers failed to maintain the structure and biological diversity essential for long term production. Expansion of agriculture into forests and the conversion of range lands into crop lands aggravated this deteriorating situation. Under nutrient and water-stressed intensive agricultural production systems, farmers increasingly rely on the use of herbicides, pesticides and pharmaceutical drugs to control a wide range of diseases and parasites that threaten their crops and livestock. Agriculture now faces the tasks of further enhancing food production while simultaneously reversing soil degradation (Borlaug, 1995), replenishing soil capital (Sanchez, *et al.*, 1977), and overcoming the harmful effects of agricultural chemicals (van

Veen et al., 1996). Degraded agroecosystems are less resilient to stresses caused by global variation and climatic changes. They are sites where there is growing concern about the projected increase in risks to human health (Lederberg, 1995). Recognizing this, the international community responded, particularly since the United Nations Conference on Environment and Development in 1992, by establishing numerous agreements, international conventions, and research and development programmes that endeavor to transform exploitative agricultural activity into sustainable development (e.g., World Bank, 1995). One consequence has been the rise of a more holistic agroecosystem view of agriculture as the paradigm for understanding sustainable production.

Human Health

In a pattern similar to the evolution of agriculture during this century, human health research and practice underwent significant progress (Lederberg, 1995; World Bank, 1995). For example, great strides in sanitation, health education, nutrition, immunization and antibiotics all contributed to the reduction of infectious diseases, the leading cause of mortality in the United States in 1900 accounting for at least 37% of deaths, to 2.8% in 1989. The number of children that die before age of five years in developing countries has been cut half since 1960 (World Bank, 1993). Much of this progress depended on advances in specialized aspects of medical science that often focused on diagnosis, prognosis and prescription in a clinical setting that separated human health from the environmental context in which people live (Ewert and Kessler, 1996). Health care and delivery were built around single specialist disciplines or on a relatively restricted set of them. In spite of the progress in developed countries, the benefits of improved health care have not been shared equally among the peoples of the world. Infectious and communicable diseases remain the most common cause of global mortality (Wilson, 1995). In sub-Saharan Africa they still account 70% of the burden of ill health. There is also growing concern that many of the advances in global health now risk being offset by many factors including climate change, new and re-emergent diseases, under-nutrition, malnutrition, respiratory illness, increasing rates of cancer, and toxic chemicals (Epstein, 1997; Daily and Ehrlich, 1995; Lederberg, 1995; World Bank, 1993). As with attempts to control agricultural pests and disease by using excessive and inappropriate use of chemicals, health professionals are now challenged by increasing resistance of pathogenic organisms and disease vectors to pharmaceuticals and pesticides (Wilson, 1995).

During the past two decades, some segments of the health care community have placed greater emphasis on a more holistic understanding of human health in the context of the environment. For example, the World Health Organization and other bodies now place greater emphasis on understanding the links between human health and a range of pollutants in air, water, soil and food (Corvalan and Kjellstrom, 1996). Looking beyond the notion of simply linking environmental components directly to human health issues, there is the growing recognition that these linkages operate within the complex structure and functioning of the ecosystems in which people live (Forget, 1997). There is increasing cognisance of the need for students of human health to take a systems approach to understand their subject in the context of the health and resilience of the ecosystems in which people live and to view human life as part of a constantly evolving biosphere (Wilson, 1995). Holistic consideration of health also recognizes that the concept of health varies among cultures (e.g., Galvin, 1992; Adelson, 1998) while within them, there are variations in health priorities among people are common (e.g., Just and Murray, 1996) and that these must be recognized (Forget, 1992). In spite of the scientific advances, the levels of health care provision taken for granted in industrialized nations are not accessible to many people because of the lack of health clinics and the high costs for treatment. Consequently, many local people in developing countries are looking for cost-effective alternatives to solving a wide range of health issues (Forget, 1992).

Links between Agroecosystems and Human Health

Human health is directly linked to and dependent on the state of health of the ecosystems that support them (Ewert and Kessler, 1996). Because people are an integral component of agroecosystems, a range of socio-economic and biophysical factors affect their health. A few examples illustrate this point. Particularly in subsistence agricultural systems, nutrition is a primary factor. Without food security, human health inevitably suffers. Although, increased food production in terms of quantity has largely kept pace with the demands of a growing population, the quality of food available may be declining (Howard, 1956) and maintaining the high rate of production may be difficult (Borlaug, 1995). Food shortages affect about 800 million billion people, but more than two billion people suffer from malnutrition (IFPRI, 1996). Although in some cases, nutrient deficiencies are simply characteristic of otherwise stable agroecosystems, land degradation aggravates the harmful effects that some factors in agroecosystems have on human nutrition. For example, iron deficiency alone affects 40 to 50% of women worldwide (IFPRI, 1996). Two hundred and fifty million children suffer from severe or moderate Vitamin A deficiency with up to 500 thousand preschoolers becoming blind annually (IFPRI, 1996). Other widespread deficiencies include zinc and iodine. There is growing evidence that even in developed countries, deficiencies in fibre, folic acid, etc., threaten human health.

Apart from nutrition, naturally occurring heavy metals, vector-borne and non vector-borne diseases, naturally occurring toxins, agricultural chemicals, and imports and exports associated with a cash economy contribute to the health risks faced by people within the context of their agroecosystem.

In recent years, mercury contamination of fish in the Amazon basin and the consequent rise in symptoms of toxicity in people who depend on fish has focused attention on the perceived negative impact of gold mining. However, new evidence (Lebel *et al*., 1997) suggests that gold mining is not the only source of this heavy metal. Rather, forest clearance followed by cultivation resulted in the leaching of mercury from exposed soil into adjacent aquatic ecosystems where it entered the food chain. The introduction of agriculture initiated a process of soil degradation that directly threatened human health. With this knowledge, local people are in a position to modify their diets by shifting from the consumption of carnivorous to herbivorous fish, to establish vegetative buffer zones between the exposed soils and the rivers, and to consider other community efforts to better manage vegetative cover of their crop lands. In short, the solution to this health problem lies in better management of the aquatic and terrestrial agroecosystems.

Participation of local people is essential

Adoption of new or innovative agricultural technologies and policies often leads to unexpected or counter intuitive impacts. Understanding and responding to these often requires an agroecosystems perspective. For example, the introduction of irrigated rice production into the savanna-humid forest transition zone of West Africa raised the prospect of increased malaria (Teuscher, 1998). Although people living near irrigated fields had greater malaria risk in the dry season than those in non-irrigated areas, it was lower in the rainy season. Averaged over a yearly basis, irrigation had little impact on malaria in risk. Apparently, "lower anopheline densities" in non-irrigated areas were offset by higher survival and increased probability of transmitting the disease from infected to uninfected persons. However, not all irrigated agroecosystems escape from increased vector-borne diseases. In addition to malaria, irrigation affects health risks associated with other diseases such as Japanese encephalitis and schistosomiasis (Service, 1998).

Migration and travel caused by the introduction of new technologies, migrant labour, the movement of people between densely populated urban centres and agricultural lands, and changing settlement patterns can enhance the likelihood of carrying new diseases into agroecosystems (Wilson, 1995).

Transformation from a subsistence cash economy can generate a number of adverse health consequences. In Uganda (Heifer International, personal communication) highland farmers used milk from their local cows to enhance the nutritional standard of their family's diets. Collecting 4 litres of milk per day did not justify the effort required to sell the milk at the nearby city market. However, after receiving improved hybrid cows, milk production jumped to about 16 litres per day. This large amount encouraged farmers to make the extra effort to sell the milk. Consequently, all the milk was sold. The cash generated was used to purchase maize meal, beer and other goods. The outcome of introducing improved dairy cows was a decline in the family's nutritional regime.

The move to cash economies can result in externalized health risks. For example, chemical fertilizers, pesticides, herbicides, and fungicides applied to food crops can be leached into the ground water supplies contaminating downstream and underground water. Apart from government regulation and enforcement, there is little incentive for farmers to actively concern themselves about health impact resulting from the use of such chemicals. Even if concerned, they are more likely than not to be ignorant of the problem. Having sold their harvest, many cash croppers in turn use the proceeds from the sale of their crops to purchase food for their families. Unknowingly, they are in danger of purchasing contaminated food. In Africa, the high incidence of aflatoxin contamination of grain and ground nuts is in part a consequence of the cost and inability of farmers to pay the cost of properly drying them. They see little point in spending money to dry grain only to have it weigh less thereby reducing the cash they receive from the sale of it.

Land degradation can adversely affect human health by changing the ecology of pathogenic and harmful organisms. One consequence of soil degradation is reduced water holding capacity and greater likelihood of drought stressed crops. Peanuts subjected to drought develop high concentrations of pre-harvest aflatoxin (Sanders *et al*., 1993). Aflatoxin is believed by many to cause acute liver damage and cancer (Adams, 1996). Although this connection has not been conclusively demonstrated in humans (Park, 1993), the fear of its carcinogenic effect motivates a number of governments to regulate trade in potentially contaminated food crops.

Not only do the condition and management of agroecosystems affect the health of people that depend on it for sustenance, human health also directly influences the ability of people to manage the system itself. For example, Acquired Immunodeficiency Syndrome

(AIDS) caused by the Human Immunodeficiency Virus (HIV) causes major labour shortages and the diversion of family income to cover increased health care costs (Haslwimmer, 1994). Thereby, they contribute significantly to a decline in soil fertility, an increase in agricultural pests and diseases, changes and delays in cropping practices, a decline in the variety of crops grown, and a decline in the people's access to and ability to purchase external farm inputs. HIV/AIDS apparently discourages farmers from making long term investments in soil conservation measures that do not provide immediate income and that carry a significant labour cost. For pastoralists, a reduction in herd size and a shift towards less labour demanding animals such as pigs and poultry are common. The sale of animals may be required to cover increased health care costs. HIV/AIDS also contributed to a 20 to 50% loss of working time for extension services in Uganda and a loss of agricultural skills at both professional and farm levels. Beyond HIV/AIDS, other aspects of poor health make effective management of agroecosystems more difficult.

Elements of an Approach to Research on Improving Human Health Through Ecosystem Management

The basic working hypothesis is that better management of agroecosystems is a cost-effective strategy for improving human health. This implies that agriculture must be viewed as ecosystem management and that the principles of natural resource management are applied to it. To test this hypothesis and to ultimately contribute to the well-being of the rural poor in developing countries, a number of requirements must be considered.

Participation by all stakeholders. Local people are not mere objects of scientific study. As participants, they play research roles as both the observer and observed. In development, they become the managers and the managed. Successful ecosystems research depends on full and relevant participation by all stakeholders in the characterization of ecosystems and prevailing health status, the setting of research priorities, the selection of potential interventions, the conduct of data collection, and the analyses and interpretation of results (Forget, 1992: Forget, 1997). Similarly, full participation is required in community action plans arising from the research and their implementation. Although the need for participation is often recognized by individuals having an agricultural or medical background, there is strong evidence to suggest that researchers require formal training in the methods of community involvement, participatory methods and policy development (IUCN, 1997) in order to succeed in this endeavour. Although recent trends call for more bottom-up than top-down participation there is some suggestion that "inside-out" rather than "outside-in" participation is most important (Roe, 1996).

Legitimacy. Full participation in ecosystem projects depends upon the legal, financial and political legitimacy of all stakeholders (MacKenzie, 1996). Political pressure may be necessary when some key ministries or agencies are reluctant to act or when local people are not given the opportunity to effectively participate.

Empowerment through knowledge. Understanding the complexity of agroecosystem structure and function is knowledge intensive, but essential for all stakeholders. Involving local people in the identification of their health priorities and the linking of these to agricultural and other activities is essential. Achieving a holistic understanding of the varying perceptions of agroecosystems and health is critical in enabling the selection, testing, and evaluation of an efficient set of technical, policy and behavioural interventions that can bring about improved human health. Because each agroecosystem is unique, knowledge will be the key to the dissemination of an appropriate approach to its management.

Gender and equity. Including gender considerations in research protocols is not merely a question of equity but of good science. There has been much scholarly research on the differential way that the environment affects the health, social and economic lives of men and women. In brief, they simply occupy different life spaces (Kettel, 1996) or niches in the agroecosystem so that they face different health risks and differ in their sharers of the costs and benefits that arise from the agroecosystem and management and the introduction of new technologies and policies. The differing characteristics of women's and men's reproductive, productive and social roles may be responsible (Just and Murray, 1996). For example, in much of sub-Saharan Africa, women are the primary givers of health care and at the same time are largely responsible for farming and maintaining the households. Additional demands on their time through either increased illness of themselves and family members or from additional requirements for farm labour often cannot be met. When men control the family cash, women may be denied the opportunity to hire labour to assist them in their work. Collection and analyses of gender dis-aggregated data must be a priority if research results are to benefit the well-being of both sexes. Research must also recognize the relevance of other key categories in social structure such as age and ethnic composition.

Interdisciplinarity. The challenges posed by global environmental and demographic changes and new and reemerging diseases require research and analyses of the ecosystem as an integrated whole and not merely as a sum of the parts studied separately. In contrast to traditional efforts of drawing conclusions from simultaneous but independent component research, an ecosystems approach demands language, paradigms and models that enable researchers at the outset to understand the complex nature of systems that cannot come from separate studies of the components. Experience suggests that researchers must not underestimate the effort required to build an effective unified interdisciplinary team (MacKenzie, 1996).

Because, local people's health and well-being are dependent on a myriad of processes operating on and within agroecosystems, they are the natural focal point for interdisciplinarity. They will likely demand that simple solutions arise from understanding complex systems (Roe, 1996). Although local people are the reservoirs of much valuable local knowledge, there is no guarantee that their understanding is correct, complete or relevant. For example, education is often needed, and outside expertise is essential to assist local people to understand the intricacies of soil fertility and the ecology of agricultural pest and human disease vectors. When human populations are subject to rapid change in their ecosystems or the populations themselves move to a new environment, the knowledge that they once had may no longer be helpful in managing agricultural and health care.

Hypothesis testing and assessment. A rigorous methodology in experimental design forms the foundation of much research particularly in the specialized single discipline of agricultural and health sciences. However, each agroecosystem is unique in terms of its structure, function, human society, management, and its exposure to inputs and outputs. Methods for testing interdisciplinary, multi-scale, and multi-cultural hypothesis have not been formally developed. Ecosystem research directed to the understanding of the complex set of biophysical and socio-economic interactions within agroecosystems is expensive, and replication may be difficult. To overcome these difficulties given limited budgets, IDRC encourages two approaches. One is the integration of human health into ongoing and proposed ecosystem research. Because these large studies often lack effective participation and community-based control over development, IDRC also encourages a local assessment process that requires community participation in the research-development process to enhance the health of agroecosystems and the human well-being (IUCN, 1997). This assessment process that allows for all stakeholders to enter into a reiterative cycle of diagnosis, action, monitoring, evaluation, and reflection brings the research process to a practical community level.

Defining and characterizing agroecosystems and human health. Ecosystems are complex. Their boundaries and scale are arbitrary and there is no particular definition that is likely to satisfy all stakeholders (Roe, 1996). They contain all the atmospheric and geological characteristic along with the living components that include microbes, flora, fauna and people. These diverse elements are linked together through a variety of biophysical and socio-economic processes. A multi-stakeholder approach requires that all participants reach a common definition of the ecosystem that they intend to manage. Some workers stress the need for models that capture the essential interactions among component parts of ecosystems. Commonly used approaches include simulation, decision support systems, and geographic information systems. Even if useful for some purposes, these are often computer-based technologies to which local people have no access. To overcome this, a variety of community-based assessment methods exist that enable local people to understand the holistic nature of their agroecosystems (e.g., IUCN, 1997).

Ethical issues. The health, social and agricultural sciences separately recognize a number of ethical standards that they endeavor to follow. By integrating these disciplines each may face ethical issue not normally considered. Issues related to informed consent, compensation for losses resulting from the testing of interventions, and the ownership and sharing of data and access to them must be considered. In a multi-stakeholder environment, some parties will have conflicting codes of ethical standards while others may have none at all. In cross cultural setting, unexpected differences may arise. A clear set of standards acceptable to all is needed.

Project management model. International development has been characterized by a project management model that typically starts with an expert's concept paper that results in an agreement by recipients (usually developing country governments) and donors to "do" a project for a target population. Such "a vertical problem-solving method ignores the developing country context ... making the intervention irrelevant to the circumstances at hand" (Forget, 1992). Subsequent steps typically include the development of a "request for proposal" (RFP), selection of an executing agency based on responses to the RFP, project inception, a project operational phase, midterm evaluation, project completion and a final report. Funding usually covers a period not exceeding five years although follow up phases are common. With the project's objectives fixed prior to starting work, there is usually little opportunity or inclination to effectively characterize the ecosystem components and the links that connect them. The target population often has little or no role in setting project objectives, implementing the research, and evaluating the results. This project model limits the ability of stakeholders to adopt the ecosystem approach by constraining activities to the number, range and quality specified in the terms of reference, by limiting the learning opportunities for many stakeholders, by encouraging projects of limited duration, and by restricting the responsibility and role of the intended beneficiaries. To overcome these constraints, a new model for project development will be needed. It must provide for consultative process that is time consuming and often requires the expenditure of funds to bring people together to describe their agroecosystems and the health of the people within them and to formulate their research and development priorities. It must also recognize that these priorities are not static and will change over time. Thus, a new project model must enable the appropriation of funds before specific project objectives and deliverables have been defined and agreed upon.

IDRC's Support of International Development Research on Ecosystem Approaches to Human Health

IDRC has gained considerable experience in supporting international health, agricultural, and NRM research. Participatory research, gender analyses, and communication technologies and policies have received considerable emphasis. Building on these, the Centre now encourages collaborative research designed to determine the degree to which agroecosystem management can be an effective tool for improving human health. Ideally research teams should draw on expertise from the biophysical, health, and socio-economic fields of study. The Centre encourages partnerships among NGOs, private enterprise, and research institutions operating in Canada and developing countries. Interdisciplinary ecosystem level research is expensive, and financial resources are scarce. Therefore, IDRC encourages a pragmatic two-pronged strategy. One encourages the inclusion of human health research in ongoing or planned ecosystem level studies. Conceptually, the addition of health research is only a small but an important step forward in achieving a more holistic view. The second approach recognizes that effective local participation may be overwhelmed by large complex multi-stakeholder projects. Therefore, IDRC also encourages local communities and NGOs to undertake more modest agroecosystem research at the community level intended to identify, understand and test interventions that can result in improved human health.

This program of research is nothing less than testing the application of principles of integrated pest management to the management of human health. It is an interdisciplinary, knowledge intensive, community-based management approach that encourages natural maintenance of human health by anticipating illness and preventing them from jeopardizing the well-being of the people (adapted from van Veen, 1996). The experience gained in IPM by the agricultural community has much to offer the health sciences. The fact that agroecosystems are major determinants of human health globally strengthens the case for cross sectoral collaboration. In all countries, the needs for alternative cost-effective improvements in human health are great. Developed nations such as Canada can also benefit if this research results in less contamination in imported food products.

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