



A new conceptual base for food and agricultural policy: the emerging model of links between agriculture, food, health, environment and society

Everywhere in the world, food and agricultural policy is under scrutiny. Questions are being asked about both past and present public policy and strategy. The motives for reassessment are various, including trade wars, health impact, ecological concerns, population, citizens rights.^[1,2,3] After decades in which policy was centrally concerned with raising productivity and production, using a fairly simple Input-Output Model, the need for a more complex model for food and farming is becoming clear. The success of the dominant Input-Output Model of farming is that it can claim to have kept up with rising population trends and unleashed astonishing efficiencies.^[4] Critics point out, however, that these efficiencies have insufficiently accounted for costs to the environment, health and social well-being.^[5] A debate about these considerations grew in intensity during the 1990s,^[6] but had earlier roots.^[7] As a result, a new model of food and agriculture's contribution to health is emerging.

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In this paper, we propose that the debate about the future of food and farming may be usefully conceptualized in terms of two competing models. The Input-Output Model's conceptual base is unilinear and two dimensional. Science is a neutral tool whose prime purpose is to raise production and to increase efficiency. Coupled with improved distribution, the model proposes that improved health will be the outcome. The policy context for the Input-Output Model is completely open. It is currently the dominant model within capitalist agriculture, but it was also applied under the old Soviet system, with disastrous results. It has been applied

with more favorable results under neo-liberal frameworks. Market systems have a better track record of enabling the Input-Output Model to work, i.e. to maximize production, than controlled economies.

The Input-Output Model, however, has a tendency to over-simplify factors that can affect output. It also has a tendency to externalize costs. For instance, it may deliver cheap food (defined as food accounting for a reduced proportion of household expenditure) but it has an unfortunate tendency to disguise or add to the environmental health bill.^[8,9] The use of pesticides has grown immensely world-wide under the tutelage of the Input-Output

Model.^[10] The Model in general assumes that humans are in control of all important variables.

The Complex model, by contrast, posits non-linear relationships between agriculture, food and health. It assumes infinitely more complexity. Health is not an output, so much as a roof under which life can shelter. Health in turn relies on a diversity of factors. These are the pillars and pedestals in Figure 2. Another visual image for representing the model differently might be as a network or web. The choice of image for the Complex Model is immaterial. Our concern here is to stress that the relationship between food and farming and health is highly interconnected. It is characterized by feedback rather than unilinear and causal relationships. Within public policy, this Complex Model is emerging rather than dominant.

The role of knowledge and science in both models is critical. The Input-Output Model has as its key premise that science can accompany investment (capital) to raise production. Science and technology are keys to the unleashing of productive capacity. Efficiency is defined in restricted terms: quantity rather than quality, total output rather than range. Insufficiency of food supply is presumed to be the main determinant of (ill)health. It follows that the challenge for public policy is to remove any impediments on production.

This vision of the need to harness science to raise production is not new. The model dates from the late 19th century, with the application of modern chemistry to farming. The role of science, in the words of one proponent of the Model, is to “control Agriculture.”^[11] It is, of course, possible to trace the intellectual and practical origins of the Input-Output Model to early plant and animal breeding, which was in turn framed by a rising need to feed the new urban masses of the industrial revolution. Notions of food and farming, like other areas of human discourse, do not change overnight, as if struck by lightning. As Kuhn and others have noted, two competing (but unequal) models can co-exist.^[12]

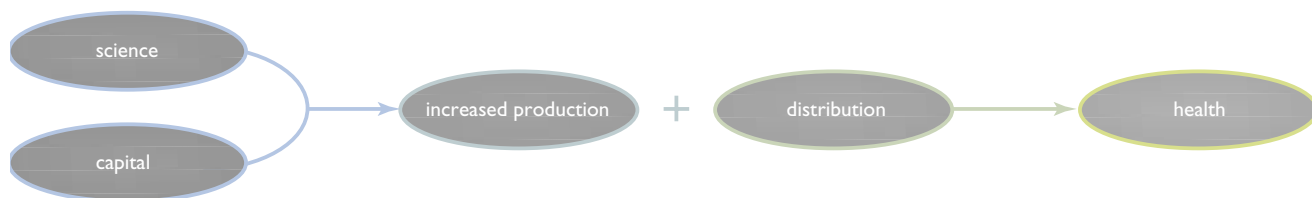


Figure 1 Food's contribution to health: the input – output model

By the mid 20th century, the Input-Output Model had become the dominant policy model in the West. ‘Scientific’ farming was the paradigm for post World War II agricultural reconstruction.^[13,14] Then, as now, it was promoted world-wide by European and US interests. Boyd Orr, the first Director of the newly formed United Nations’ Food and Organization, better known for his work on poverty, saw post war policy as unleashing the capacity of farmers in the West to feed the world.^[15] Political will, he argued, was necessary to unlock the capabilities of the world to feed itself.^[16] In the words of one historian, “the immediate concern (post World War II) ...was to raise agricultural production as rapidly as possible.”^[17]

But is the raising of production still a - or indeed the sole - policy challenge for the 21st century? We think not. Notions such as social justice,^[18] biodiversity,^[19] soil health,^[20] climate change,^[21] equity,^[22] good governance,^[23] and more, are just as pressing. What is required is a more sensitive understanding of how food production and human health depend upon complex ecological and social factors.

At present, the input-output model is still well rooted in public policy despite growing evidence of its faults. The emerging model lacks coherent policy backing. Although it has gained in policy legitimacy, it still lacks hard political backing. It is, however, suffering the fate of being bolted on in parts, as ‘consumer-friendly’, ‘green’ or ‘ethical’ extras. Farmer consultation exercises are often recommended even by proponents that the farm is best viewed as an input-output system.^[24] Consumer consultation exercises are also now *de rigueur* in dissemination (rather than formulation of) food safety policy, a pressing concern for governments world-wide. But less attention is given to why there are food safety problems in the first place. Proponents of the Input-Output Model are also drawing on the ecological notions in the Complex Model to justify continued use of scientific farming. One proponent, for instance, has argued that the only way to save

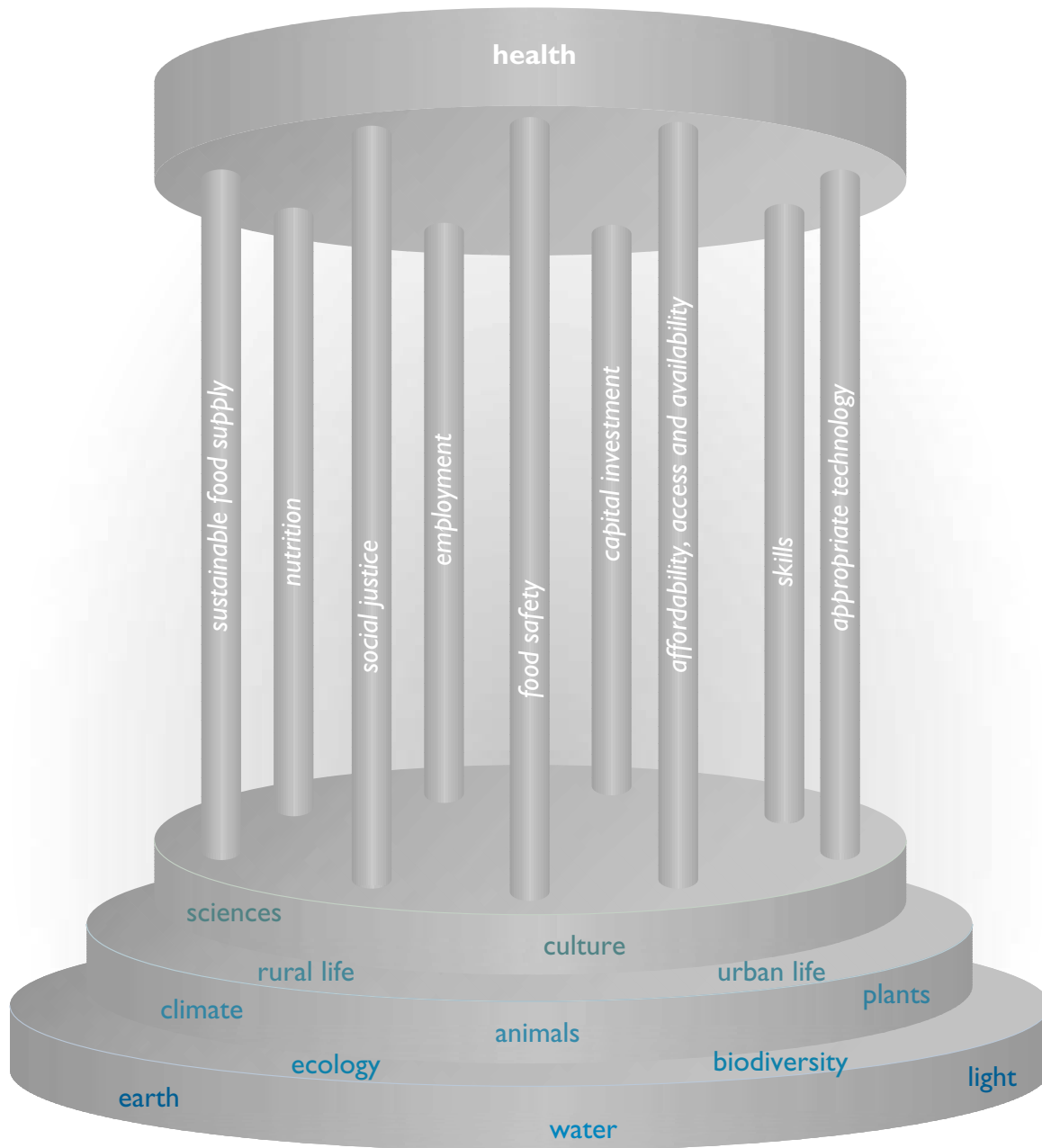


Figure 2 Food's contribution to health: the complex model

the diversity of the South is to intensify farming still further; the goal being to leave islands of biodiversity in a sea of agricultural intensification.^[25]

**The philosophical questions:
what is food and farming for?**

The rise, shape, and sustainability of human civilizations in the past ten centuries can be directly linked to our agricultural strategies, that is, how we feed ourselves. Philosophical choices shroud development.^[26] Although much public discourse in

affluent societies has been concerned with modernity as progress, this rule applies equally to rich as to poor societies. Alongside the persistent hunger crises in the South have emerged concerns about issues as varied as food safety, ecological damage and new technologies.^[27] After decades in which agricultural strategy has been something perceived in the North as a problem for the South where countries with largely rural populations produce primary commodities for export, suddenly in the North too food and farming policies have rocketed

up the policy and political agenda. The return of agriculture and food as policy headaches has dented the triumph of neo-liberalism in public policy, a process well underway even before the collapse of the Soviet Union and its empire.^[28]

Prior to the modern era of regional and globalizing food trade, it was only countries with empires (e.g. Ancient Rome, Britain) or mercantilist zones of influence (e.g. Venice, Soviet Russia) who had the option or who could afford to act otherwise. Seeds, plants, animals and farm practices had spread around the world for millennia, of course. The general rule before the 20th century, however, was that most industrializing societies in Europe and North America had farming policies wholly based, at least initially, on what materials they had at hand. Britain at the height of its Empire phase (early 19th to mid 20th century) chose to abandon its farmers. In 1846, it repealed its protectionist Corn Laws and initiated a century-long policy experiment in which it gradually came to rely upon foods produced from within the Empire, to which it in turn sold goods produced at home. The mercantilist ‘bargain’ was goods in return for cheaper food than it could produce for Britain’s industrial mass labor force. The Empire’s vast land and labor could produce agricultural commodities cheaply only with the infrastructure of sea transport, policed by Britain’s mighty navy. But this policy is the historical exception. Most countries have eaten mostly what has been produced reasonably locally, i.e. regionally if not nationally.

For any given civilization - from ancient China and Rome to the Incas and the Zulus - reliance upon maintaining the proximity of land and food has had implications both for the integrity of the ecosystems which have supported (or failed) those civilizations, and for the physical and mental well-being, creativity and adaptability of their citizens.^[29] Even in Britain, two world wars and a restless citizenry forced policy changes by the mid 20th century. Although retaining the rhetoric of a ‘cheap food policy’, in fact Britain quietly rebuilt its agricultural base, a process consolidated by entry to the European Economic Community (now the European Union).^[30]

Citizens of the most memorable of our ancestral homes transcended local limitations through trading with other communities, introducing new crops, cross-breeding animals, subjugating other people

and stealing their food, or, when all else has failed, migrating to greener pastures.^[31] The mother of one of the authors (DW-T), who has lived through the Russian Revolution, civil war, famine, plenty, migration, drought and floods, is fond of saying there is nothing new under the sun. Many pro-globalization warriors might agree: what is really new about global trade, genetic engineering, economic monopolies and emigration?^[32]

And yet, if these science-based, “modern” activities are intended to improve human well-being on the planet, why is it that agriculture world-wide not only produces more food than ever before, but also more ill-health, environmental destruction and social disintegration? If the Input-Output Model has been so successful, why has agriculture become so problematic? Why are hundreds of animal and plant food species slipping into oblivion before our eyes, even as we unravel the wonders of the genomes? Why are millions of people dying from under-eating disorders at the same time as millions are dying from over-eating disorders? If health is connected to wealth, why is this global economic boom resulting in so much misery? The more starry-eyed proponents of globalization, at best in pursuit of freedom for all,^[33] at worst mere ideologues for corporate welfare,^[34] and the old cynics are correct about the categories of change. It is not *what* is changing that is important; it is the speed, intensity, scale and ownership of change at the dawn of the 21st century that make all the difference. Speed, these anti-critics seem to imply, is irrelevant; one can only hope that we don’t have the misfortune of encountering them on the highways. Intensity doesn’t matter, they say, and we are gratified that they are not designers of lighting equipment. “Of what importance is scale?” they ask, and we wonder to which ‘empty continent’ on which ‘empty planet’ they are planning their next migration. And why worry about ownership? Are Cargill and Monsanto any different from the British and Dutch East India companies? Are they not even more benign? To which one answer might be to wonder whether anything has been learned from the past several centuries of struggle to improve democracy, health, and sustainability.

Introduction of new species and changes in trading patterns activities have always led to the deaths and extinctions not only of many plant and animal species, but of whole human communities. Over the

long haul - centuries, millennia - we and our fellow organisms have co-evolved into new relationships (or died) and the socio-ecological systems of which we are part have adapted.

Local adjustments may still be possible, but ecological and global adaptation is increasingly in doubt; evolution favors the fleet only if they have lairs in which to rest periodically and even then only sometimes, over the long haul. Economic, agricultural, health and environmental policies at the dawn of this century are tearing open the skins of the ecosystems and communities in which we live, the better to free us to trade. But an animal without a skin is not an animal for long. Based mostly on the facile and inappropriate science of controlled laboratory conditions, our policies and actions are not based on full, complex, socio-ecological accounting. We may well save a few cormorants or ferrets, while all around we are putting billions of people and other species at risk. The sky may not be falling, but is already clear that we have punctured some rather large holes in it.

In order to describe and resolve the dilemmas we are facing, we need to consider not only the separate connections between agriculture and the environment; the food system and agriculture; eco-

nomics and political policies and the food system; and health, nutrition, disease, and public policy. These are, after all, well-established connections. We need to learn to see all of these elements and their interactions simultaneously. Figure 3 gives a simplified version of how we might look at human diseases related to agriculture: corporate-driven economic policy is creating increasingly divided populations of rich people (small numbers with high profiles) and poor people (large numbers, many invisibly laboring in the service of glossy corporate logos); family members in rich families work for self-fulfillment; in poor families, they work for survival. Both demand fast food; the poor need it cheaply, so they can live; the rich want it fresh, so they can live better. Fast, cheap food requires energy subsidies and economies of scale, which require environmental simplification, which fosters large niches of opportunity for pathogens such as *Salmonella* and *E. coli*. Fresh food year round requires global sourcing and subjugation of local well-being to that of the wealthy consumers elsewhere. We would ask that you explore this figure further as you read the article, and perhaps add some connections we have missed. We doubt that you will find yourself erasing any of them.

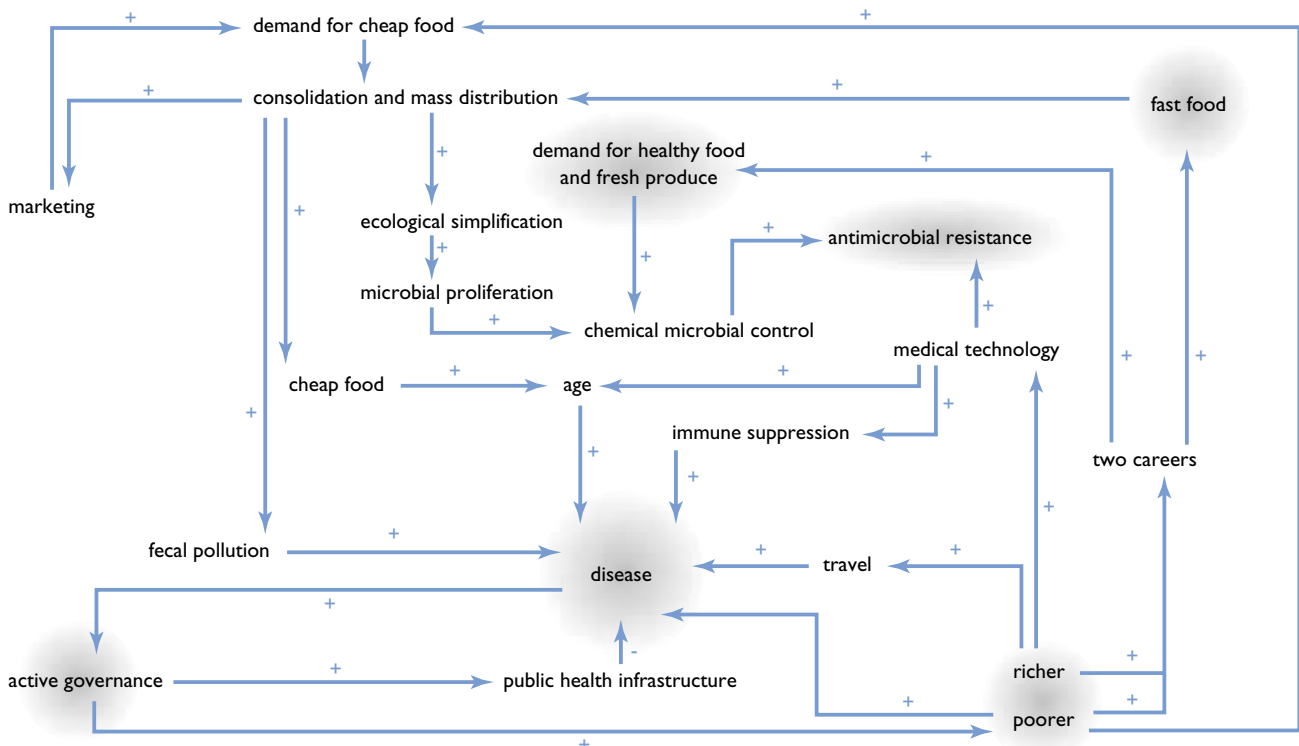


Figure 3 Agro-food and disease: some connections

To help us begin to see this new world where everything is connected, we shall tease it apart and look at a few of the pieces. In the end, we shall propose some new ways of putting our vision of this complex world back together in a way that not only makes scientific sense, but will enable us to gain more effective control over the global events which are so disrupting our lives. Indeed, since health is really nothing more or less than the capacity to achieve reasonable goals within the biological constraints we are all born into, we hope, by definition, thus to improve our health.

The nature of the problem

Agriculture is facing an unprecedented challenge: how can the world feed more than six billion people?^[35] More food is needed and quickly.^[36] About a third of the world's children are underweight and/or undernourished and, although this has been declining in recent decades, it still translates into tens of millions of children.^[37] This not only has direct effects in terms of permanent damage to learning and coping. Under-nutrition also predisposes people to succumbing to infectious diseases, which kill some 13 million people per year, more than half of them children under five, most of them in poor southern countries.^[38] Many of these diseases are clearly the result of over-crowding, poor sanitation, contaminated water supplies, and insufficient food.

Yet it is not at all clear that the problem is simply one of insufficient food. Even as millions starve, the industrialized world's obsession with "thin" versions of female beauty has induced an equally destructive backlash which lauds obesity as a badge of personal acceptance.^[39] In fact, the world is now facing a global epidemic of debilitating obesity – associated with diabetes, heart disease and a plethora of other diseases.^[40] Tragically, this is occurring especially among children and poor people within industrialized countries, and in those selected areas of the world which are appearing to "benefit" most from our new economic system. A significant part of this epidemic is attributable to changes in diet and lifestyle actively promoted by the trade, economic and cultural actions of the West, many of whose governments purport to want to aid development and solve the problems of the developing world. At stake is what is meant by development. Is development the apeing of the West's trajectory?^[41] Or just when its lifestyles stand condemned

as grossly wasteful of the earth's resources, is this the wrong kind of development?^[42] Development, like all aspirations, can be interpreted and pursued in different ways. In much of global public policy, the model is that of a ladder, with the affluent West at the top, and according to ideology either helping or cajoling or blaming developing countries which are in turn scattered around the foot of the ladder or on its lower rungs.

The kinds of agriculture being promoted by global traders tends to be energy-inefficient, fertilizer- and pesticide-intensive, focusing on cash crops at the expense of local food security,^[43] and reflecting inappropriate dietary habits. Thus, Guatemalan farmers are enticed to intensively produce "non-traditional" crops for export to United States, even as almost half of Guatemalan children suffer from malnutrition; at this point, Americans discover that other countries further south can produce these crops more cheaply, so that Guatemalans lose even the small benefit of incoming cash. These scenarios are repeated globally with depressing regularity.^[44,45]

At the same time, huge areas of arable land are being lost to such forces through urban sprawl, salinization, and soil erosion. This is resulting in declining yields and declining availability of food. Furthermore, most of the world's rapidly degrading ecosystems are in poor southern countries, where the lands are need most. Ironically, many of these are the result of mismanagement of arable land related to attempts to "improve" agriculture.^[46]

It can be argued that globally the cause of all this human and ecological destruction is total resource consumption by the human species, which some attribute to the massive per capita over-consumption of industrialized countries, and some to the overall high consumption (because of high population numbers) by non-industrialized countries.^[47,48] Rarely explicitly incorporated into public policy are the well-documented facts linking the wealth of northerners with the poverty of southerners, yet the overall problem of sustainable human life on this planet cannot be resolved if these issues are dealt with in some kind of de-coupled fantasy. More than 80% of the patents granted in developing countries, for instance, are held by residents in industrialized countries.^[49] The so-called healthy countries of North America and Europe are sucking up the world's energy and resources at an alarming rate

to maintain their “healthy” environments. It is no wonder that increasing attention is being paid to, and criticism voiced about, the advisability of pursuing unfettered free trade.^[50,51] This is the mechanism promoted by the corporate elite through groupings such as the International Chamber of Commerce and other commercial lobbies, yet the inequalities which arise are implicated as a major cause of ill-health and the most intransigent roadblock to attaining health for all.

The ideological underpinning of unfettered free trade and globalization is a warped vision of Darwinian *individual* competition and a confusion of refinements in medical technology with improvements in health. In contrast, all the major public health gains in the world in the past century have owed less to gains in medical technology, but have come about more through *public* co-operation and investment in infrastructure such as housing, employment, water and food supply.

While there is little doubt that fewer people and better technology would raise somewhat the great burden of disease borne by the poor, there is no evidence that the ownership patterns and power structures favored by corporate libertarians will help in this task. The power of the global corporate elite is considerable. Their turnover is greater than many countries. Yet the food that they are associated with is less at the fruit and vegetable ‘end’ of the health spectrum and more at the fats, sugar, meat, alcohol and drinks end (See Table 1). Income inequality has grown rapidly both within and across the world as globalization has intensified. The income gap between the fifth of the people living in richest countries to the fifth living in the poorest has grown from 30:1 in 1960 to 74:1 in 1997. The assets of the world’s top three billionaires are more than the combined GNP of the 600 million people living in the world’s poorest countries.^[52] Although politicians and researchers rightly argue over exact mechanisms, there is no doubt that these income inequalities are associated with increased morbidity and mortality rates.

Although the industrialized world clearly has an huge advantage in life expectancy, it would be seriously misleading to argue that the West lacks health problems. Nowhere is this more apparent than when we look at food-borne and waterborne diseases. The European Union, for instance, has been wracked with a meat-borne crisis since the

Table 1 The world's top 10 food & beverage companies

company	1997 food & drink US millions	food & drink as % of total revenues
Nestlé SA (Switzerland)	45,380	95%
Philip Morris Co. Inc. (US)	31,890	44%
Unilever Plc/NV (UK & Netherlands)	24,170	50%
ConAgra, Inc. (US)	24,000	100%
Cargill, Inc. (US)	21,000	38%
PepsiCo, Inc. (US)	20,910	100%
Coca-Cola Co. (US)	18,860	100%
Diageo (UK) Guinness + Grand Metropolitan (UK)	18,770	93%
Mars Inc. (US)	14,000	100%
Danone (France)	13,970	94%

Source: RAFI/ Seymour Cooke Food Research International⁹⁰

late 1980s over Bovine Spongiform Encephalopathy (BSE).^[53] More than any other single disease, BSE has accentuated the tensions between trade and health policies.^[54] Despite having a Single Market since 1986, barriers to trade have had to be hastily re-erected as hundreds of thousands of cattle have been slaughtered. At the time of writing, 85 human deaths in the UK and 2 in France are attributable to variant Creutzfeld-Jakob Disease (vCJD). The structural imbalance of Europe’s public health policy in relation to commerce is now a key political question.^[55,56,57,58]

Another illustration of our case is that since the 1970s, the incidence of reported infectious food- and water-borne illnesses has more than doubled in all industrialized countries. Figure 4 shows rates of various food-borne and waterborne infections for the Japan, Australia and the United States, which are fairly typical for those of most industrialized countries. While some of the reported increases are due to better reporting and diagnostic capabilities, most serious researchers do not dispute that these reflect real, underlying increases.^[59] Food safety specialists tend to focus on describing and controlling individual diseases such as salmonellosis or verotoxigenic *E. Coli*, but this ignores the fact that in any ecosystem, including the eco-food system, new pathogens will simply substitute for those which

are deleted. The problem is not one of particular microbes, but one of niches created by a particular way of organizing the agri-food system. The Centers for Disease Control in Atlanta has estimated that, every year, 76 million Americans come down with food poisoning, and 5000 people die.^[60] While industry propaganda would have us believe that all these people are getting sick because North Americans and Europeans, sometime in the 1980s, forgot how to wash their hands, epidemiological studies have pointed out that the major driving forces of this food-borne disease epidemic is economic and social, ranging from consolidation and mass distribution, to globalization of trade, to a demand for fresh fruits and vegetables year-round.^[61]

Underlying all this, and probably the most damaging driving force in the world today, is the consumer demand for cheap food, which is part of a set of positive feedback cycles linked to environmental impacts ranging from pollution of aquifers to global climatic change, and health effects ranging from food-borne diseases to community breakdown. This cheap food policy is in part driven by an ideological framework which dictates that lower food prices - rather than greater equality of income - is the correct way to solve the very real problem of malnourishment among the poor.

An underlying scientific rationale for a sustainable agri-food system

Food is part of the environment which is used for nourishment by people and other animals. The particular of pieces of the environment (roots, animals, fruits, etc) selected to be modified for consumption, and how those foods are produced, are inevitably environmental issues. Options for how foods

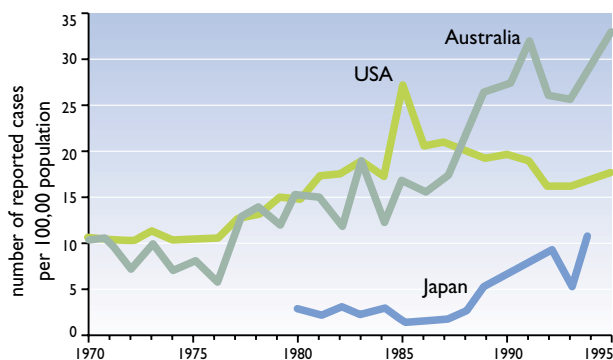


Figure 4 Increasing trends in reported food-borne salmonellosis in Japan, United States and Australia (from Käferstein et al, 1997).

are grown, cultivated, harvested, stored, processed, distributed, cooked and eaten all have environmental implications – energy usage, waste, use of resources, and so on. Food is also used by people to establish group / cultural identities; the sharing of food is an act of trust between the consumers, the producers and the food handlers in between.^[62]

Food webs are thus the basis for convivial human communities. Health - the capacity of people to achieve reasonable social goals within given biophysical constraints – is related to both nutrition (the biophysical connection) and community (the socio-cultural connection). Food is thus a key link between environmental, health and cultural issues. Yet in the rules of the world trade system, food is viewed primarily as a commodity and health as a potential barrier to trade.^[63] Countries, for instance, have to justify why they want to keep a food from entering their borders. The presumption is that trade is good. Yet there is growing awareness that whatever its benefits (and to whom they mostly accrue), there are also disadvantages such as spread of diseases, unhealthy cultural patterns, inappropriate infrastructures.^[64]

The process Popkin has termed the nutrition transition, for instance, in which western eating patterns are drifting southwards brings in its wake immense and costly health challenges.^[65,66] Another feature of the new global food culture is an acceleration of meat eating. One estimate is that meat consumption will grow 43% world-wide by 2020, with an accompanying 40% rise in demand for cereals to feed the animals.^[67] Yet since 1950, the area per person available for grain harvest has declined from 0.23 hectares to 0.12 hectares by 1998.^[68]

Over the past several decades, a series of practical and theoretical developments have laid the foundation for multi-level, sustainable management of public health, the environment and agriculture. These developments, sometimes grouped together under the rubric of “The Ecosystem Approach”, are based on insights from ecology and socio-economic systems, and how they are linked.^[69,70,71] The key themes are holarchy and feedback, the policy implications of which also have to be addressed.

Holarchy

Both social and ecological complexities may be seen as occurring in nested hierarchies, for which Arthur Koestler coined the word holarchies^[72]. This sys-

temic view of reality is explicitly socially constructed as a useful way to understand complex phenomena, rather than, necessarily, describing physical realities. If we look at reality in this way, we consider each unit, or *holon* (individual, family group, neighbourhood / locality, subwatershed, watershed) as both a whole and a part of something larger. The smaller units represent a richness of possibilities (individual creativity, genetic variation, diversity of all kinds) while the larger units in the same set provide constraints (culture, soils, climate). Societies and ecosystems have co-evolved in such nested systems, which has both stimulated evolutionary change, and put brakes on the speed at which evolution can occur. In an ever-changing context such as the world we live in, BOTH are necessary ingredients for sustainability: the creativity to allow for new possibilities to enable adaptation to changing circumstances, and the holarchic context to provide some stability over time so that new adaptations have a context in which to flourish.

If we look at the world this way, we can see that species in any given locale are more co-dependent than species outside that locale; loss of some species, or disruption of some relationships, can have serious impacts on a whole range of other species which have co-evolved in the same locale. Massive destruction (species extinctions, collapses of civilizations) have consistently occurred in the past when these nested boundaries were ignored. These problems of invasive species can occur naturally when species are transported by wind and water, or migrate overland. People have increased the speed and scale of such invasions as we have migrated to different parts of the globe, carrying plants, animals and microbes with us from one locale to another. More recently, rapidly changing the genetic make-up of local crops, which changes the nature of relationships which have co-evolved locally over long periods of time, has been seen to have major disruptive effects on local communities and ecosystems, making them more vulnerable to global power shifts. Historically, people have tolerated these extinctions of other species and human communities, either because they did not understand the causes and thus could view them as being outside their sphere of influence, or because subjugation and destruction of foreigners was considered to be politically and ethically acceptable. Both these explanations or excuses are now unacceptable.

Feedbacks

Socio-economic and ecological components of reality interact in both self-reinforcing (positive) and negative feed-back loops. The negative feedback loops provide mechanisms of adaptation and control. Positive feedbacks result in particular stable patterns (deserts, tropical forests, oligarchies, democracies). These stable patterns are sometimes called attractors. Thus building a road may change access to markets, which changes crops grown, which changes local nutrition as well as economic variables, which alter market demands, and so on (see Figure 3). By changing either the nature or the rate of change of key variables, the entire system may itself be pushed into the domain of a new attractor. For instance, adding pollutants to the Great Lakes in the USA changed the system from a benthic to a pelagic one. Migration to cities, population increases overall, and economic market forces created through political policies have been associated with a shift from extensive to intensive agriculture. Crossing such thresholds results not just in changes in the particular variable (e.g. the price of a food as a critical enterprise-scale is crossed), but a whole range of other variables connected to that variable in the domain of the new attractor (e.g. the sudden change incidence and patterns of foodborne diseases in the 1980s; waterborne epidemics related to the inability of local ecosystems to absorb intensive agricultural pollution).

The combination of holarchy and feedbacks has two major implications. The first is that the prediction of outcomes of interventions are associated with a very high degree of uncertainty, and cannot be adequately assessed using conventional linear risk assessments. This means that, if we hold sustainability to be important, new interventions such as bio-engineered crops should be viewed more skeptically, with the onus of proof of benefit to the community being on those introducing the new technology. Secondly, even in a reasonably well understood situation, there will be different perspectives on what the important outcomes are, and whether they are beneficial or not. Thus where one group of people sees economic expansion and increased wealth, another sees ecological destruction and increased disparity. In a sense, both are correct; indeed, the notion that we can manage ecosystems to achieve a single goal such as food production or cash inflow is a kind of fatal attrac-

tion which invariably leads to destructive effects elsewhere in the system.

For instance, emphasis on economic efficiency in the British food system, noted earlier, led quite logically to the re-cycling of proteins within the system. The goal of reducing waste and improving animal production simultaneously seemed sensible.^[73] But the result was that farmers ended up unwittingly recycling disease by the feed containing rendered contaminated cow parts.^[74] No labels of bags of feed indicated this fact.^[75] ‘Science’ dictated that protein was protein, not its source. Cows thus became both cannibals and vectors for a new human disease. The impact of restructuring of the food system to pursue increased production, based on the philosophical assumptions of the Input-Output Model, are now clear. All variables were not accounted for. New disease opportunities for growth and travel were created for micro-organisms ranging from prions to *Salmonellae*. The issue of which exact agents are involved is less relevant than the fact that new niches were created which would invariably be filled.

In Honduras in the 1970s and 1980s, the heavy policy emphasis on increased productivity in agriculture was associated with environmental changes and altered the nature and size of malaria epidemics.^[76] In the first case, feedback loops were created which short-circuited naturally evolved mechanisms which controlled the passage of micro-organisms between species. In the second case, local farm production was stimulated by regional and global incentives, but there was no way for the “market” to respond to local disturbances in any timely fashion. In other words, feedback loops - normally present in local agricultural systems which limit environmental destruction by more deftly matching demand to capacity to supply - were simply not present.

These kinds of dynamics mean that negotiation based on explicitly stated values, both within and across specific levels in the holarchy (households, communities, regions), is an essential component of a scientific response to these kinds of issues. Negotiation raises questions of power as well as knowledge, which “pure” scientists can be uncomfortable dealing with or even acknowledging.

Policy Implications: the search for new processes

The decision-making stakes of continuing to use and promote the Input-Output Model of food, agriculture and health are high. We are not argu-

ing that policy-making must now wallow in complexity or hide behind it. On the contrary, if scientific evidence is inherently uncertain and if ethical and epistemological conflicts are rife, such features should be built into any approach to food and farming. In practice, however, politicians and policy-makers are prone to look for policy and technical ‘fixes’. Partly in response to food safety scandals and partly to create a separation of industrial promotion from regulation, a wave of food agencies is being set up across the West.^[77,78] But no agency, any more than any Ministry, can be expected on its own to resolve this philosophical problem. The challenge is policy and practice, not just instruments or institutions.

Although there is increasing recognition that the issues being faced by decision-makers in public health, environment and agriculture are rooted in complex interactions, there is no consensus on what this means for scientists and politicians. Reactions tend to fall into several camps. In general, the literature, interests and methods of the two groups are different, and there is no particular reason for them to meet. In the first camp, there are those who see complex systems research as being another new branch of science with little relevance to others. Members of this camp would argue that complex systems researchers study simulation models (for instance) and that food safety researchers study the survival of micro-organisms in food, except perhaps if the simulation models can be used (in lieu perhaps of statistical models) to understand the survival of micro-organisms. This is the dominant scientific response.

The second camp argues that complex systems may exist but that there are no good methods for studying such phenomena,^[79] and that there is no practical way to apply the Complex Model to real world problem solving. It follows that since there is a lack of methods needed to answer applied questions in a context of complexity in policy-making, methods should be restricted to those which can help answer the questions that can be addressed, whether or not these are the appropriate ones. This position could be termed the “muddle through” camp. In many ways, those who are working with complexity and decision-making have invited these kinds of responses by emphasizing the uncertainty and mathematical obtuseness of their work.

A third position is emerging, however. This is articulated by practitioners and scholars who have been working on issues of “sustainable development” and “risk assessment”, where theory, as it were, hits the ground of needing to make substantial, usually controversial, policy decisions in a context of uncertainty.^[80] Researchers exploring the policy implications of this unfamiliar terrain have suggested that a new, post-normal science is needed, a science of the world outside the laboratory, probably drawing heavily on complex systems theories, and certainly dependent on an extended peer group, including a wide range of legitimate stakeholders, for quality control.^[81]

Three approaches to science in policy-making

Viewed as a whole, the 20th century witnessed three approaches to the role of science within policy-making, which have been called the Classical, the Modern, and the Emerging.^[82] The Classical Approach assumed that science operates in a vacuum and that it can provide adequate evidence for policy decision-making. Risk communication is expert-led. The Modern Approach, currently dominant (but fraying at the edges) distinguishes between risk assessment – said to be a purely scientific enterprise – and risk management which is acknowledged to involve non-scientific considerations such as economic, social, cultural and evaluative considerations, i.e. the hard realities. This approach like the Classical assumes that science operates in a vacuum but unlike the Classical it accepts that science is not a sufficient basis for policy decision-making. In the Emerging Approach, risk assessments are framed by a range of non-scientific considerations such as what and whether risks are deemed relevant or how much uncertainty can be tolerated. Non-scientific considerations are presumed to play a distinctive ‘upstream’ role by providing the prior framing assumptions shaping how risks assessments are conducted and constructed.

Discussions such as these suggest that formulations of the role of science in policy-making are themselves subject to policy options. The Complex Model, unlike the Input-Output Model of food, farming and health offers a far richer but more sober basis for public policy. Thinking in the World Health Organization is turning in this direction, but needs to be accelerated. The WHO European

Region and EU French Presidency initiatives are taking a welcome co-ordinated lead in proposing that nutrition policy, for instance, should no longer be viewed as a separate policy stream.^[83,84] They propose that nutrition and food safety, both long viewed as key determinants of health, cannot be satisfactorily addressed unless coupled with delivery of sustainable food supplies. Joint rather than isolated policy goals are now essential.

New policies for food, farming and health are needed but they are based upon conceptual bases and assumptions, as all policies. The central assumption for the new Complex Model is that an agri-food system should be sustainable, that is, should have the capacity to continue in the long-term and to open rather than close options for future descendants compared to those of today.

The goals for food and farming under the Complex Model would include, for example, local diversity. For this to happen, the source of opportunity would need to be protected. For this in turn to happen, the context of local diversity (habitats, communities,... holarchies) needs to be preserved, so that the opportunities can be realized. In order for this to happen, communication across holon boundaries needs to be fostered even as those boundaries are maintained. Scientific and other scholarly inquiry, democratically derived values, public policy and management need to be brought into the same arena. This is so systemic feed-back loops can be more appropriately studied and trade-offs be explicitly negotiated. Table 2 gives a comparison of the policy approaches of the Input-Output and Complex Models.

Proponents of both Input-Output and Complex Models agree that the world faces immense challenges in the 21st Century. As has been noted, shifts in policy are already occurring, albeit slowly and patchily. Changes in a hopeful direction are already occurring at the local, regional, and global scales. There is considerable effort even from the heartlands of old-style agricultural efficiency that human survival, however conceived, requires more effective engagement with local, geographically-defined communities in inter-related problems of environmental management, agriculture, and public health.^[85,86] A major constraint on this work has been the fanatical corporate libertarian policy context which *actively* works against local democratic control; in poor countries, this is often compounded

Table 2 Comparison of the Policy Approaches of the Input-Output and Complex Models

Policy Issue	Input-Output Model	Complex Model
Economic framework	Globalization; long trade routes; protection bad.	Localization; short trade routes; protection good (depends who for and how).
Agricultural policy	Farms should intensify; monoculture; efficiency; use of agrochemicals; capital replaces labour to control nature.	Farms should extensify; protect biodiversity; nature-friendly/organic pest control.
Ecological Health policy	Opens biosphere to market-led controls (e.g. pollution permits); promotes biotechnology and pharmaceutical solutions to globalization of disease.	Supports bio-regional ecosystem; maintains boundaries around ecosystem where possible.
Food distribution policy	Processed (stored) food from factories; supermarkets; encourages urbanization.	Fresh (perishable) food from the land; local markets and shops; supports rural-urban mix.
Food cultural policy	De-skilled consumers; social fragmentation and inequality; burgerization & fast food; consumers.	Skilled consumers; common culture; local specialties; slow food; citizens.
Approach to health costs	Externalized health costs; health defined as healthcare costs; cheap food is the goal.	Food prices reflect fully internalized costs; affordable, accessible food the goal.
Role of Science in supply	Replaces on-land labor; privatization of genetic and biological materials.	Maintains and supports labor on the land; promotes community-led knowledge systems; public ownership of all genetic and biological materials.
Role of science in policy	Expert-led; 'top down' risk communication; assumes (some) certainty; politicians allow others such as 'arms length' agencies to take decisions.	Collaborative; assumes uncertainty; politicians make decisions.
Level of policy making	Global filters down to local; centralization; token consultation; top down flow of information.	Appropriate level for each problem; information flows between all levels but primacy on bottom up definition of problems and policy agenda.
Political framework	Centralization and de-democratization of control over agriculture and food; fragmented decision-making.	Regional democratic control over food and agriculture; integrated decision-making.

by poor levels of literacy; in wealthy countries, this is undermined by a weak sense of community and an emphasis on individuality.

At the regional level, Europe has been at the forefront of debates on these issues. A recent review of the changing nature of public involvement in scientific debates in Europe.^[87] Case studies such as of the factory explosion at Seveso, Italy, the BSE epidemic, and the regulation of genetically modified food crops, all make it clear that governments and scientists are being forced to deal explicitly with the

contradictory and value-laden ramifications of their decisions in an increasingly transparent manner. The use of the 'Euro' word 'transparency' with regard to decision-making is itself illuminating. Glass is transparent but it is still a barrier. The older political discourse around democracy suggests that what is required is accountability, not just transparency.^[88]

Globally, there has been an increasing recognition in World Bank documents as well as those of the Consultative Group on International Agricultural Research (CGIAR) that participation of

legitimate stakeholders is an essential ingredient of any sustainable programs for global development. Indeed, after years of research which has been successful in conventional scientific terms, the CGIAR has launched a major, system-wide participatory initiative. The United National Development Program, as part of its discussions about sustainable livelihoods, has been the global institution which has most explicitly addresses the problems of complexity.^[89] But the marginalization of UN programs such as UNDP and UNEP in comparison with the political and economic muscle of the World Trade Organization suggests that scientists, together with other progressive social movements and Non Governmental Organizations, will have to work hard to give such bodies and leads the publicity and political clout they warrant. In this, the kind of cross-boundary and mutli-scalar networking and consensus (geographically, institutionally and in terms of disciplinary and practical interests) that has emerged in response to the attempted imposition of mainstream In-Put Output policies globally may itself serve as a model of how resilient, sustainable policies may be created in a world of complexity and uncertainty.



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