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Plant Disease Management in Agricultural Ecosystems

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Abstract:
Infectious plant diseases pose a significant threat to global agricultural productivity, economic development, and environmental sustainability. There is widespread concern that these social and natural disasters caused by infectious plant diseases will worsen as climate change progresses, and computer modelling provides a unique opportunity to address this concern. We examine the inherent problems with current modelling strategies and emphasise the importance of incorporating evolutionary principles into polytrophic, eco-evolutionary frameworks to improve predictions. We specifically discuss how climate change-induced evolutionary shifts in functional trade-offs, relative adaptability between plants and pathogens, ecosystems, and climate preferences may feedback to future plant disease epidemics, and how technological advances can facilitate the generation and integration of this relevant knowledge for better modelling predictions. Plant Disease Management in Agricultural Ecosystems will be discussed in this paper.

Keywords:
Plant, Disease, Management, Agricultural, Ecosystems, Global, Economic, Development, Ecological Integrity, Pathogens, Ecosystems, Climate, Chemical Fertilizers.

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I. Introduction:

Growing interest in agricultural production for access to higher productivity has resulted in increased farming systems that rely on chemical pesticides or chemical fertilisers, which has caused significant damage to soil, water, air, and climate over the past decades. However, over time, scientific research began to focus on sustainable agriculture, organic farming, clean agriculture, and other concepts, which evolved into agricultural systems that maintain balance in all aspects of the agricultural and production processes, as well as consumer and environmental concerns. Many farmers have expressed interest in these agricultural systems, and many large farms are now interested in organic farming in the context of sustainable agriculture. The concept of sustainable agriculture is simply the production of food, fibre, other plants, or even animal products through agricultural techniques that protect the environment, public health, and human societies from the negative impacts of carrying out that process in the traditional format, as well as technology that also considers animal welfare, such as this type of agriculture will enable us to produce healthy foods without compromising the ability of future generations to do this [1].

Disease management in agriculture is the practise of reducing disease in crops in order to increase the quantity or quality of harvest yield. Fungi, oomycetes, bacteria, viruses, viroids, virus-like organisms, phytoplasmas, protozoa, nematodes, and parasitic plants are among the organisms that cause infectious disease in crops. Ectoparasites such as insects, mites, snails, slugs, and vertebrate animals can also affect crops, but these are not considered diseases. Resistance genes, fungicides, nematicides, quarantine, and other methods can be used to control diseases. Disease management can account for a significant portion of farm operating expenses. [2]

Disease Management Practices on Organic Farms:

Peatland disease eradication is frequently attempted in conventional, intensive agriculture. Most organic farmers believe that a certain level of infestation is acceptable as long as crop growth is not significantly harmed. In general, crop protection in organic farming does not aim to control pathogens or pests once they are present, but rather to manage the crop and the environment so that plants can withstand potential attacks and pathogens and pests are avoided. These farmers carefully observe their crops and manage the crop and its surroundings to deoptimize, rather than maximise, crop growth. However, more commercially minded farmers have recently switched to organic production, drawn by the higher prices. These farmers frequently manage their crops in a manner similar to conventional crops, substituting synthetic inputs for alternative inputs permitted by regulatory agencies. This review focuses on ecologically conscious organic farmers who are not necessarily small-scale or traditional. Their farming operations may be highly mechanised and cutting-edge.

The use of disease and nematode resistant cultivars is just as important, if not more, for successful organic production as it is for conventional production. Decisions to grow a specific cultivar are based on a number of interacting factors, and thus disease resistance does not always receive explicit attention but is frequently implicitly factored into such decisions. Many organic farmers prefer open pollinated cultivars to hybrids because they have more control over selecting cultivars and phenotypes that are best suited to their specific climate, soil characteristics, fertility management practises, and pest pressures. Organic farmers prefer cultivars with moderate to high levels of quantitative resistance if they are available, especially if they are well adapted to the local conditions. Some seed companies are beginning to choose cultivars that are better suited to organic management practises. [3]

Infectious Plant Diseases in Agricultural and Natural Ecosystems:

In natural ecosystems, climate change may have a greater impact on infectious plant diseases than in agricultural ecosystems. Although genetic variation in natural plants is generally higher than in agricultural ecosystems, natural plants lack artificial evolution, unlike agricultural plants, which can greatly improve plant adaptation to climatic change through continuous and timely integration of adaptive traits into crop varieties through breeding, making natural plants more vulnerable to climate change and pathogen infection. Furthermore, unlike in agricultural ecosystems, the effects of climate change on host-pathogen interactions in natural ecosystems are generally not amenable to mitigation through field practises and plant protection systems. Irrigation systems, for example, can greatly reduce the impact of short-term precipitation reductions associated with climate change on the growth and physiology of agricultural plants, and thus their susceptibility to pathogens, but similar practises are difficult to implement in natural ecosystems. These mitigations should be considered when simulating the impact of climate change on future plant diseases to assess sustainability. [4]

II. Review of Literature

This toll poses a significant threat to the long-term supply of high-quality food, heightening concerns about food security, especially given the potential for ongoing climate change to create conditions conducive to disease spread and localization (Zhan, 2020). [5]

Agriculture is under significant pressure to increase productivity in the face of changing environmental conditions and an increasing global human population. Plant diseases caused by pathogenic microbes result in massive annual losses estimated to range between 13 (Oerke, 2006). [6]

Due to their susceptibility, these varieties must be withdrawn from commercial use or rely on heavy agrichemical application to ensure necessary levels of productivity - a production strategy that is frequently associated with enhancing evolutionary changes in the pathogen, negative environmental effects, and increased economic costs for growers and society as a whole (Wright et al., 2021). [7]

The potato-Phytophthora infestans interaction was used as a model system to address some of the key remaining questions about the role of in-crop diversification in plant disease management. The causal agent of potato and tomato late blights, Phytophthora infestans, is one of the major factors limiting global sustainable potato production. The pathogen caused the Irish famine in the 1840s and is still one of the most serious agricultural diseases (Dean et al., 2012). [8]

Many plant pathogens are extremely well established, causing disease with depressing predictability in any given location, at least in the absence of crop protection. Other pathogens, or new strains of existing pathogens, are actively spreading, causing disease-related losses in new areas. Our focus here is on such "emerging epidemics" (Almeida, 2018), because control has a strong spatial component. [9]

Objectives:

- Weakening the host by constantly absorbing food from host cells for their own consumption.
- They kill or disrupt the metabolism of host cells by secreting toxins, enzymes, or growth regulating substances.
- Interfering with the transport of food, minerals, nutrients, and water through the conductive tissues.

III. Research Methodology:

This study's overall design was exploratory. Conventional farming systems are biologically depleted ecosystems that rely on constant external inputs to provide nutrients and keep pests and diseases at bay. Withdrawing these inputs or switching to organic farming can be viewed as a significant disruption to these technologically controlled ecosystems. It takes several years after conversion for a new equilibrium with relative stability to be established, but it is difficult to predict how long this transition period will last. The severity of plant diseases does not always increase after switching to organic farming. In fact, the severity of root diseases is generally reduced within a few years of switching to organic farming. An increase in diseases during the conversion phase may sometimes be caused by the inexperience of the new organic farmer. To solve plant disease problems in organic agriculture, disease management research requires a systems approach in which scientists from various disciplines collaborate. It is critical to develop ecosystem health indicators and understand the factors that contribute to disease suppression. To that end, there must be continuous feedback between whole-systems and component-level research. Because plant nutritional and resistance conditions, as well as the biological environment, have a profound effect on disease development, research findings from biologically deficient conventional farming systems cannot be easily transferred to organic farming systems. Furthermore, disease control must be balanced with nutrient and environmental management. This presents new challenges for young plant pathologists and may provide impetus for epidemiology science. However, it also allows molecular biologists to investigate the complexities of biodiversity in organic farming systems. [10]

IV. Result and Discussion:

Ecological Environments Adverse to Host Plants but Favorable for Pathogens:

Through their impact on pathogen density, particularly of soil-borne diseases, the structure of beneficial microbe communities, and the availability of organic and inorganic nutrition for plant growth and development, healthy soils are the key to sustainable agriculture, including plant disease management. Water and air pollution from industrial emissions and agricultural wastes, as well as the overuse of chemicals to nurse plants and manage pests and weeds, has resulted in many near-irreversible changes that have reduced farmland quality through soil compaction, reduced organic material, mineral imbalances, and heavy metal and pesticide residue contamination over the past decades. Furthermore, the decline in farmland quality may reduce host plant immunity to pathogen infection.

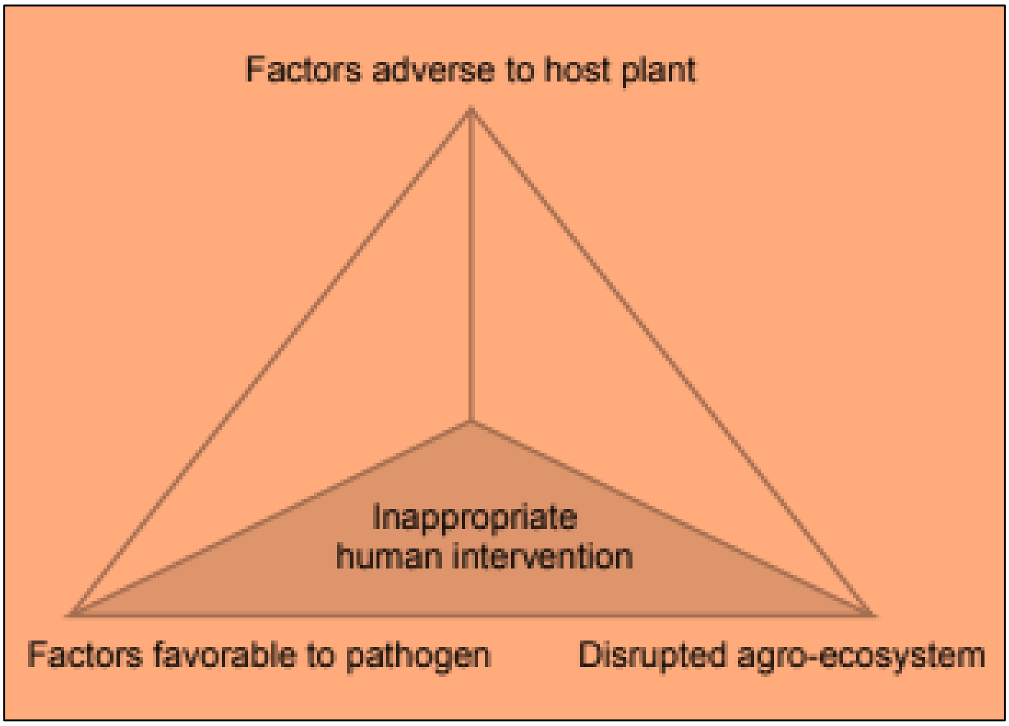

Figure 1: The mechanism of plant disease epidemics in agricultural system

Figure 1 depicts the epidemiology of plant diseases in the agricultural system. Plant disease epidemiology in modern agriculture is driven by disrupted eco-systems that create conditions favourable to pathogens but detrimental to hosts as a result of ineffective human intervention.

The Economic Analysis of Plant Disease Management:

Externalities arise when the impact of plant disease management on other parties is not taken into account in the cost-benefit analysis. Externalities related to plant disease management can be positive or negative, and they can be classified into short- and long-term ecological, social, and economic components (biotic and abiotic, see Table 1). Environmental pollution, toxin production affecting humans or livestock, ecological damage, resource depletion, reduced disease management efficiency, and costs associated with meeting minimum chemical residues on produce are all negative externalities of plant disease management. Positive externalities include improved disease management in neighbouring farms, reduced pathogen evolution potential, and ensuring social stability and safety. These externalities are currently not considered in economic analyses of plant disease management. Farmers are only responsible for the direct costs of pesticide application, not the costs of residue removal and ecology restoration, and those who use environmentally friendly disease management methods receive no additional benefit. Because farmers only pay the direct costs of plant disease management, they prioritise strategies that generate the highest immediate economic returns while ignoring potential negative environmental consequences. Some highly effective disease management strategies have been used in the past without adequate consideration for their long-term ecological impacts. Regulatory policy related to industrial sewerage management serves as a model for how externalities could be captured when evaluating plant disease management strategies. The system penalises the discharge of industrial waste into the environment in order to reduce pollution. Because of the transformation of externality to products, the net profits of management strategies are determined not only by the quality of the commodity but also by the level of potential environmental damage. Using pesticides and ecological plant disease management as examples, actual profits for the former are significantly reduced but increased for the latter when externalities are considered in economic analysis (Fig. 2). [11]

Table 1: Short and Long term goals of Plant Disease Management

Table 1 Short- and long-term goals of plant disease management

Short-term benefit	Long-term benefit
High and stable yields	High efficiency and security (without residue, pollution and catastrophic effects)
Quality improvement	Sustainable production capacity
Low input	Reduced speed of pathogen evolution
High output	Social stability

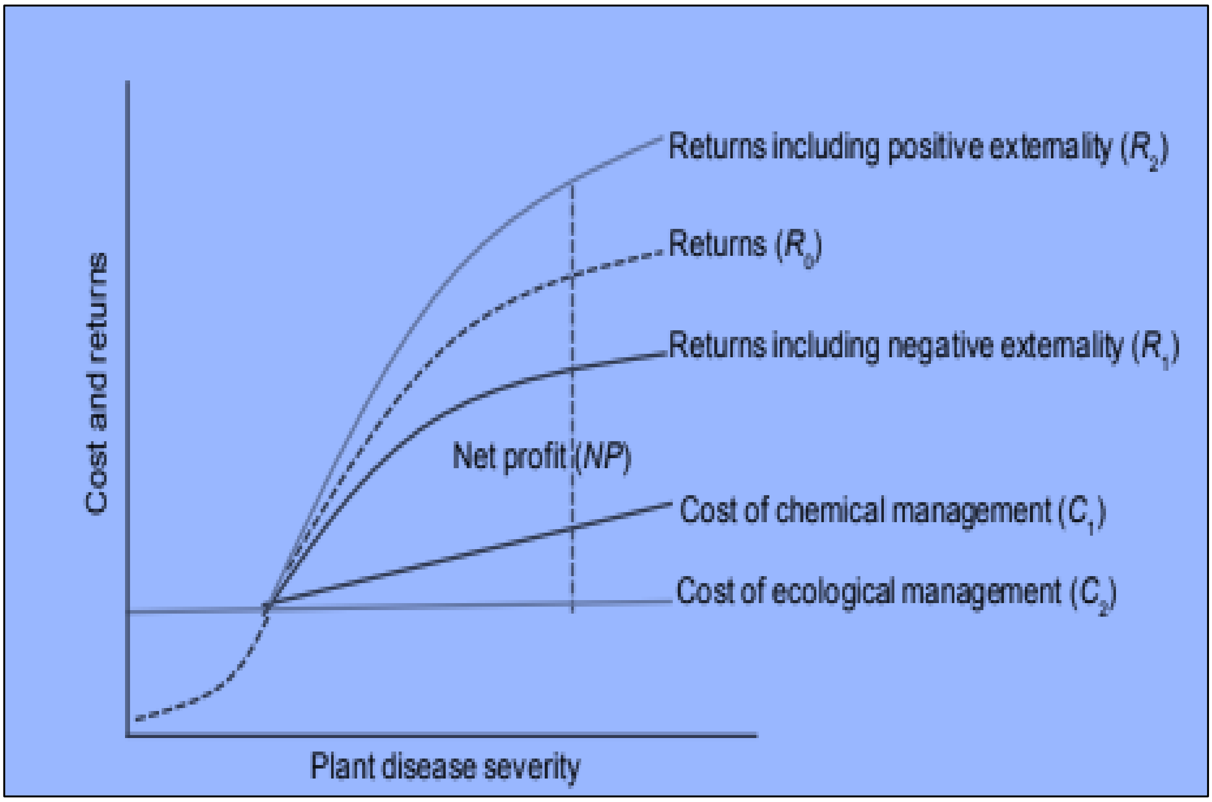

Figure 2: Externality of Plant Disease Management.

If plant diseases are controlled through chemical application, management costs are proportional to disease severity. On the other hand, if plant diseases are managed using ecological approaches aimed at improving plant health, the cost is relatively stable and the environmental impact is minimal. The profit (R1 -C1) of chemical management is gradually reduced after peak disease, while the profit (R2 -C2) of ecological management remains stable, according to the Diminishing Marginal Returns principle.

According to an overview of international agricultural research, the majority of efforts have been devoted to acute diseases (such as bacterial blight and blast in rice, dry root rot in chickpea, and late blight in potato) and, in a more erratic manner, emerging diseases such as wheat stem rust, wheat blast, and Phytophthora blight in pigeon pea. Chronic diseases, such as brown spot in rice, wheat spot blotch, and maize ear rot, do not appear to have received the attention they deserve (Fig. 2). One explanation for the emphasis on acute diseases is that the primary control option targeted by international research programmes has frequently been breeding for complete resistance with major genes: this is because breeding for such types of resistance on large numbers of entries was possible. [12]

Schematic categorization of some important diseases in the developing world on various key crops:

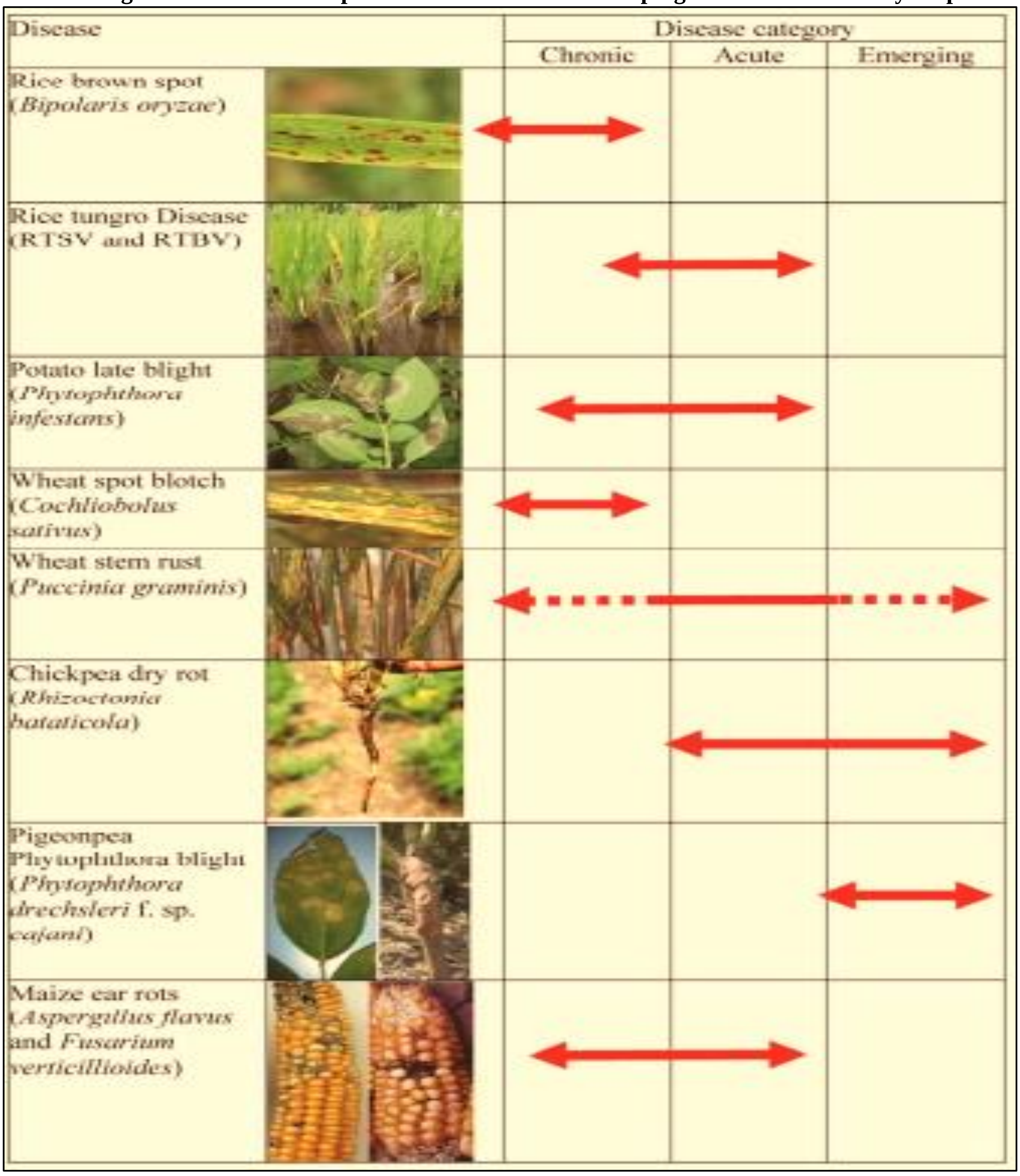

Figure 3: Schematic categorization of some important diseases in the developing world on various key crops. [13]

Table 2: Principles of Plant Disease Management [14]:

Table: Principles of plant disease management.	
Method	**Examples**
Protection	Practical disease avoidance and use of pesticides, use of biocontrol and fungicides, avoid of the time of planting that favor causal agent, provide adequate plant spacing avoid crowding, group plants according to their nutrient and water needs, avoid injury to the plants and make proper pruning cuts, use care when harvesting, and handle plants and plant parts carefully during transplanting, harvest.
Exclusion	Prevent the transportation and introduction of plant pathogens, Government regulations, prevent introductions, Quarantine stations, Purchase of certified disease "free stock, clean seed", Seed treatments (fungicides on seed coating) and disinfestations, modify actions to prevent spread into uncontaminated area
Resistance	The most reliable, effective and economical way of controlling plant diseases; Contain resistance genes within the plant, Horizontal resistance and physical barriers, synthesis of toxins, plant systemic immune response like Salicyclic acid, mild infections "Vertical resistance – one gene - one protein, no infection; Resistance crop can endure an attack by a pathogen (Penetration, no colonization).
Therapy	Achieved by incorporating a chemical control agent into the physiological processes of the plant to reverse the progress of disease development after infection has occurred.
Avoidance	Like the cultural practices that help avoid the potential for infection, such as planting date, seedbed preparation and water management, also fertilization and space for each plant. prevent injury of plants… etc.
Eradication And reduction of inoculum	Prevents spread of introduced diseases, reduction of inoculum density, sanitation, removal infected plant debris, pruning of diseased plants and infected wood, crop rotation, eliminate weeds and alternative hosts, use of techniques that disfavor vectors movement, soil sterilization and biocontrol.

V. Conclusion:

The disease affects plants in both biotic and abiotic ways, causing significant losses in the agricultural system. The success and sustainability of the IDM strategy, particularly with resource-poor farmers, is heavily reliant on their participation in helping to generate locally specific techniques and solutions suitable for their specific farming systems, as well as integrating control components that are ecologically sound and readily available. Training and awareness raising of farmers, disease survey teams, agricultural development officers, extension agents, and policymakers remains a priority. IDM is a disease management strategy that employs all available management strategies to keep disease pressures below an economic injury threshold. It does not advocate a routine chemical application programme for disease prevention, but rather encourages the integration of cultural, physical, biological, and chemical control strategies. The routine application of fungicides for insurance purposes is inappropriate because it diverts attention away from the real issue and can lead to resistance and potential environmental issues. IDM has the added benefit of better disease control than the individual method.

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