

Exploring the Advantages and Challenges of Agricultural Biotechnology in South-West Ondo State, Nigeria: An Ecological Validity Approach.

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Abstract: This study is a systematic review that explores, the advantages and threats of agricultural biotechnology from an ecological validity perspective, that hold the potential to address food insecurity while considering environmental sustainability as tool to achieve the aim of this study. Agricultural biotechnology has emerged as a transformative tool for enhancing food security, particularly in regions like South-West Ondo State, Nigeria, where ecological and socio-economic challenges persist. Key advantages identified in this study include, improved crop yields, resistance to pests and diseases, and reduced reliance on chemical inputs such as pesticides and fertilizers. The study made use of thirteen (13) articles using CASP, PICO and PRISMA in data collection and to select studies that were utilized in this study. This study made use of secondary data from existing literature that was published between 2013 and 2024. This study underscores the importance of public skepticism towards genetically modified organisms (GMOs), balancing technological innovation with ecological preservation by promoting “agro-bio” driven policies, public education, and stakeholder collaboration that mitigate the inadequacy of regulatory frameworks that exacerbate the challenges of adopting biotechnology in this region. Concerns about biodiversity loss due to monoculture practices, potential contamination of native species through gene flow, and long-term soil health degradation are critical issues discussed. By addressing these threats proactively, agricultural biotechnology can serve as a viable solution for sustainable development in South-West Ondo State while safeguarding its unique ecological systems.

Keywords: Agricultural Biotechnology, Ecological Perspective, Advantages and Threats.

I. INTRODUCTION

Agricultural biotechnology has emerged as a pivotal tool in enhancing food security and agricultural productivity, particularly in regions like South-West Ondo State, Nigeria. The establishment of National Biotechnology Research and Development Agency (NBRDA) in November 2001 under the Federal Ministry of Science and Technology is a testament to this fact [45]. Agricultural technology encompasses a range of techniques, including genetic engineering, molecular markers, and tissue culture, aimed at improving crop yields, pest resistance, and environmental sustainability [29]. In Nigeria, where agriculture is a major economic driver and employs a significant portion of the population (approximately 70% according to the National Bureau of Statistics), the adoption of biotechnological innovations is crucial for addressing challenges such as climate change, soil degradation, and food scarcity [1]. The application of scientific tools and techniques, including genetic engineering, molecular markers, and tissue culture, to improve plants, animals, and microorganisms for agricultural purposes is called “agricultural biotechnology” [30] [31]. In South-West Nigeria, agricultural biotechnology has gained attention as a

potential solution to enhance food security and agricultural productivity and this have led to scientific collaboration between researchers and policy makers [32]. This could be significant because Ondo state is an agrarian society, where most indigenes are subsistence farmers, and lesser number of people are engaging in mechanized farming. Given the multiplicity of farmers in Ondo State, this marks the state as an important region in the practice of agricultural biotechnology.

Against this background, the prevalence of agricultural biotechnology has gradually increased. Reports suggest that in 2023, approximately 10% of Nigerian farmers have adopted genetically modified organisms (GMOs) in their farming practices [2]. By 2024, Nigeria had approved 25 GMO seedlings and products for various agro-allied purposes, including field trials and commercial release. Though, these statistics reflects a growing acceptance among farmers who recognize the potential benefits of biotechnology in improving crop resilience and productivity [47]. Nonetheless, these approvals do not necessarily translate into nationalist or widespread adoption by farmers [46]. Current reports suggest that approximately less than 5% of Nigerian farmers have adopted genetically modified organisms (GMOs) in their farming practices between 2000 and 2023 [48]. Furthermore, studies indicate that crops such as *Bacillus thuringiensis* Bt cotton and Bt maize have shown significant yield increases up to 30% compared to conventional varieties [3] [50]. The evolution of agricultural biotechnology can be traced back to the early 1990s when the first genetically modified crops were introduced globally [51].

In Nigeria, research into agricultural biotechnology began around this time but faced numerous challenges including regulatory hurdles, public skepticism about GMOs, and limited funding for research initiatives [49]. Currently, Nigeria stands as one of the leading countries in Africa have embrace agricultural biotechnology adoption. Nigeria has developed several biotech initiatives and crops that are undergoing trials or have been approved for commercial use [33]. Ecologically, for instance, drought-tolerant maize developed by African Agricultural Technology Foundation (AATF) has been released to help farmers cope with erratic rainfall patterns, a pressing issue exacerbated by climate change [4] [33]. Despite these innovations, there remain threats arise with the use of GMO's associated with agricultural biotechnology including ecological concerns such as biodiversity loss and potential impacts on non-target species. While agricultural biotechnology presents numerous advantages such as increased crop yields and improved food security in South-West Ondo State Nigeria, it also poses ecological threats that must be carefully managed through robust regulatory frameworks and ongoing research. In ecological terms, farmers must clear the weeds before planting their seeds. With herbicide-tolerant soybean, however, the weeds can more easily be controlled at a later stage; farmers can plant the seeds by sowing them directly in relatively undisturbed soil. This conserves moisture and soil fauna and flora, and reduces water and wind erosion. The creation of alternative, renewable sources of energy (for example, biodiesel). The creation of new, more environmentally friendly raw materials for industry [42]. Examples include biodegradable plastics from plant starches and high-value specialty chemicals. The evidence so far suggests that fewer chemicals are used on herbicide-tolerant and insect resistant GM crops [43]. This in turn saves the energy that would have otherwise been used to produce and transport those chemicals. There are potential energy savings on the farm, as well.

II. RELATED WORKS

Reports from several risk analyses, have shown that, it is important to consider possible benefits of biotechnology to the environment which lead to increase in the productivity of crops without requiring additional inputs and increasing crop resistance to insects and diseases and reducing weeds will help reduce crop losses [34] [35]. For example, from an ecological perspective, 7 to 20% of the world's annual maize harvest is destroyed by the European corn borer. If the corn borer can be successfully controlled by Bt, maize yields in Europe and the United States alone could increase by 7–10 million tons equivalent to the annual food supply in calories for 60 million people [36]. In Nigeria and Ondo State particularly, reports show that susceptibility of the grains to attack by insects is determined by their water activity hence, long-

term storage [37]. The vulnerability of grains to microbial growth is determined by their water activity [38] as the higher the water activity, the higher the chances that maize grain will become vulnerable to microbial deterioration. The ecological implications portend that farmers in the Nigeria have reported significant reductions in herbicide and insecticide usage where transgenic crops are grown. For example, one type of insect and virus-protected potato, no applications of insecticides to control either the flea beetle or leaf roll virus were needed [39]. In other countries like the UK, research studies [40] [41] have shown that herbicide-tolerant sugar beet needs to be sprayed only twice during the growing season with glyphosate, whereas non-transgenic beet must be sprayed at least five times with a range of selective herbicides.

Agricultural biotechnology can significantly increase crop yields through the development of genetically modified (GM) crops that are resistant to pests and diseases. For instance, Bt cotton and Bt maize have been shown to reduce losses from insect pests [5]. This is particularly important in Ondo State where subsistence farming predominates. Biotechnological advancements allow for the bio-fortification of crops to improve their nutritional content. Crops like Golden Rice have been engineered to contain higher levels of Vitamin A [6]. This could address malnutrition issues prevalent in rural areas of Ondo State. Environmental sustainability through the adoption of biotech crops can lead to more sustainable farming practices by reducing the need for chemical pesticides and fertilizers. This not only lowers production costs but also minimizes environmental pollution [7]. Reduced chemical usage can help preserve local biodiversity in Ondo State. Drought resistance with climate change leading to unpredictable weather patterns, developing drought-resistant crop varieties is crucial. Biotechnology enables the creation of crops that can withstand periods of drought without significant yield loss [8]. This is essential for farmers in Ondo State who rely on rain-fed agriculture. The introduction of biotech crops can stimulate economic growth by increasing farmers' incomes through higher yields and reduced losses from pests [9]. Additionally, it can create job opportunities in research and development sectors related to biotechnology.

III. MATERIALS AND METHODS

A. Study Area

The research was conducted in South-West Ondo State, Nigeria, which is characterized by a diverse agricultural landscape. This region is known for its cultivation of various crops, including cassava, maize, and cocoa. The ecological validity approach was employed to ensure that the findings are representative of real-world conditions faced by local farmers.

B. Study design

This study's design is a systematic review, a unique type of literature review that locates, evaluates, and summarizes all relevant articles on a given topic or research issue using a methodical and methodical methodology [52]. Systematic evaluations such as the one used in this work presage deeply ingrained faults due to the over-reliance on positive outcomes. The bulk of evaluations in this paper were positive and some grey literature was taken into account not enough to show significant changes.

C. Method of Data Collection

In other to conduct data collection procedures, this study made use of secondary data from existing literature that was published between 2013 and 2024. In order to improve the validity and reliability of their findings while maintaining transparency throughout the review process, data was collected using structured steps (depicting the data sources and study characteristics, ensuring data quality, and addressing discrepancies).

D. Inclusion and Exclusion Criteria

Articles thoroughly screened in line with the stipulated inclusion and exclusion criteria as presented in Table 3. These studies were published between 2013 and 2024 and those published before 2015 were not considered extant enough for this review. For the purpose of providing history, subject definitions, meaning-making and to expand ideas, the introduction and discussion section drew on earlier research.

E. Search Strategy

The objective of systematically putting into practice a structured search strategy was to organize and collect a significant volume of information to support the study's research issue. Numerous sources of scientific studies were found and gathered for this study. Embracing, [53] conception of the PICO framework (Table 1). The search strategy incorporated the Population, Intervention, Comparison, and Outcome (PICO) paradigm. These resources include primary databases like the, British Biotechnology Journal Sciencedomain International (BBJSI), BioMed Central, Scopus, African Journal of Agricultural Research (AJAR), Springer's Natures Sciences Societies and Pub-med. In order to find relevant papers, the systematic review started a search that looked at the titles, dates, methods, and abstracts.

Table 1: The PICO framework for Search Strategy.

Population
The population of interest in this study includes farmers, agricultural stakeholders, and local communities in South-West Ondo State, Nigeria.
Intervention
The intervention involves the introduction and implementation of agricultural biotechnology practices. This can include genetically modified organisms (GMOs), bio-pesticides, bio-fertilizers, and other biotechnological tools aimed at improving crop yields, pest resistance, and overall agricultural productivity.
Comparison
The comparison aspect will involve contrasting the outcomes of farmers who adopt agricultural biotechnology with those who continue to use traditional farming methods without such interventions. This could also include comparisons between different regions within Ondo State or between various types of biotechnology applications to determine which methods yield better results.
Outcome
Agricultural Productivity: Measuring changes in crop yields before and after the adoption of biotechnology. Economic Impact: Evaluating the financial benefits or challenges faced by farmers adopting these technologies compared to traditional methods. Environmental Effects: Assessing ecological impacts such as biodiversity changes, soil health, and pest populations resulting from biotechnological practices.
Social Acceptance: Understanding community perceptions and acceptance levels regarding agricultural biotechnology.

F. Database Search Procedure

Each article publication was critically assessed using the Critical Appraisal Skills Programme (CASP) [53] checklist after a thorough review. As repository proof of the critical review process, the papers used in this study were electronically recovered and stored on the researcher's backup hard drive. Each publication's extracted data, including details like the number of participants, research interventions, procedures, measuring methods, and outcomes, is shown in Table 2. This made it possible for the researcher to give a general overview of every study that was included. Thirteen (13) articles were carefully picked because they satisfied the inclusion criteria out of the twenty-five (25) papers that were initially chosen after the PICO and CASP checklists were completed.

Table 2: Showing the Database Search Procedure

Database	Search Dates	Inclusion Year	Search Result	Excluded	Included
African Journal of Agricultural Research	15//01/25	2013-2024	8	6	2
Bio-Med Central	18/01/25	2013-2024	5	4	1
Scopus	21/01/25	2013-2024	4	3	1
Research Gate	03/02/25	2013-2024	6	3	3
British Biotechnology Journal Science Domain International (BBJSI)	05/02/25	2013-2024	12	11	1
African Journal of Agricultural Research (AJAR)	13/03/25	2013-2024	6	4	2
Springer's Natures Sciences Societies.	9/04/25	2013-2024	8	7	1
PubMed	11/04/25	2013-2024	5	3	2
TOTAL					13

G. Inclusion and Exclusion Criteria

A variety of study types are included in this evaluation. These consist of empirical investigations, longitudinal studies, meta-analyses, conference papers, journal articles, systematic reviews, quantitative and qualitative research. Table 3 has comprehensive details.

Table 3: Showing the Inclusion and Exclusion Criteria in the Systematic Review

PICO	INCLUSION CRITERIA	EXCLUSION CRITERIA
Population	Studies that focus on agricultural biotechnology specifically within agro-allied settings.	Studies that do not specifically address agricultural biotechnology or are focused on non-agro-biotechnological approaches.
Intervention	Research articles published in peer-reviewed journals from 2013 to 2024.	Studies that were published before 2013.
Comparison	Research focusing on IT sectors or unrelated fields such HR management with a clear link to IT project management.	Research focusing on non-IT sectors or unrelated fields such as education or healthcare without a clear link to IT project management..
Outcome	Significant positive impact of agricultural biotechnology's influence on agricultural practices.	Articles that are opinion pieces, editorials, or non-research-based publications (e.g., blogs, white papers).
Setting	Studies conducted whose participants from Africa (Nigeria), Europe, United Kingdom, United States of	Studies conducted in the Caribbean's, South-America, Africa and Middle-East were excluded.

America, and Asia were
eligible for this.

PRISMA flowchart of the selection of studies.

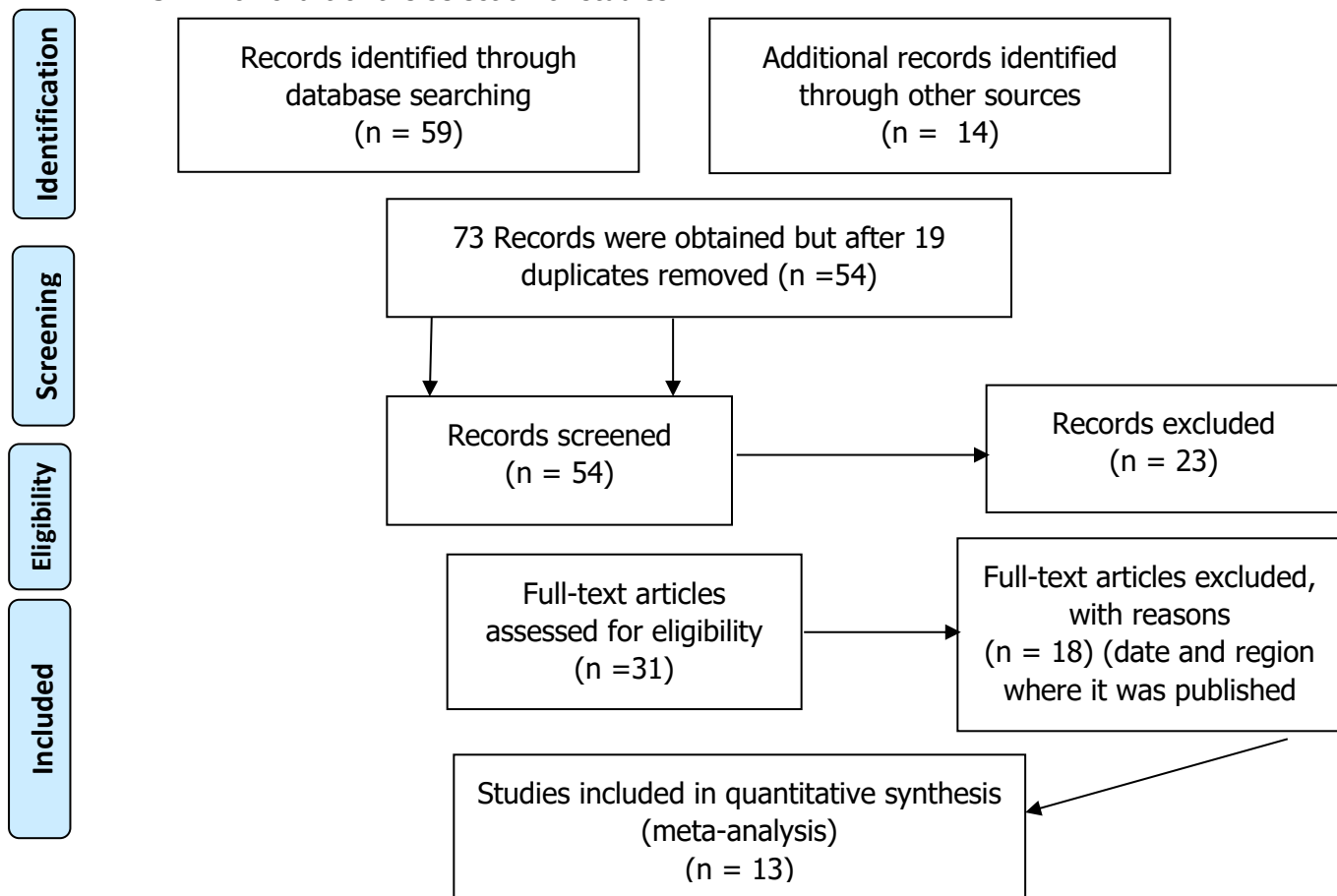


Figure 1: Showing the PRISMA Table.

H. Quality Assessment (QA)

In order to synthesize findings and draw conclusions, QA was carried out in this section using the data extraction technique. To accommodate various study designs, CASP checklists are used while doing quality assurance (QA) utilizing the data that was taken from the article under review. A template that describes how this study evaluates each study according to particular criteria may be found below.

Table 4: Showing the Quality Assessment in the Systematic Review

Study Type	Study Reference	Criteria 1: Clear Aim	Criteria 2: Appropriate Methodology	Criteria 3: Sample Size Adequacy	Criteria 4: Validity of Results	Overall Score (out of 10)
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Empirical review	[5]	Yes	Yes	No	Yes	7
Empirical review	[6]	Yes	Yes	No	Yes	6
Systematic review	[7]	Yes	Yes	Yes	Yes	8
Empirical review	[8]	Yes	Yes	No	Yes	9
Narrative review	[9]	Yes	Yes	No	No	8
Systematic review	[10]	Yes	Yes	No	Yes	8
Scooping review	[34]	Yes	Yes	No	Yes	7
Empirical Review	[35]	Yes	Yes	Yes	No	8
Qualitative analysis	[36]	Yes	Yes	No	Yes	8
Empirical review	[37]	Yes	Yes	Yes	Yes	9
Qualitative analysis	[38]	Yes	Yes	Yes	Yes	9
Empirical Review	[39]	Yes	Yes	Yes	Yes	9
Empirical review	[40]	Yes	Yes	Yes	Yes	9
Empirical review	[41]	Yes	No	Yes	Yes	8

I. Ethical Considerations

In this work, the systematic reviews made use publicly accessible documents as evidence therefore, they do not require an institutional ethics approval before commencing a systematic review. However, ethical considerations in the reviewed studies are taken very seriously. Potential conflicts of interest that might affect results without compromising any of the research are revealed by the systematic review in this paper. In order to prevent biases examined in this paper, the systematic review considers a variety of viewpoints while highlighting those that are not widely accepted. Given the possibility that researchers may submit papers with good outcomes rather than ones with negative or ambiguous findings, this publication ensured that all reviews were accurately represented. The fact that this study was funded entirely by the researcher's

own money rather than funding from other sources guarantees that no organization's interest will be taken into account in the review.

IV. RESULTS AND DISCUSSION

Biodiversity loss was a major concern regarding agricultural biotechnology is its potential impact on biodiversity. The widespread cultivation of GM crops may lead to the displacement of traditional crop varieties and local species [10]. This could result in a loss of genetic diversity which is vital for ecosystem resilience. There are ongoing debates about the safety of consuming GM foods. Some studies suggest potential health risks associated with long-term consumption; however, regulatory bodies like the World Health Organization maintain that GM foods currently on the market are safe [11]. Nonetheless, public skepticism remains high in Nigeria. While biotechnology has the potential to boost productivity, there is a risk that smallholder farmers may not have access to these technologies due to high costs or lack of knowledge [12]. This could exacerbate existing inequalities within the agricultural sector in Ondo State. The regulatory framework governing biotechnology in Nigeria is still evolving. Inadequate regulations may lead to misuse or unintentional consequences such as cross-contamination between GM and non-GM crops [13]. Effective governance is crucial for ensuring safe practices.

Public perception plays a significant role in the adoption of agricultural biotechnology. Misinformation about GMOs can lead to resistance among consumers and farmers alike [14]. Building trust through education and transparent communication is essential for successful implementation. Agricultural biotechnology presents both significant benefits and notable threats in South-West Ondo State, Nigeria [16]. While it offers solutions for increasing food production and improving nutritional quality amidst environmental challenges, careful management is required to mitigate risks associated with biodiversity loss, health concerns, economic disparities, regulatory issues, and public perception. In addition, one of the concerns about GM crops is that the genes could 'escape' and, through crosspollination, mix with non-GM crops or their weedy relatives [15]. For example, herbicide-tolerant gene available in Ondo state Nigeria which are resistant to commonly used pesticide could be transferred to weeds in wild habitats, turning them into 'superweeds' for instance, Carboxylesterase (CarEs). While the potential for gene flow from genetically modified herbicide-tolerant crops to wild relatives or weeds is a recognized scientific concern and has been studied in various agricultural systems globally, and herbicide resistance in weed populations is a known issue in many farming regions, including parts of Nigeria, specific documented instances or studies detailing the transfer of herbicide-tolerant genes and the subsequent emergence of 'superweeds' specifically within Ondo State are not prominent in the current scientific literature or public reports. Research on genetically modified crops and weed management in Nigeria exists [54]. These risks should be assessed case by case, taking into account factors such as:

- i. Whether a close relative of the crop is present in the area. The ability of different species to cross-pollinate with themselves or their weedy. Relatives does pollen move any distance from the crop, or does the crop outcross at all?
- ii. Whether the particular genes would provide any 'selective advantage' to the new plants. For example, a gene for delayed ripening would probably not cause an environmental problem. If a potential risk is identified, various means can be used to manage this risk for example, by the use of border rows or 'buffer zones' of non-transgenic plants, and physical isolation from other cultivated fields. In Ondo State, monitoring of gene flow can be carried out to assess the effectiveness of these methods. Most crops are produced as a result of centuries of selective

breeding and do not survive well in natural habitats [17]. Hence, most transgenic crops (based on these existing crops and altered for product quality) are unlikely to present a problem to the surrounding ecosystem [17]. Although transgenic super-weeds are referred to, none has yet been shown to exist [18].

Effects on Non-Target Species and Pest Resistance.

Transgenic crops modified to be resistant to a particular pest or disease may have a negative effect on harmless or beneficial organisms [19]. For example, there are recent reports that Bt corn pollen may be toxic to the Monarch butterfly. Extensive testing is carried out on all transgenic crops to identify such non-target effects and such risks, if found to be valid, may still be able to be effectively managed [44]. In the case of the Monarch butterfly, laboratory experiments are continuing to investigate factors such as the actual levels of pollen present in the fields and the timing of pollen release relative to larval feeding [20]. It is important to note that the currently available alternative to transgenic crops is often much more harmful to the environment [21] [22]. For instance, the normal practice of routine spraying of broad-spectrum insecticides kills all insects, regardless of whether they are beneficial or harmful to the crop.

The more often any pest control method is used, the more likely it is that resistance to it will emerge in the pest it is designed to control. One current concern is that insects will develop resistance to toxins such as the Bt protein, thus reducing the effectiveness of this control method [23]. Resistance management is not, a new concept to agriculture, and techniques exist that can decrease the likelihood of resistance arising in pest populations. For example, in the United States, areas of susceptible plants (refugia) are grown alongside transgenic crops [24]. This is either legally required or a voluntary practice in many areas. Researchers are also looking for new types of Bt toxins that could be alternated, mixed or combined in transgenic crops to reduce the selection pressure on the pests [25]. To date, there have been no confirmed cases of resistant pest populations developing in the field [23] [25]. It has been suggested that the very success of transgenic crops could lead to a loss of biodiversity so that less successful crops are not grown and available varieties are reduced; however, the main potential cause of loss of biodiversity is population growth [26]. The needs of a growing global population have largely been met by bringing more land into agricultural production [27]. Transgenic crops are unlikely to be a significant factor in accelerating biodiversity loss, compared with the enormous problems of habitat loss. In fact, transgenic crops may be able to help preserve uncultivated habitats by increasing yields on land already under cultivation [28].

V. CONCLUSION

Agricultural biotechnology presents a dual-edged sword for South-West Ondo State, Nigeria, offering significant advantages while posing notable threats from an ecological validity perspective. On the positive side, biotechnology has the potential to address critical agricultural challenges in the region, such as low crop yields, pest infestations, and climate change-induced stresses like drought and flooding. Genetically modified (GM) crops, such as insect-resistant cotton and drought-tolerant varieties, can enhance productivity and food security by improving resilience to biotic and abiotic stresses. Additionally, biotechnology can reduce reliance on chemical pesticides and fertilizers, thereby mitigating environmental degradation caused by traditional farming practices. However, the adoption of agricultural biotechnology also raises ecological concerns. The introduction of genetically modified organisms (GMOs) may disrupt local ecosystems by affecting non-target species or leading to the emergence of resistant pests and weeds. Furthermore, there are socio-economic risks tied to dependency on foreign biotech companies for seeds and technologies, which could marginalize smallholder farmers. Ethical debates surrounding GMOs and limited public awareness further complicate acceptance in the region. To effectively address agricultural challenges in Ondo State, policy recommendations should focus on integrating biotechnology into local farming practices. This includes promoting the adoption of genetically modified (GM) crops that are resilient to pests and climate stresses, thereby enhancing productivity and food security. Additionally, policies should

encourage research and development in biotechnology to tailor solutions specific to the region's unique socio-political and environmental context. Furthermore, implementing educational programs for farmers about the benefits of GM crops can facilitate acceptance and reduce reliance on chemical inputs, which aligns with sustainable agricultural practices. Collaborating with local stakeholders, including farmers' associations and agricultural extension services, will ensure that policies are practical and culturally appropriate. To maximize benefits while minimizing risks, it is crucial to adopt a balanced approach that integrates robust regulatory frameworks, public education campaigns, and sustainable practices tailored to Ondo State's unique ecological context.

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