biology and life sciences forum

MDPI

Proceeding Paper

A Roadmap for Sustainable Disease, Pest, and Weed Management †

Frank Yeboah Adusei [1,*], Mavis Afriyie Adusei [2] and Benjamin Lartey [3]

[1] Department of Agricultural, Leadership and Community Education, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, USA
[2] Chicks and Chickens Services Limited, Kumasi P.O. Box UP 459, Ghana; adwoafriyie88@gmail.com
[3] Department of Agriculture, Asokwa Municipal Assembly, Kumasi 233, Ghana; sirbenl5@gmail.com
* Correspondence: fyadusei@vt.edu

† Presented at the 3rd International Electronic Conference on Agronomy, 15–30 October 2023; Available online: https://iecag2023.sciforum.net/.

Abstract: Effective disease, pest, and weed control are essential for achieving sustainable agricultural practices. The ever-growing global population, coupled with the increasing demand for food, poses a significant challenge to agriculture systems globally. To address this challenge sustainably, farmers must employ effective disease, pest, and weed control measures that minimize the negative impacts on the environment, human health, and biodiversity. This study investigates the impact of innovative control methods on agricultural productivity, focusing on 30 farmers (21 male and 9 female) in the Bosome Freho District of Ghana. The goal of this research is to offer scalable solutions to maximize crop yields while reducing the use of environmentally-unfriendly agro-chemicals. This study employed a participatory approach, engaging farmers in the co-creation and implementation of sustainable control measures. Through a combination of integrated pest management techniques, biological control, and cultural practices, farmers were able to significantly reduce the prevalence of diseases, pests, and weeds on their fields. The results demonstrate a remarkable improvement in crop health, with increased yield and quality observed across various crops, such as maize, pepper, and plantain. The scalability of these achieved results is a key highlight, as the implemented strategies are easily transferable to other farms within the Bosome Freho District and beyond. The innovative nature of this study lies in the collaborative approach, which incorporates traditional knowledge and modern agricultural techniques, thereby bridging the gap between traditional and sustainable farming practices. This study proposes workable ways to increase agricultural productivity while safeguarding the environment and ensuring the long-term viability of farming communities by tackling the key issue of disease, pest, and weed control in a sustainable manner.

Keywords: sustainable farming; biodiversity; pest; weed; disease

Citation: Adusei, F.Y.; Adusei, M.A.; Lartey, B. A Roadmap for Sustainable Disease, Pest, and Weed Management. *Biol. Life Sci. Forum* **2023**, *27*, 24. https://doi.org/10.3390/IECAG2023-14989

Academic Editor: Thorsten Kraska

Published: 13 October 2023

1. Introduction

Insufficient agricultural supplies have posed an immense challenge at both national and global levels, as the task of meeting the ever-expanding food demand from the growing population becomes increasingly daunting [1] The rise in food consumption coupled with diminished crop yields resulting from population growth has thrust the agricultural sector into a critical role in addressing the prevailing productivity crisis. To enhance agricultural efficiency, the health and fertility of both plants and soil emerge as vital factors that demand careful consideration. Especially noteworthy is the plight faced by farmers in regions such as sub-Saharan Africa (SSA), where they grapple with profound challenges related to plant protection and phytosanitary risks. These issues manifest in several ways.

Firstly, within traditional low-input agrosystems like subsistence systems in SSA, the repercussions are dire, resulting in food insecurity and diminished income for local communities. Secondly, the utilization of pesticides in intensive systems, as witnessed in locales like French overseas islands in the Caribbean, the Indian Ocean, and the Pacific, as well as in peri-urban horticulture in Africa, exacts a toll on human health and the environment, casting shadows over the sustainability of these practices. Lastly, the implications reverberate beyond the local sphere, affecting global trade dynamics. Stricter regulations imposed by importing countries concerning quarantine pests and minimum limits on pesticide residues have led to export restrictions, further underscoring the complexities of these challenges [1,2]. In essence, the multifaceted nature of these issues showcases the urgency of addressing them within the broader framework of agricultural development and sustainability.

To address the challenge of feeding expanding global populations sustainably, a fundamental transition from conventional agrochemistry to agroecology is imperative. Agroecology embodies a paradigm shift by leveraging the optimization of intricate biological interactions within agroecosystems to ensure crop viability and protection [3–6]. Modern intensive agroecosystems, owing to their over-simplification, are exceptionally vulnerable to the ravages of pests and diseases [7]. The concept of sustainable agriculture emerges as a beacon of efficient resource utilization that simultaneously benefits humanity while harmonizing with the environment. This holistic approach demands ecological appropriateness, economic viability, and social desirability as its cornerstones.

The objectives of a successful sustainable agriculture endeavor are intimately intertwined with its definitions. This pursuit aims to ensure food security by elevating both quality and quantity while safeguarding the interests of future generations. It strives to conserve precious water, soil, and natural resources, alongside judiciously managing energy consumption within and beyond farming domains. Moreover, the sustenance and enhancement of farmers' profitability, the vitality of rural communities, and the preservation of biodiversity all converge as pivotal goals within this context [8–10].

This research was carried out within the Bosome Freho District. We aimed to delve into the effects of innovative control methods on agricultural productivity. The primary objective of this study was to comprehensively examine and analyze how these innovative control methods influence and shape agricultural productivity in the specified area.

2. Materials and Method

2.1. Approach Used and Farmers' Biographical and Farming Details

Pests, diseases, and weeds present formidable obstacles to food crop farmers, jeopardizing crop yields, quality, and overall agricultural output. Traditional chemical-centered solutions come with their own set of limitations, including environmental apprehensions and the emergence of pest populations that are resistant to chemicals. Within this context, an inventive agroecological paradigm, merging the principles of diversification within agroecosystems and augmentation of soil quality, emerges as a viable avenue for sustainable resolutions. This study centers on a systematic approach aimed at effectively managing pests, diseases, and weeds via a qualitative methodology, utilizing a sample of 30 food crop farmers (comprising 21 male and 9 female participants).

The farmer profiles presented in Table 1 showcase a range of backgrounds, genders, ages, educational levels, and farming practices. These variations highlight the diversity within the agricultural landscape and underscore the need for context-specific solutions. Challenges such as pest resistance, soil fertility issues, and local environmental conditions are evident and set the stage for investigating innovative strategies.

2.2. Systematic Methodology Involved: Step 1

The systematic methodology employed in this study covers seven distinct steps, each contributing to the development and dissemination of effective agroecological strategies for managing pests, diseases, and weeds. The first step, denoted as Step 1, marks the initiation of the process with an introductory assessment and the involvement of farmers. In this initial phase, a diverse group of farmers was thoughtfully selected, representing various agroecological settings and farming approaches. Through participatory workshops, the farmers engage in discussions aimed at understanding their existing methods for pest, disease, and weed management, alongside the challenges they encounter within their local contexts.

Table 1. Farmers' biographical background and farming strategies.

Farmer ID	Gender	Age	Educational Background	Farming Practices	Current Strategies	Challenges Faced	Local Context
1	Male	45	MSLC	Mixed cropping	Chemical pesticides	Pest resistance	Proximity to commercial farm
2	Female	32	Primary	Intercropping	Minimal pesticide	Pest outbreaks	Close knit-farming community
3	Male	58	Primary	Intercropping	Manual weeding, synthetic fertilizers	Low fertility	Mountainous terrain
4	Male	40	MSLC	Mixed cropping	Manual weeding, minimal synthetic chemicals	Pest outbreaks	Hilly area and proximity to commercial farm
5	Female	50	NFE	Mixed cropping	Manual weeding	Soil degradation	Traditional practices
6	Male	28	High school	Conventional	Monoculture, synthetic chemicals	Pest resistance	Commercial farming
7	Male	52	MSLC	Conventional	Monoculture, synthetic chemicals	Pest resistance	Commercial farming
8	Female	39	JSS	Intercropping	Minimal weedicide	Soil compaction	Close-knit farming community
9	Male	60	MSLC	Intercropping	Minimal pesticide	Pest outbreak	High altitude
10	Male	42	Primary	Mixed cropping	Minimal pesticides	Pest outbreak	Proximity to home
11	Male	28	JSS	Conventional	Synthetic chemicals	Pest resistance	Commercial farming
12	Male	55	MSLC	Conventional	Synthetic chemicals	Pest resistance	Commercial farming
13	Male	48	High school	Conventional	Monoculture, synthetic chemicals	Pest resistance	Commercial farming
14	Female	30	Primary	Intercropping	Minimal synthetic fertilizer	Low soil fertility	Sandy soil
15	Male	37	High school	Conventional	Synthetic chemicals	Pest resistance	Commercial farming
16	Male	59	MSLC	Mixed cropping	Minimal pesticide	Pest outbreak	Proximity to commercial farm
17	Female	44	NFE	Mixed cropping	Minimal synthetic fertilizer	Low soil fertility	Mountainous terrain
18	Male	31	High school	Conventional	Monoculture, synthetic chemicals	Pest resistance, low fertility	Commercial farming
19	Male	52	MSLC	Conventional	Monoculture, synthetic chemicals	Pest resistance, low fertility	Commercial farming
20	Female	35	High school	Conventional	Synthetic chemicals	Pest resistance	Commercial farming
21	Male	43	High school	Conventional	Synthetic chemicals	Pest resistance	Commercial farming
22	Male	39	Primary	Mixed cropping	Minimal synthetic fertilizer	Low soil fertility	Mountainous terrain
23	Female	28	JSS	Conventional	Synthetic chemicals	Pest resistance, soil compaction	Commercial farming
24	Male	50	MSLC	Conventional	Synthetic chemicals	Pest resistance	Commercial farming
25	Male	47	Primary	Intercropping	Minimal pesticide	Pest outbreak	Commercial farming

Table 1. *Cont.*

Farmer ID	Gender	Age	Educational Background	Farming Practices	Current Strategies	Challenges Faced	Local Context
26	Female	33	JSS	Intercropping	Minimal pesticide	Pest outbreak	Commercial farming
27	Male	58	MSLC	Mixed cropping	Minimal fertilizer	Low soil fertility	Hilly area
28	Male	41	High school	Conventional	Synthetic chemicals	Pest resistance, soil degradation	Commercial farming
29	Female	29	JSS	Conventional	Minimal synthetic chemicals	Pest resistance, low fertility	Commercial farming
30	Male	36	JSS	Conventional	Synthetic chemicals	Pest resistance, low fertility	Commercial farming

JSS: junior secondary school, MSLC: middle school leaving certificate, NFE: no formal education. Synthetic chemical: inorganic weedicide, inorganic pesticide, inorganic fertilizer.

2.3. Agroecosystem Diversification: Step 2

Proceeding to Step 2, the focus shifts to the formulation of plans for agroecosystem diversification. Collaborating closely with the farmers', diversified agroecosystems were meticulously designed to suit their unique conditions. Techniques such as crop rotation, intercropping, and companion planting were explored, all of which disrupt pest and disease life cycles while inhibiting weed proliferation. Companion planting represents a specialized form of polyculture where two distinct plant species are deliberately cultivated in close proximity due to the anticipation of a mutually beneficial interaction that supports their growth. This approach hinges on the concept that these plants can harmonize their characteristics in ways that lead to positive outcomes. In simpler terms, these plant pairs are strategically chosen to obscure the specific chemical signals that pests use to locate their target hosts. Alternatively, the plants might host and nurture natural predators that are highly effective at controlling the pests of their companion plant. This practice is supported by research from various sources [11–13], highlighting its potential to optimize agricultural or horticultural activities. Maize flourished alongside the companionship of cowpea, Stylosanthes, and Mucuna, forming a harmonious tapestry of growth. Similarly, pepper found a compatible partner in cucumber, intertwining their roots and aspirations. Meanwhile, the companionship of plantain and sweet potato nurtured a flourishing ecosystem. This deliberate integration of diverse crop species, including both economically significant harvests and nurturing cover crops, emerges as a central and transformative factor in fortifying biodiversity and elevating the robustness of ecosystems [14,15].

2.4. Enhancing Soil Quality: Step 3

Step 3 emphasizes the enhancement of soil quality as a cornerstone for effective pest, disease, and weed management. Advocating for soil health practices, including the incorporation of organic matter, cover crops, and reduced tillage, takes center stage. Composting and mulching were employed to refine soil structure, increase moisture retention, and optimize nutrient availability, ultimately nurturing vigorous plant growth and reinforcing crop resistance.

2.5. Habitats for Beneficial Insects: Step 4

Transitioning to Step 4, the strategy hinges towards creating favorable habitats for beneficial organisms. An educational dimension was introduced, highlighting the significance of beneficial insects and natural predators in curbing pest populations. An ecologically healthy farm environment was created by planting flowering plants and native vegetation, which also helped to attract beneficial insects [16].

2.6. Monitoring: Step 5

Monitoring and decision making converge in Step 5, where farmers were educated to vigilantly oversee their fields for signs of pests, diseases, and weeds. Integrated pest management (IPM) emerged as the preferred approach, involving cultural, biological, and chemical control methods, with chemical methods being reserved as a last resort.

2.7. Data Collection and Analysis: Step 6

Step 6 revolves around data collection and analysis. Qualitative data were acquired through farmer interviews, focus group discussions, and direct observations. The ensuing analysis aimed to identify successful practices, encountered challenges, and factors contributing to effective pest, disease, and weed management.

2.8. Dissemination and Upscaling: Step 7

The final stride, Step 7, culminates in knowledge dissemination and upscaling of successful practices. The insights gained from the study were shared with the participating farmers, fostering mutual learning and experience exchange. This endeavor extended further with the creation of educational resources, workshops, and field demonstrations, enabling the effective communication of successful agroecological strategies to a broader farming community. This study produced a thorough framework for long-term pest, disease, and weed control through these seven methodical processes, all the while encouraging knowledge exchange and community empowerment. Collectively, this series of steps spanned a duration of seven months.

3. Results and Discussion

In addressing the challenges, this study employed a collaborative approach that blended traditional knowledge with modern agricultural techniques. The farmers were able to drastically reduce the prevalence of diseases, pests, and weeds by employing a combination of integrated pest management approaches, utilizing biological control, and adopting cultural practices. The results were remarkable, showcasing significant enhancements in crop vitality, which in turn resulted in increased yields and elevated crop quality across a wide range of varieties. For instance, the introduction of organic matter into the soil fosters a notable augmentation in overall microbial activity, as demonstrated in studies by [17]. As the microbial population flourishes in the soil, so do the prospects of encountering antagonistic microorganisms that can combat pathogens, as highlighted by research [18,19]. This positive interaction arises from the capacity of organic inputs to enhance the soil's biological status, leading to heightened diversity and increased populations of beneficial species, as observed in studies by [20–23]. In this respect, rotating a variety of crops provides ecological niches for microorganisms and encourages microbial diversity.

The results of this study reveal a high level of satisfaction and enthusiasm among the participating farmers for the agroecological paradigm introduced. Of the 21 male farmers, 19 expressed satisfaction with the approach, representing an impressive 90.5% satisfaction rate. Similarly, out of the nine female farmers, eight expressed satisfactions, accounting for 88.9% satisfaction. These percentages underscore the favorable reception of the agroecological strategies among both male and female farmers. Several quotes from satisfied farmers illustrate their perspectives:

Male Farmers:

"I've seen a noticeable reduction in pest damage since implementing these strategies. It's amazing how working with nature can yield such positive results."—Farmer 1

"The diversity in my fields not only keeps pests in check but also improves soil health. I'm definitely continuing with these practices."—Farmer 10

"I was skeptical initially, but witnessing the impact on my crops convinced me. I'm excited to expand these techniques on my entire farm."—Farmer 15

Female Farmers:

"I've been struggling with pests for years, and this approach has been a game-changer. It's not just about the crops; it's about a sustainable way of farming."—Farmer 26

"The workshops helped me understand the bigger picture. I feel more in control of my farm's health now, and I'm eager to share this knowledge with other women in my community."—Farmer 17

The satisfaction expressed by both male and female farmers underscores the significance of the agroecological approach in addressing the challenges posed by pests, diseases, and weeds. The high satisfaction rate indicates a strong likelihood of adoption and implementation of these strategies, contributing to improved agricultural sustainability and food security.

4. Conclusions

This study demonstrates that innovative control methods, grounded in agroecological principles, can effectively address the challenges of disease, pest, and weed control while enhancing agricultural productivity. The collaboration between traditional knowledge and modern techniques proved essential in achieving sustainable outcomes. The results, as observed in improved crop health, yield, and quality, signify the practical feasibility of these methods, underlining their potential for broader application. In light of the imperatives posed by a burgeoning global population and the escalating demand for food, this study presents pragmatic avenues to simultaneously nourish the land and its inhabitants. These pathways guarantee the sustained prosperity of farming communities for the forthcoming generations, thereby contributing to sustainable food production, community well-being, and the preservation of the environment.

Author Contributions: F.Y.A. conceived the research idea; F.Y.A., M.A.A., and B.L. conducted interviews and literature review; F.Y.A. wrote and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are available in this manuscript.

Acknowledgments: The authors wish to thank the farmers for their time and use of their land during this research.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Davis, K.F.; Gephart, J.A.; Emery, K.A.; Leach, A.M.; Galloway, J.N.; D'Odorico, P. Meeting future food demand with current agricultural resources. *Glob. Environ. Chang.* **2016**, *39*, 125–132. [CrossRef]
2. Renard, D.; Tilman, D. National food production stabilized by crop diversity. *Nature* **2019**, *571*, 257–260. [CrossRef] [PubMed]
3. Ferron, P.; Deguine, J.-P. Crop protection, biological control, habitat management and integrated farming. *A review. Agron.* **2005**, *25*, 17–24. [CrossRef]
4. Nicholls, C.I.; Altieri, M.A. Agroecological bases of ecological engineering for pest management. In *Ecological Engineering for Pest Management: Advances in Habitat Manipulation for Arthropods*; Gurr, G.M., Wratten, S.D., Altieri, M.A., Eds.; CSIRO Publishing: Collingwood, Australia, 2004; pp. 33–54.
5. Ferron, P.; Deguine, J.-P. Vers une conception agroécologique de la protection des cultures. In *Enjeux Phytosanitaires pour L'agriculture et L'environnement*; Regnault-Roger, C., Ed.; Lavoisier: Paris, France, 2005; pp. 347–366.
6. Wood, D.; Lenné, J. Nature's fields: A neglected model for increasing food production. *Outlook Agric.* **2001**, *30*, 161–170. [CrossRef]
7. Tilman, D.; Cassman, K.G.; Matson, P.A.; Naylor, R.; Polasky, S. Agricultural sustainability and intensive production practices. *Nature* **2002**, *418*, 671–677. [CrossRef] [PubMed]
8. Eskandari, H.A. Yield and quality of forage produced in intercropping of maize (Zea mays) with cowpea (Vigna sinensis) and mungbean (Vigna radiate) as double cropped. *J. Basic Appl. Sci. Res.* **2012**, *2*, 93–97.

9. Earles, R. *Sustainable Agriculture: An Introduction*; NCAT: Greensboro, NC, USA, 2005.
10. Gruhn, P.; Goletti, F.; Yudelman, M. *Integrated Nutrient Management, Soil Fertility, and Sustainable Agriculture: Current Issues and Future Challenges*; International Food Policy Research Institute: Washington, DC, USA, 2000.
11. Cunningham, S.J. *Great Garden Companions: A Companion Planting System for a Beautiful, Chemical-Free Vegetable Garden*; Rodale: Emmaus, PA, USA, 1998.
12. Finch, S.; Collier, R.H. Host-plant selection by insects—A theory based on 'appropriate/inappropriate landings' by pest insects of cruciferous plants. *Entomol. Exp.* **2000**, *96*, 91–102. [CrossRef]
13. Franck, G. *Companion Planting: Successful Gardening the Organic Way*; Thorsons Pub. Group: Wellingborough, UK, 1983.
14. Eskandari, H.; Ghanbari, A.; Javanmard, A. Intercropping of cereals and legumes for forage production. *Not. Sci. Biol.* **2009**, *1*, 7–13. [CrossRef]
15. Anil, L.; Park, J.; Phipps, R.H.; Miller, F.A. Temperate intercropping of cereals for forage: Review of potential for growth and utilization with particular reference to the UK. *Grass Forage Sci.* **1998**, *53*, 301–317. [CrossRef]
16. Mazaheri, D.; Madani, A.; Oveysi, M. Assessing the land equivalent ratio (LER) of two corn (Zea mays L.) varieties intercropping at various nitrogen levels in Karaj, Iran. *J. Cent. Eur. Agric.* **2006**, *7*, 359–364.
17. Wardle, D.A.; Yeates, G.W.; Watson, R.N.; Nicholson, K.S. The detritus foodweb and the diversity of soil fauna as indicators of disturbance regimes in agroecosystems. *Plant Soil* **1995**, *170*, 35–43. [CrossRef]
18. Altieri, M.A. The ecological role of biodiversity in agroecosystems. *Agric. Ecosyst. Environ.* **1999**, *74*, 19–31. [CrossRef]
19. Widmer, T.L.; Abawi, G.S. Relationship between levels of cyanide in sudangrass hybrids incorporated into soil and suppression of Meloidogyne hapla. *J. Nematol.* **2002**, *34*, 16–22. [PubMed]
20. McGill, W.B.; Cannon, K.R.; Robertson, J.A.; Cook, F.D. Dynamics of soil microbial biomass and water-soluble organic C in Breton L after 5 years of cropping of two rotations. *Can. J. Soil Sci.* **1986**, *66*, 1–19. [CrossRef]
21. Rasmussen, P.E.; Collins, H.P.; Smiley, R.W. *Long-Term Management Effects on Soil Productivity and Crop Yield in Semi-Arid Regions of Eastern Oregon*; USDA-ARS: Pendleton, OR, USA, 1989.
22. Rodriguez-Kabana, R.; Kokalis-Burelle, N. Chemical and biological control. In *Soilborne Diseases of Tropical Crops*; Hillocks, R.J., Waller, J.M., Eds.; CAB International: Wallingford, UK, 1997; pp. 397–418.
23. Malézieux, E.; Crozat, Y.; Dupraz, C.; Laurans, M.; Makowski, D.; Ozier-Lafontaine, H.; Rapidel, B.; de Tourdonnet, S.; Valantin-Morison, M. Mixing plant species in cropping systems: Concepts, tools and models. A review. *Agron. Sustain. Dev.* **2009**, *29*, 43–62. [CrossRef]