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Chapter 11: Exploring the impact of healthcare and pharmaceutical advances on agriculture

11.1. Introduction

Advances in healthcare and pharmaceuticals play a major role in improving social, economic, and agrarian development across the globe. Healthier individuals—especially agricultural workers—show improved labor productivity and management abilities. Consumers with better knowledge of health, disease, and nutrition are able to demand new foods, stimulating new agricultural production and economic growth. Finally, as increased life expectancy creates an aging population that survives longer years, medical and health-related needs generate new demand for nonstaple food products, such as flowers and other ornamental goods, resulting in further economic and agricultural development. The work presented explores the effects of health and pharmaceutical advances on the agricultural sector and how agriculture generates a positive contribution to health (Pretty & Bharucha, 2015; Jeyaraj et al., 2016; Munir et al., 2020). In this paper we highlight several aspects of the interaction between health, pharmaceuticals, and agriculture, including both positive and negative links, and attempt to provide some empirical foundations for our explorations. Our goal is to show you, the reader, how the experimental evidence supports the idea that pharmaceutical and healthcare advances do have a significant and positive impact on agriculture, especially on developing nations. We present an overview of the various concepts and empirical findings about the interaction between health and agriculture, providing much of the theoretical background needed, in a systematic way. This survey neither attempts to be a completely exhaustive overview nor provides a comprehensive set of citations for previous work. Rather our treatment serves as a suitable introduction for researchers with an interest in the area (Singh et al., 2018; Riaz et al., 2020).

11.1.1. Overview of Key Themes

The 21st century has witnessed a remarkable explosion of healthcare and pharmaceutical advances. The emergence of mRNA vaccines arose from a decades-long focus on explicitly delivering nucleic acids, and industries developed to enable prophylactics against contaminants and vectors of infectious disease, native to us and exotic. Drug delivery innovations altered innate immune reaction, shifting the paradigm to small molecules for large effects. New classes of medicines, such as monoclonal antibodies, CAR-T cells, and RNA therapeutics, represent other modes of innovation. New treatments for chronic diseases that plague modern living have arrived, such as cancer and diabetes. The "Golden Age" of drug discovery continues, propelled by innovations in compound screening, structure-based design, sequencing and genomics in general, and artificial intelligence. The impact of these innovations is presented herein.

While innovations in healthcare and pharmaceutical technologies are oftentimes stated in a context to only humans, livestock health and wellness is at least partially dependent upon the same parameters. The human health industry has a strong animal health component. Livestock health is the intersection of human and animal health. Crops require livestock in the development of fertility by impact of manures. Animal source foods provide nutrients to humans that they are unable to directly obtain from meals based on crop production. Therefore, success in these healthcare and pharmaceutical advances will have downstream effects on livestock health and well-being. This, in turn, will have subsequent effects on crops and crop production related to fertility and food. Further, a major global health phenomenon, as the population increases, is that diets are shifting toward animal source foods, and more specifically red meats produced by ruminant livestock – cattle, sheep, and goats.

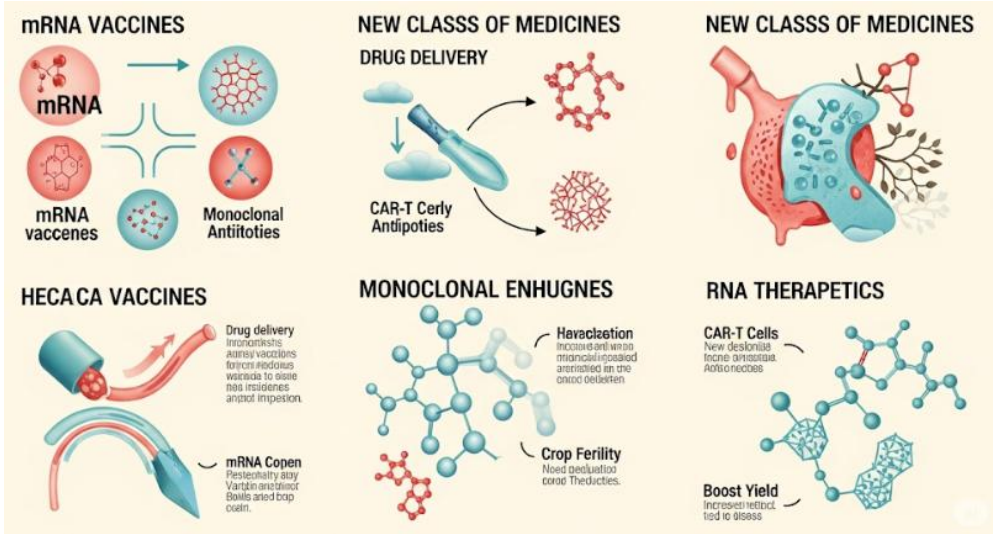

Fig 11 . 1 : One Health: Pharma Innovations in Agriculture

11.2. Historical Context

Historically speaking, exchanges of advances between these two scientific fields were rare. Civilizations have used medicinal plants for thousands of years. Ancient Egyptians, Greeks, Chinese, and other civilizations utilized plants as medicines and used their intoxicating properties as early as 3000 BC. The "founding father" of medicine wrote some 300 medical dissertations about healing, surgery, and observation of patients, while both the Greeks and Romans had their own pharmacopoeias, with descriptions of herbal medicines and dosages.

Even before Europeans began colonizing the Americas, Native Americans were adept at pharmacognosy, having developed a wealth of knowledge concerning plant chemical effects on conscious and subconscious states of human beings. This interest in pharmacognosy began to increase in Europe with the Renaissance. Western medicine increasingly began to pay attention to using plant products for making medicines.

In the 17th century, a Dutch botanist illustrated many poisonous plants, while an English physician wrote and published a practical guide to herbal remedies. Insulin is a remarkable case where the discovery of a biological chemical to treat diabetes was made at the same time as the first method of producing it synthetically was developed by a different research group. The coordination between agriculture/food production and healthcare/pharmaceutical research and development has not been uniformly harmonious. However, biodiscovery work on medicinal plants has given rise to an expansion of agricultural diversity, and has produced "natural product" medicines. Nature has provided a toolkit from which these lessons may prove useful in the future to address some of the challenges arising for agriculture because of healthcare and pharmaceutical advances.

11.3. Healthcare Innovations

Healthcare is all about magnifying the health potential of the particular people who an industry serves. Healthy individuals build economies, generate products, and provide consumer demand for goods and services. A more productive society albeit one requiring less infrastructure investment only benefits the utility to the individual and contributes to the efficiency of society at large. The local agriculture industry provides the basic food requirements of that society but telehealth service and pharmaceutical efficiencies are reducing lost production from communicable disease and other health related absenteeism, diminishing the child and elderly dependency load while increasing the

number of working age individuals engaged in productive activities relative to the dependent members of society. The local agri-food distribution system continues to expand worldwide with increasing involvement of major chain stores in the food selling end of the chain but the distance between consumer and producer with the disconnection of the local farmer from his clientele still raises problems. Industrial pollution and health disparities promote ill health that may or not be remedied by modern medical practices. There are major disconnects in service provision between urban and rural areas with the former benefiting from modern healthcare interventions while the latter are becoming increasingly isolated. The full social cost of a modern society tends now to neglect individuals in these remote areas even in a consumer driven economy. Services are offered on the basis of profitability with diets high in refined carbohydrates and sugar leading to dependency on health services rather than the local food producers. Telemedicine is now making inroads into these areas with the goal of bridging the healthcare delivery gap between the urban and rural centres. In the past, the primary focus has been on the development of more genetic research and dealing with the actual biological problems encountered by various specific crops. Biotechnology has now enabled the introduction of specific or novel characteristics into existing crops thus avoiding some of the inefficiencies encountered with alternative and older selection methodologies. Current research could make it possible to supplement normal horizontal disease resistance via gene transfer with high virulence crops carrying specific desirable gene attributes within the existing fields.

11.3.1. Telemedicine in Rural Areas

Innovations that improve healthcare delivery also improve the lives of people in rural areas. The lack of ready access to quality healthcare is an issue that impacts rural areas worldwide from Africa to North and South America, and Asia to Europe. Throughout the world, telemedicine is being adopted as a remedy to alleviate the problem of scarce or nonexistent healthcare resources such as specialists. A major contributor to this lack of access to healthcare is the shortage of general practitioners and other professionals that has worsened due in large part to differences in income potential and work-life balances. In fact, many rural healthcare facilities have closed due to these shortages. The pandemic increased government support of telemedicine training and reimbursement policies, raising awareness about and adoption of telemedicine. As specialists are in relatively short supply in many countries, the movement towards telemedicine and teleradiology is likely to continue to grow in the future, addressing timely care and efficient solutions of difficult healthcare delivery problems, at least for some tight financial periods.

Telemedicine innovations and adoption as an enabler of healthcare access is more than just being able to connect patients to remote specialists or radiologists or indeed even physicians. Given the skill and technology available presently, now it is possible to provide specialty-level add-ons to the more general practice of those rural healthcare providers who remain. Yet, rural telemedicine adoption does serve some major obstacles. Individuals in rural areas are less likely to have internet access than their urban counterparts, both to seemingly lack of wireless access and affordability of services, as well as device ownership. The cost of travel to and from necessary appointments may outweigh the benefits of lower provider mode rate will need to consider additional costs involved where both rural healthcare provider and remote provider, plus family time out of community resources, are accounted for, compared to local providers.

11.3.2. Genetic Research and Crop Health

The importance of a healthy human population rests on the basis of a healthy and productive global agriculture, requiring greater productivity to feed the world's population. Rapidly advancing molecular genetic research is occurring within the medical and veterinary arenas, and some of those developments are of immediate potential use in crop agriculture. Starting with the cloning of plant genes, this work has rapidly expanded to include not only the dissection of regulatory DNA sequences and the elucidation of the genetic and molecular basis of quantitative traits, but also advances in plant genome sequencing, molecular tagging of genes predicted to be useful in selection, development of molecular markers for breeding purposes and, for some species, development of transformation methods for introducing novel genes with predicted agronomic utility. Large investments are being made in developing transgenic plants with enhanced commercial value by expression of animal and human products, particularly secreted products that require glycosylation. Collection of diverse germplasm and utilization of natural variation across species should continue to yield high returns. Plant research is closely related to both animal and human medical research via protein secondary structure prediction and exploration of protein databases from diverse species. The world-wide investments support major increases in understanding specific genomic 3D protein structure and function across taxa. Reciprocal usage of that information by researchers focused on plant genome structural prediction offers developmental opportunities. Development of crops that are resistant to environmental stress, such as drought, salinity, and heat, is probably the greatest need in developing areas of the world.

11.4. Pharmaceutical Advances

Vaccines represent an underappreciated area in agriculture. Most people probably don't think of livestock vaccines spending more than a billion dollars in annual research and development costs, but they do. Researching and developing vaccines to protect the health of herds and flocks of livestock, from cows to cats, is a shared priority, and a pretty new one too. Vaccines offer two levels of protection from zoonotic disease: protecting animals from becoming ill, and using animal health to bolster human health through decreased pathogen loads in the environment. This second protective level has historically received little attention; priorities have often skewed vaccines and vaccine research towards diseases that do not impact human health. But this is surely changing.

There is competing demand for food produced by livestock, and potential demand associated with pig butchering. Demand in the animal sector has increased in parallel with demand in the human sector. This examination of both sectors together will continue. It is still possible, however, that livestock vaccines can be made to treat CDAD or CDI in humans. Lethal excesses of intensity of pig butchering have led to demonstrated and potential human health costs that come from exotic pathogens and other causes associated with zoonotic disease. In principle, pharma companies might be willing to collaborate with the animal sector and research livestock vaccines for pig diseases that cause zoonotic disease.

We have discussed human pharmaceuticals, diagnostics, and devices, along with agricultural vaccines and livestock diagnostics. These advances have positive effects on agriculture, in both sectors, without a question. The downside is antibiotic resistance, but that is part of human and animal health economics.

11.4.1. Vaccines for Livestock

Vaccines were first developed to prevent disease in humans, but during the last century many vaccines have been developed to protect livestock. The impacts of these veterinary products on animal health, food production, and food security are difficult to measure, but large socio-economic benefits have accrued from preventive vaccination against both endemic and epizootic diseases of livestock, and vaccine development continues to be a high priority. The volume of livestock vaccine available on the market is greater than that for human application, and many more vaccines are available for livestock, especially if the vaccine routes include mucosal delivery. Vaccination using pathogen-attenuated, inactivated, and subunit vaccine approaches is used to prevent many bacterial and viral diseases of livestock, but only limited numbers of vaccines are available for parasitic infections. These help protect food production from the threats of endemic diseases, and are used under veterinary oversight.

Veterinary vaccines operate by inducing immunity in the animal. However, in the animal, the vaccine may trigger not just protective immunity, plus ideally a rapid and potent immunological memory, but also reactogenic effects. Animals' suffering and technical shortages in vaccine production capacity need to be minimized. Protective immunity can be transferred from vaccinated mothers to their young, without use of any vaccine in the young animals; better still, maternal antibodies can be engaged early on to ensure strong specific immunity in the young later in life. Farm biosecurity also helps decrease the risk of livestock infections. By using vaccination thinking as part of a livestock herd health plan, the effect is to ensure a high level of protection for susceptible animals, as well as contributing to the herd immunity necessary to protect the animals most vulnerable to infection. Veterinary vaccinologists know that vaccine choice is important if optimum effects are to be achieved onboard a given herd.

11.4.2. Antibiotics and Resistance

Drugs that cure or prevent zoonotic infections not only provide direct, though usually short-term, benefits to animals but also prevent these infections from being transmitted from animals to people. Antibiotics shorten the duration of colibacillosis, for example, an enteric illness that is especially dangerous in swine herds when pigs are weaned and stressed by the move to separate housing. Reduction of colibacillosis in weaned pigs reduces the shedding of pathogenic strains of Escherichia coli into the environment, fewer piglet infections, and thus a decrease in the need for treatment. Shorter weaning periods and fewer rounds of treatment reduce the exposure of people, primarily meatpacking workers, to the zoonotic source of the bacterial disease. Similar effects can be envisioned in a number of other bacterial diseases, such as pasteurellosis, brucellosis, leptospirosis, listeriosis, cystitis, piglet infectious anemia, osteitis, and actinobacillosis.

Antibiotics are also used to prevent bacterial diseases in poultry and swine that can consume vast amounts of food in a short time. Swine and poultry alone account for about 70% of domestic animal antibiotic use and a large, but unknown, fraction of the world's antibiotic use. Physicians have warned that indiscriminate use of antibiotics reduces the efficacy of antibiotics for the treatment of human illnesses. As a result, the ban on the use of antibiotics for growth promotion in livestock has prompted a search for alternative methods of delivering antibiotics to crops or livestock feed and for alternative means of disease prevention. However, several countries have banned the importation of meat boosted by antibiotics. Concerns about antibiotic use have led to discussions for decades on the dilemma between non-stop reduction of the efficacy of antibiotics used in human medicine and the associated economic loss to farmers.

11.5. Interconnection Between Health and Agriculture

Agriculture provides food and other products to keep humans well-nourished and functional; the development of health is thus propitious for agriculture. Advances in healthcare may lead to population aging and changes in family structure, with less family labor available to work on smallholder farms, greater demands for labor efficiency in producing labor-intensive fruit and vegetable products, and more interest in corporate-sector managed large-scale agriculture. Increased per capita income in emerging economies may lead to greater demand for food safety and product quality, such as safe food free from pesticide residues, and organic farming, particularly for fruit and vegetable products. Such demand will drive changes in agriculture R&D investment in innovations of farming technology and transition in agricultural policy to promote labor-saving agricultural technologies. The transition from product support to environmental public goods support will lead to farming innovation in order to reduce constraints to trade that is included in the provisions of harmony between farming subsidy and agricultural development policy. The development of pharmaceuticals and vaccinations to eliminate animal disease is propitious for agriculture.

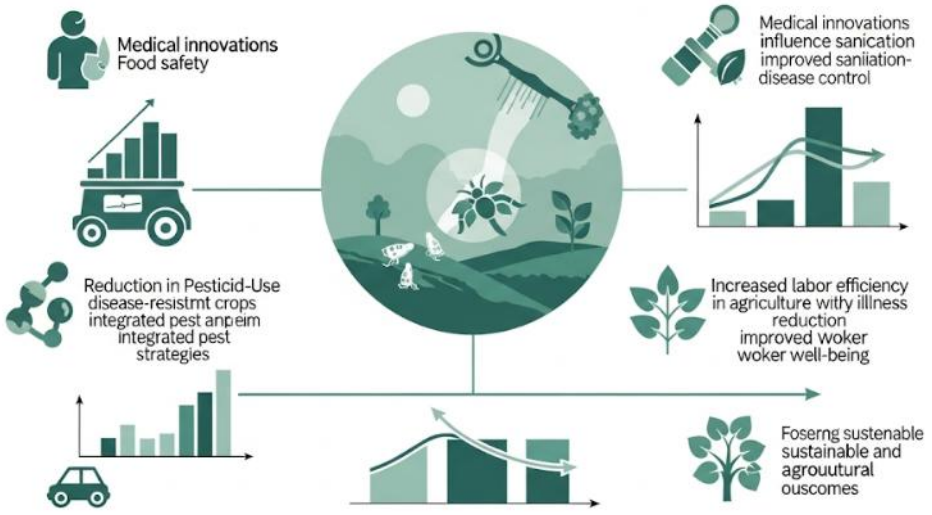

Fig 11 . 2 : The Intertwined Worlds of Health and Agriculture

Nevertheless, the problems of pesticide overuse and misuse have become an obstacle for promoting sustainable agriculture development. Pesticides have been extensively used in agriculture since their commercial availability, leading to significant improvements in pest control and profits for farmers, food security, and growth of the agriculture economy. Use of pesticides enables farmers to reduce their labor input and are thus essential to promote mechanization in developing countries. However, the frequent food safety and environment pollution incidents induced by the excessive residues of

pesticides in food, drinking water, and in environment, and by the non-selective insecticides have led to audits of the hazards of pesticides on human health and ecosystem health, and to exploration of alternatives and restrictions on the use of synthetic pesticides. Health factors for humans exposed to pesticide residue, including acute and long-term effects, focus on short-term symptoms of pesticide intoxication on work days, chronic diseases, or irreversible diseases.

11.5.1. Food Security and Nutrition

The increasing interdependence of health, nutrition, and agriculture means that farmers do not merely provide raw ingredients for manufacturers of food products: they play a key role in the nation's nutritional health. Greater cooperation is needed between the health and agricultural policy assistants of government because it is agriculture that supplies the foods that have a critical bearing on the health of the population. Health policies that encourage the consumption of specific food products or modifications in pattern and type of food consumption need to be subordinated to and supported by appropriate agricultural policies. In many developing countries, agriculture not only supplies food: it provides employment and income, and therefore affects the purchasing power of the population. There is a very real need to increase the availability of that food and to reduce food prices in order to allow the poor to procure the quantity of food they need for a minimum level of health, growth, and development. There is no agreement on how to best define, measure, and increase food security. Large parts of low-income countries currently are or are at risk of being food insecure, many of whom experience also high burdens of malnutrition. Problems of food security and malnutrition are intertwined.

Health advances have changed the burden of disease and contribution of specific diseases to the global problems of malnutrition. Child malnutrition generally considered to be associated with insufficient energy intake is decreasing all over the world, partly because excess can be attributed to the improvements of health over the last century, such as better health care, vaccination programs, and pharmaceutical advances related to infectious disease. Nutrition recommendations regarding vitamin A and iron intakes help to define the population, particularly in low-income segments, which is still at risk of malnutrition and some infectious diseases, leading research to promote the bio-fortification of certain crops, such as rice and cassava, via transgenic technology. But much still remains to be done; for instance, progress on the bio-fortification of rice to address vitamin A deficiency has only been mild.

11.5.2. Pesticides and Human Health

There is a growing body of research that implicates pesticides in many potential health risks associated with industrial agriculture. For example, children exposed to high levels of insecticides from agricultural spraying had a greater risk of developing childhood leukemia compared to those who were not exposed, with a clear dose-response relationship. Pesticides are associated with chronic health issues, such as cancer of the prostate, lung, and bladder, and there is also evidence linking pesticide exposure to increased incidence of non-Hodgkin lymphoma. Prolonged exposure to pesticides may also be a risk factor for congenital malformations of the heart. Another chronic effect of pesticide exposure that has reached epidemic levels is neurodevelopmental impairment in children. There is new evidence that exposure to respiratory toxicants, including certain pesticides, was associated with increases in the prevalence of respiratory symptoms among children. Interestingly, children might be more susceptible to the deleterious effects of pesticide exposure because their detoxification systems are still immature and their growth and development are undergoing rapid changes. Acute and long-term effects of pesticides on human health are deeply associated with toxic burden, which refers to the total amount of chemicals and environmental pollutants that accumulate in a body over time. Vaccination, antibiotics, and many other mechanisms of the human immune system can only help humans cope with infection pressure; however, the immune system was not originally designed to deal with food additives and an increasing number of other toxic chemicals entering the human body from various sources. Science has long documented the maturity and development of the immune system, and recently published data indicate that food and pesticide toxicants are capable of disrupting the human immune system. The level of immune disruption might be higher in regionally exposed children. Now, the new generation of immune-disruptive pesticides increases the importance of looking at the combined immuno-toxic load – meaning the combined exposure to chemical contaminants during sensitive life periods in children and fetuses – and the possibly amplified effects of these contaminants on the human immune system.

11.6. Economic Implications

Technological change in agri-health may impact not only human health but also the agricultural economy, albeit indirectly. Demand-side implications are mainly through changing food preferences and changing input utilization for food production. Supply-side implications are mostly about changing agricultural production efficiency, increasing supply as a result. The effects of technological change in reducing agricultural supply costs will increase the volume of world agricultural trade and promote third-world countries' development. Modernizing agriculture in third-world countries will

both achieve a basic level of social preference with equity through a fair distribution of the benefits of unequal capital accumulation and will also act as a provider of labor force for the developmental process in those fast-growing countries. The alleviation of urban congestion through labor movement will reduce the occurrence of ideas connected with massive production in both industrial sectors. Economic growth through income increase and the arrival of a higher level of preference will mean a change in demand patterns for the urban market. Income growth will increase the level of demanded safety.

Agri-health technologies therefore have implications for short-run and long-run market supply and demand. In the absence of market failures, such as monopolies or asymmetric information, changes in market supply and demand will in turn affect market prices and quantities. Market dynamics create incentives for innovative research, design and marketing by the private sector, only if it is financially feasible. Without matching consumer willingness to pay for agri-health services with research and development investments, demand-side implications direct effects on consumption will be absent. Without research investment even if demand habits change in healthcare and pharmaceutical markets, impulse matching supply side changes in agriculture will not be an automatic result. In order to yield full benefit of agri-health market dynamics both supply-and demand-side policies will be necessary.

11.6.1. Investment in Agri-health Technologies

Creating specialty crops and associated outputs rich in health-promoting nutrients will require a targeted investment in Agri-health technologies. Human health research increasingly recognizes the importance of significant dietary sources of health-promoting nutrients such as phytochemicals, omega-3 fatty acids, dietary fiber and micronutrients for reducing risk of chronic disease. Epidemiological studies have shown that high dietary intake of several of these nutrients is associated with lower mortality rates from such diseases as coronary artery disease, stroke, certain cancers and even age-related eye diseases of elderly persons. Crops which are either already high in these nutrients, or have been genetically modified to increase concentrations, will be needed in the future. Multi-disciplinary partnerships linking medical, dietary and nutrient management research disciplines are necessary to ensure that bio-fortification technology is successfully utilized to deliver on-farm productivity and enhancement of food and health quality. We also need newer diagnostic tests which monitor health markers associated with specific health-related crop or livestock components. The main constraints to ingestion of large quantities of these specialized foods are cost and taste. The specialized health-promoting foods produced by Agri-health technology biotechnology research are those with the potential to produce the largest quantity of commercially viable products that are desirable to health-promoting diets. Like their

medicinal counterparts, these functional foods have associated relatively high costs of research, development, testing and regulatory approval. The relatively limited size of the market for the specialty crops will cause Agri-health crops and associated food products to have relatively high prices as well, thereby limiting demand. The crop, livestock, and product novelty, together with their desired phytonutrient contents, will be attractive to produce with the potential of generating the high prices possible with other specialty crops. However, innovative research enabling extension of the current production conditions, improvement of cost and taste associated with the specialty Agri-health products, and provision of new specialty Agri-health products will go a long way in increasing the commercial activity of the Agri-health Technology market.

11.6.2. Market Dynamics and Consumer Behavior

The commodity sector has tended to ignore important changes in demand and market dynamics, focusing above all on trade at major markets. Yet if agri-health is to see its full potential realized, it needs to be treated differently. Speculation about the next rich market victim to price volatility – often based on the demand for corn to make biofuels – predominates in profit making and policy making decisions. The econometrics appear to show that anything other than food commodities will not influence significantly the behavior and profitability of producers and traders exporting for the global markets. Within the demand function, the responsiveness of emerging market countries to changes in global export prices will be small compared with that of consumers in the developed countries. It is suggested that if agri-health should be seen as the next major growth area, a fundamental change overview of market demand and trading relationships is needed. It will certainly be different from what it is now.

To see the challenges and the exciting potential of these changes outlined here in a market demand area, the following section outlines four relevant features of the commodities markets: perceptions of the importance of agri-health demand, radically increased global market activity, the role of retailing, and the behaviors of consumers. It is no accident that processed food has taken off so dramatically with the increase in world income. It is also no accident that at almost the same time, the incidence of chronic health problems has exploded, triggering some of the greatest healthcare market place opportunities. Just as demand for processed food exploded, the need for secondary healthcare was found to be only creating more cost burdens with little evidence to say it was improving health outcomes. The time has come for governments and their health delivery sectors to start focusing on building health and preventing illness. Consideration will have to be given as to how best to build health, just as is already calculated for creating illness.

11.7. Environmental Considerations

The previous sections discussed the role of healthcare and pharmaceutical advances on the agriculture sector. This is largely from the perspective of the need for agriculture to keep up with the changing demographic and health needs of the population with a diverse product line of better quality. What drives these advances to occur is the increasing economic activity over time along with the demand for higher quality products, such as organically grown produce, which are sold at a premium price. However, the pharmaceutical and healthcare advances also drive changes to agriculture by reducing the burden of animal and plant disease and reducing the impact of agriculture on environmental pollution.

Sustained population growth, combined with changing ideas of prosperity and wealth, has promptly increased the demand for healthier food. This requirement has put enormous pressure on agriculture to produce higher-quality food without excessive chemical inputs. The advances made in the healthcare industry in actuating early disease diagnosis and stimulating recovery processes will also assist agriculture in replenishing its lost resources in nature. As awareness for a nonpolluted environment created a ballooning demand for organically grown products globally, which can be sold at a premium price compared to conventional agriculture products, the long-term sustainability of agricultural production will depend on the adoption of organic farming practices which optimally utilize the input without environmental degradation. In the developed world, consumers' choice for organic produce has translated into increased interest in organic farms. However, contrary to the increased booming demand for organic produce, organic farms still remain only a minute fraction of total farmland. The need for production of optimum scale and nominal cost has undermined the interest towards organic farming.

11.7.1. Sustainable Practices in Agriculture

Achieving a sustainable model for agricultural systems requires premier management to allow their operation with minimum environmental impact, whilst obtaining sufficient products to feed the increasing world population and, increasingly, lower availability of arable land per capita with the expected growth of people that will appear in the future. It is also recognized that in developing countries a part of their economies is still depending on agriculture, thus this economic activity has to be favored and not discouraged with sanctions that appease specific developed countries' citizens who favor that kind of actions as a way to attract prestige. Many of the products and solutions offered by life sciences industries can and should have a huge and positive impact on agricultural practices and extensions. They can help in finding new sustainable solutions concerning increasing plant and animal productivity, but also to allow the conversion of

neglected areas into agricultural production; and allow the maximization of production, and the minimization of damages both to human and animal health, also protecting biodiversity and creating a balanced ecosystem. All these actions will contribute to detect and counteract natural economic instabilities such as upturns and downturns in the price of basic crops, allowing a stronger and fairer agricultural economics in most parts of the world. Living in a complicated world where existent advantages upon rational and sustainable agriculture are almost vanishing; where agricultural practices deprive the environment of its basic services; and where a part of the world's inhabitants are affected by famine whilst its production is declining or, sometimes, even being totally destroyed, biodiversity is a crucial tool for ensuring a sustainable future in the production of food supplies whilst also conserving the world's unique and varied natural heritage.

11.7.2. Impact of Pharmaceuticals on Soil and Water

Through the last decades, the pharmaceutical industry went through major developments, both from the perspective of sales and new products. There is little doubt that such developments led to huge benefits for mankind, especially in the health area. However, when used by livestock, some of the pharmaceuticals not only remain unbroken after passing through the animal's metabolism but actually come out in an active form. Moreover, while elements such as Cu and Zn are needed for animal nutrition, they are excreted in large amounts when administered the respective pharmaceuticals. Upon land application as fertilizers, the excreted products may contaminate the soil not only with the costs of land rehabilitation, but also with the additional costs for cleaning the water used for urban supply.

Drugs can produce their desired therapeutic effects and cause toxic effects at very different doses, and the drug at the recommended dose may not be totally effective in every patient. It is not possible to predict the effects of various drugs and their combinations on soil and water micro-organisms, but it is unquestionable that waste plastics may potentiate the drug toxic effects. These toxic effects can induce anthracnose in AI-resistant cultivars of common beans and delay allogamy and galactosylation in mango, motive haste, both important in mango exportation, or in citrus plants, economically important in Brazil. But what are the levels of drugs that may exert their expected effects without inducing side effects in other plant species? These conclusions are important in the context of sustainability because the reduction of biodiversity, which occurs when pharmaceutical products hinder the development of some species but not of the others, may negatively affect the whole environment and then the economy involved in plant exploration.

11.8. Conclusion

Healthcare and pharmaceutical advances will presumably impact agriculture either directly or indirectly through multiple channels. Quantifying these impacts is notoriously difficult. In the context of direct effects, canonical growth accounting exercises highlight the difficulties in measuring productivity gains resulting from innovations in H and C. In fact, these methods fail to measure innovation-driven gains affecting the total-factor productivity of farms, because H and C affect the latter through multiple channels other than innovative progress or efficiency improvements: these channels include, for instance, input price changes. However, the estimation of production functions could account for these price changes, and then measure the gains in productivity of agricultural innovation, as suggested by recent contributions. In this respect, it is mentioned that the relatively earlier consideration of innovation for H and C only relied on some qualitative expert evaluations assigned to individual innovations, while a recently developed conceptual framework unifies the lessons learned from the past.

From an indirect perspective, the impact of H and C on agriculture has been almost exclusively analyzed through econometric studies or numerical methods to quantify demand- and trade-supply elasticities derived from some specified model structures. Moreover, the scarce evidence mostly only reviewed H and C impacts on traditional final-demand commodities, following little reflection on the structure of commodity demand systems. Empirical studies using more elaborate multi-stage budgeting systems that account for demand interdependences involving groups of demand commodities remain scarce. The past and present contributions reviewed allow some conclusions to be drawn. Firstly, according to most studies, both H and C tend their demand effects on traditional food commodities to be at least small elasticities.

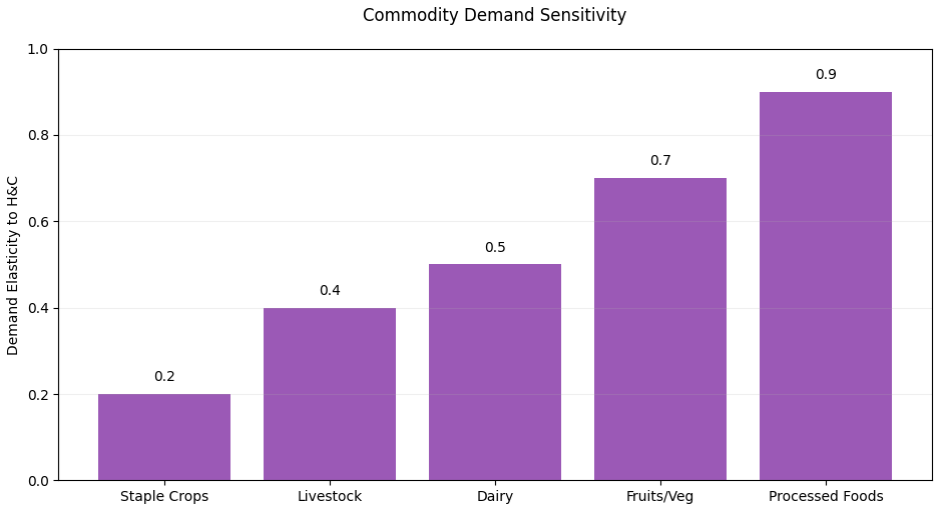

Fig 11 . 3 : Commodity Demand Sensitivity

11.8.1. Summary and Future Perspectives

Over the last three decades, the health and well-being of humans has improved by a series of advances in the field of healthcare and pharmaceuticals, thus enabling the resolution of previously lethal diseases and the improvement of life quality and expectancy. Such changes have also favored the adequate sanitary conditions in many developing countries, that up till then were presented with environmental devastation and poor sanitary states. This has resulted in the increase of available work force in these countries as well as to some extent, different dietary habits, including increased animal protein consumption. Both advancements have strongly swollen market demand for animal products, particularly in developing regions, but also in expanded markets such as Eastern Europe or Asia. As a consequence, to satisfy the consumption needs and requirements of animal protein, not only was a significant increase in global livestock production made, but also entire developing agricultural economies moved primarily to commercialized intensive animal production systems.

The ability to raise animals in increasingly crowded farms and the drive to deliver safe products to consumers and thus constant inclusion of stringent regulations within a globalized environment have favored the search for novel alternatives to classical disease control methodologies, such as antibiotics, vaccines, and minerals or organic compounds evermore included in the animal feed, that allow for better thermal stress management, increase animal health status and bolster internal defenses. This new outlook of decreased pharmaceutical intervention, based on adding nutraceutical components to animal diets, has moved us to a new revolution. With time, requirements will continue to increase whilst increasingly stricter regulations will be imposed upon farmers to maintain environmental sustainability. Technological advances are essential for adequate livestock development and meeting consumer and market demands.

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