Integrated Nutrient Management (INM) and Integrated Pest Management (IPM) as Pakistan`s Roadmap to Climate-Smart Agriculture policies

Policy Statement

It is proposed that INM and IPM strategies can be integrated into Pakistan's agricultural policy framework, to enhance resilience against climate change and promote sustainable agricultural practices. This can be made possible by promoting collaboration among government agencies, research institutions, and farmers. this research aims to develop and implement a comprehensive climate-smart agriculture policy that prioritizes the adoption of INM and IPM approaches. Resultantly, the policy will not only improve agricultural productivity and food security but also contribute to environmental conservation and the well-being of rural communities.

Abstract

This research aims to evaluate: the current adoption and practice of Integrated Nutrient management (INM) and Integrated Pest Management (IPM) in Pakistan's agriculture sector; the influence of climate variation on the prevalence of pest and nutrient requirements across different geographical regions of Pakistan; the key challenges in the integration of INM and IMT strategies into agricultural policy; and the existing agricultural policy in meeting the challenge originating due to climate change.

This research uses a mixed methodology; the quantitative analysis uses 100 respondents (both male and female involved in agricultural activity), and the qualitative analysis used a series of key informant interviews in district Upper Dir, Khhyber Pahtnkhwa, Pakistan. Quantitative analysis generated moderate-high-levels of awareness about and practice in INM and IMP practices among farmers is high, but points to gender and literacy level differences as well as the need for adult education programs. Qualitative findings however suggest; the key barriers in the awareness and adoption of these strategic approaches are the farmers' technical capacity and institutional support, and socio-economic constraints to their adoption.

The final recommendations include targeted education in this area, capacity-building programs, institutional reform, and enhancements to existing policy, leading to the adoption of agro-ecological principles; by addressing the current challenges and

leveraging the existing opportunities for Pakistan to enhance its agriculture resilience and sustainability, in the face of climate change.

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1. Introduction

1.1. Background and Context

The United Nations (UN, 2020) defines climate change as the variation in temperature as well as weather patterns, attributed primarily to human activities including carbon dioxide and methane emissions. The 2021 Intergovernmental Panel on Climate Change (IPCC) report underscores the fact that global greenhouse gas emissions have already increased the global temperature by 1.1 degrees Celsius over pre-industrial levels, with projections indicating a rise to 1.5 degrees Celsius within the next few decades (IPCC, 2021). This phenomenon presents a unique threat to agricultural productivity across the globe.

The agriculture sector of Pakistan, being an integral part of its economy, is under immense pressure in the wake of the mounting climate crisis. The country's predominantly rain-fed agricultural system is especially susceptible to climate vagaries which manifest as heightened frequency and intensity of droughts, floods, and heat stress (Dehlavi et al., 2015). Pakistani crops are reportedly highly sensitive to fluctuations in temperature and water availability, with projected temperature rises expected to invoke yield reductions ranging between 8% and 10% in Pakistan alone (Dehlavi et al., 2015). Furthermore, the subsequent wave of extreme heat events, with temperatures tipping over 35 degrees Celsius, has only exacerbated the vulnerability of a number of crops, such as rice and sugarcane, leading to a marked decline in yield (Yu et al., 2013). For example, maize and soybean crops are reportedly highly susceptible to changes in climate, with a stark drop in yield (Porter, J.R, 2019).

The effects of climate change on agriculture do not just end at yield loss, but extend to pest population dynamics and distribution, and therefore, the emergence of new diseases (Savary et al., 2019). Pakistan's agricultural stress under the influence of climate change, underscores an immediate need for agriculture practices that assure climate resilience. Integrated Nutrient Management (INM) and Integrated Pest

Management (IPM) have gained prominent status within Climate-Smart Agriculture (CSA) strategies, exercised to promote agricultural productivity, resilience, as well as sustainability (Hafeez et al., 2022). However, the adoption of these practices remains constricted in Pakistan on account of a gamut of reasons, which include, but are not limited to, limited awareness, and technical guidance, as well as economic constraints (Bashir et al., 2016).

Another reason why the need to address the effects of climate change on agriculture is far more pressing than others is its economic profile. The agricultural sector secures employment for approximately 25 million people in the country, thus, catering as the primary source of employment for a substantial portion of the country (Hussain et al., 2022). However, the profession is characterized by low productivity, limited resource use efficiency, and the utilization of traditional, which often translates into unsustainable practices (Hussain et al., 2022). Therefore, addressing the impacts of a changing climate on an agricultural Pakistan is not only integral to sustaining food security, but also to sustain the rural livelihoods, and the macroeconomic stability of the agrarian Pakistan.

1.2. Research Problem

The research question at hand revolves around exploring how to combine INM and IPM (integrated pest management) to Pakistan's agriculture framework to cope with the challenges posed by climate change. The main purpose is to show how this union can lead the breakthrough of Climate-smart agriculture (CSA) policies in Pakistan. Despite Pakistan's heavy dependence on agriculture for economic stability and food security, the swelling climate issue has made these sectors extremely vulnerable. More frequent droughts have crop yields and livelihoods dried up, floods carried away everything in their path, while rising temperatures baked fields to a crisp. Climate-related risks aside, by looking at the linkages between INM and IPM in agriculture, our research seeks to suggest practical solutions. Moreover, By exploring the integration of INM and IPM in Pakistan, the research endeavors to propose sustainable solutions that enhance agricultural productivity while mitigating climate-related risks (Bibi et al., 2023).

This research issue is all the more important because of its direct influence on Pakistan's food security but also due to how it affects rural livelihoods and general economic stability. Since agriculture accounts for such a large part of the population, efforts must be made to minimize climate change impacts if rural lives are to continue reasonably well and the people are not hungry. By providing a blueprint for integrating these components into farmers' practices, the survey hopes to yield useful experience and practical lessons about integrating Integrated Nutrient Management (INM) techniques with Climate-Smart Agriculture (CSA). Ultimately, it is hoped, the research enable us not only to raise production levels through better practices that may be used for insurance but also those measures incorporating carbon sequestration technology which reduces both emissions and increases yield at the same time.

1.3. Objectives of the study

1. Evaluate the current adoption and implementation of Integrated Nutrient Management (INM) and Integrated Pest Management (IPM) practices within Pakistan's agriculture sector.
2. Investigate the influence of climate variations on pest prevalence and nutrient requirements across diverse regions (districts) of Pakistan.
3. Identify and analyze the key challenges impeding the integration of INM and IPM strategies into Pakistan's agricultural policies, focusing on barriers related to awareness, technical capacity, and institutional support.
4. Assess the effectiveness of existing agriculture policies in addressing climate change-induced challenges pertaining to nutrient and pest management in Pakistan, aiming to identify policy gaps and areas for enhancement.

1.4. Significance of the study

The significance and motivation of this research lie in that it may help tackle the huge challenges that confront agriculture in Pakistan today due to climate change. In an environment of intensified climate variability, agricultural productivity and food

security are increasingly under threat. This is putting millions out of work and jeopardising economic conditions (Ali et al., 2017). An inquiry into how Integrated Nutrient Management (INM) and Integrated Pest Management (IPM) strategies might become part and parcel of Pakistani agriculture policy is set forth in this study, which hopes to suggest feasible practical solutions for increasing resilience and sustainable development.

The conclusions of this study will have important implications for policy making and implementation alike as well as for the practical farming of climate-smart crops. This research proposes to enlighten policy-makers about the necessity for evidence-based decisions in nutrient and pest management and policy effectiveness, evaluating the extent to which INM and IPM are being employed at present and the barriers to their integration.

2. Literature Review

2.1. Climate Change and Agriculture in Pakistan

In the 21st century, climate change is considered to be one of the major areas of contention. It may very well be, like any of them who wishes that we can leave solely for all their agricultural products. Rising global temperatures, mainly caused by emissions from human activity have changed the weather patterns, precipitation regimes, and intensities of extreme weather conditions: much more so than can be expected at present, according to the Intergovernmental Panel on Climate Change (IPCC, 2021). These changes heavily influence agricultural output and threaten overall food supply for humanity.

In the world, like many other places for it, Pakistan's Agriculture is under pressure. The country's agriculture is much more reliant on rainfall, with water coming from glaciers

making up the bulk of its irrigation. Studies have found Pakistan's agriculture to be vulnerable to a broad spectrum of climate-related hazards, including droughts, floods, and heat waves damaging crops and threatening rural people in the countryside (Dehlavi et al., 2015; Yu et al., 2013). Still, projections suggest that if temperatures rise and precipitation alters, then staple crops such as corn and rice will suffer significant losses, exacerbating food insecurity issues (Dehlavi et al., 2015; Yu et al., 2013).

The agricultural sector in Pakistan faces a multitude of climate change-related challenges. The growing irregularity in weather patterns has interrupted traditional farming practices and poses severe obstacles for cultivation of crops as well as livestock management. Droughts, in particular, have increased with climate change -- they now frequently result in crop failures and water shortages, advancing agricultural productivity and even livelihoods in the lowest villages. On the other hand, intense rainfall events and floods from rivers or streams can be devastating for agricultural infrastructure, leading to soil erosion and damage to crops. And although heat stress on plants and animals is exacerbated by rising temperatures causing extra losses in agriculture and food storage (Ali et al., 2017).

2.2. Integrated Nutrient Management (INM) and Integrated Pest Management (IPM) Practices

INM and IPM are holistic approaches to sustainable agriculture that minimize environmental impact (Bibi et al., 2023). Scientific studies abound, and IPM has likewise benefited from many scientific advances including those of the parents of discoveries through natural history. INM involves the use of organic and inorganic fertilizers to balance levels, and soil amendments such as manure and satisfying the of other purposes to improve nutrient availability and promote soil health (Sharif et al., 2018). This includes crop rotation, which fits well with soil fertility by preventing soilborne pathogens from building up over long periods. INM practices seek to optimize nutrient availability and promote soil health. Application of the INM philosophy can maintain balanced soil fertility across the long term. The principles of INM emphasize

the use of locally available organic resources, judicious application of chemical fertilizers based on soil test results, and crop rotation to maintain soil fertility and improve crop yields (Afzal et al., 2015).

On the other hand, Integrated Pest Management (IPM) is a comprehensive strategy that incorporates biological, cultural, mechanical, and chemical controls, as well as other methods of pest control. This package includes the use of chemical and insecticidal substances together, with sanitation measures always. We maintain that the principles of IPM- much more than just prioritizing which pests should be targeted whether to hit them with poison gas or suck their blood make a great deal of sense too. Integrated Pest Management (IPM) strategies prioritize preventive measures such as crop rotation, habitat manipulation, and biological control components to keep the population of pests below economically damaging levels (Hagstrum & Flinn, 2018).

INM and IPM have been shown to enhance agricultural productivity and resilience by numerous studies. For instance, in experimental field trials carried out by Sharif's group, maize yields increased significantly while soil fertility improved under INM practices (Sharif et al., 2018). Likewise, organic and inorganic fertilizers applied in combination under IPM practices increased maize yields and improved soil fertility compared to conventional fertilizer-only treatments. IPM/Organic management in cotton and biological control-agent application for both pest control and improving crop yield performance can also be recommended. As a result, not only does consuming organic vegetables avoid excessive pesticide residues that damage the environment, but INM and IPM also contribute to the sustainability of agricultural systems by reducing reliance on external inputs and thereby minimizing environmental pollution (Hagstrum & Flinn, 2018). On the one hand, they contribute to the depletion of vital resources such as oil which many forms of synthetic fertilizers and pesticides are based on. Also, pests are developing resistance, but not for nothing: there are signs that they too may be biologically beneficial by killing off natural enemies of crops. By promoting the adoption of INM and IPM practices, farmers can mitigate the adverse effects of climate change on agricultural productivity and reduce the ecological footprint of farming operations (Khan et al., 2017).

At the same time, empirical research into the adoption and implementation of INM and IPM in Pakistan is still relatively scarce. That said, studies such as that by Bashir et al. (2016) have examined the adoption rates and impact of INM practices among rice farmers in Pakistan. Furthermore, studies such as those of Khan et al. (2017) analyzed how widely accepted INM and IPM practices are in Pakistan. Such research could provide a starting point for future work on the subject. These studies highlight the importance of raising awareness, providing technical support, and addressing socio-economic constraints to promote the widespread adoption of sustainable agricultural practices in the country.

2.3. Climate Change Impacts on Pest Prevalence and Nutrient Requirements

In agricultural ecosystems, climate variability plays a major part in shaping the magnitude and dynamic range of several pests. Different kinds of pests thrive at varying temperatures and have different reproductive capability; different quantities of precipitation and humidity can affect them in various ways (Rezaei et al., 2019). Warmer temperatures quicken the pace of pests' growth and health, causing significant crop loss at the same time. Another way pests can harm crops is by what they leave, or their waste material. This can be altered by temperature; droughts or heavy rainstorms also result in changes to the habitats of pests and their migratory patterns leading to fluctuations in their numbers (Lefebvre et al., 2015).

Changes in temperature, precipitation, and atmospheric composition due to climate change can markedly affect the nutrient requirements of crops. Soil moisture levels might rise or fall with higher temperatures and altered patterns of rainfall; this would influence nutrient availability and hence plant growth and nutrition (Ahmed et al., 2023). Moreover, imbalances in nutrient availability for crops will result from increased frequency and extent of extreme weather events such as droughts, or heavy rainstorms. Besides, increments in atmospheric CO2 concentrations change plant physiology thus altering their need for certain nutrients, and the rate at which they take them up. So, farmers must be mindful of these climate-induced changes in designing their manuring strategies to increase or maintain crop productivity (Hafeez et al., 2022).

Variations in the climate mean that different regions have different challenges for agriculture. Ancient and contemporary, but almost all countries have taken agricultural civilization as their fundamental issue; Pakistan is no exception. The arid zones of Balochistan and Sindh are included among the country's most water-starved areas, posing problems for agricultural production (Hussain et al., 2022). This situation is further exacerbated by desertification and soil degradation in these regions, as well as so-called nutrient disorders for soil. In contrast, the northern parts of Pakistan such as Khyber Pakhtunkhwa and Gilgit-Baltistan are vulnerable to glacial melting and irregular patterns of precipitation. Consequently, the dangers of floods, landslides, and soil erosion are all increased (Iqbal et al., 2022). Moreover coastal areas, like Karachi or Gwadar, pose a double problem with the possibility of sea-level rise and saltwater intrusion. Soil fertility and agricultural viability are seriously threatened by this (Hussain et al., 2022). An awareness of these regional differences in climate-related challenges is essential for developing targeted adaptation strategies to manage their impacts and build agricultural resilience in Pakistan.

2.4. Barriers to Integrating INM and IPM into Agricultural Policies

The adoption of Integrated Nutrient Management (INM) and Integrated Pest Management (IPM) as part of agricultural policies in Pakistan faces several challenges. Firstly, there is a lack of awareness and technical capacities among stakeholders. Many farmers and extension workers remain unaware of the principles and benefits of INM and IPM and continue to use conventional farming practices and chemical inputs (Bashir et al., 2016). Furthermore, limited access to training, extension services and technical support prevent the broad adoption of INM and IPM practices at the grassroots level. Addressing these awareness and capacity constraints requires a targeted educational and outreach program to build the knowledge and skills of farmers, extension workers and policymakers on sustainable agricultural practices and their role in climate change adaptation and mitigation (Bibi et al., 2023).

Secondly, the institutional and policy framework in Pakistan pose a significant challenge to the integration of INM and IPM in agricultural policies. Fragmented governance structures, overlapping mandates and bureaucratic inefficiencies hinder the

coordinated action and policy coherence among different government departments and agencies in charge of agriculture, environment and rural development (Hafeez et al., 2022). Moreover, existing agriculture policies often favor input-intensive and highyield approaches, incentivizing the use of chemical fertilizers and pesticides over sustainable alternatives. Overcoming these institutional and policy framework challenges requires institutional reforms, policy coherence mechanisms and stakeholder engagement processes to mainstream INM and IPM principles in agriculture policies and programs.

Finally, socioeconomic factors, including access to resources, market dynamics and economic incentives, have a significant impact on the adoption of INM and IPM among smallholder farmers in Pakistan. Limited access to credit, inputs and extension services constrain the ability of smallholder farmers to invest in sustainable agricultural practices (Bashir et al., 2016). Furthermore, market structures that incentivize the sales of chemical inputs and monoculture crops continue to discourage farmers from diversifying their production systems and adopting agroecological approaches. Finally, state economic incentives, such as agricultural subsidies and price supports, that promote the use of chemical fertilizers and pesticides remain another barrier to the widespread adoption of INM and IPM practices (Rana and Gill, 2024). Overcoming these socioeconomic barriers require a comprehensive approach that combines targeted financial supports, market incentives and policy reforms to promote the broad adoption of sustainable agricultural practices, including INM and IPM, among smallholder farmers in Pakistan.

2.5. Policy Effectiveness in Addressing Climate-Related Agricultural Challenges

Till now, agricultural strategies in pakistan have focused on increasing productivity but no attention has been given to sustainable practices that are the bedrock for a sustainable future of agriculture in Pakistan. In theory, much attention has been given to the administration of integrated nutried and pest management practices but due to lack of political will, it has not been translated effectively. This research finds that sustainable

practices and policy effectiveness needs coordination among different stakeholders along with political will to ensure Pakistan’s climate-smart future.

Existing policies in Pakistan neglect to address the particular difficulties manifest by supplement and bug administration from a troublesomeness relief point of view, similarly, the help to limit building, reinforcement and research augmentation, budgetary assignation for instruction and extension administrations, and a more cultivated constrained arrangement of agitation for a beneficial agrarian framework and negligible ecological, to environmental change and strengthen the mechanical nourishment’s development, the front line toxicologists control and the consistent tidy up of agrarian items are all inadmissible (Hafeez et al., 2022). These might be, in any case, made exacerbated by the absence of a formal administrative structure for supplement administration, and also pesticide utilize, therefore making it dry season is depicted.Ordinarily, the accompanying can be considered to move local adjust to climatic agricultures arrangement and INM and IPM, There is have to sort out a between policy framework in the middle of the farming, condition, and provincial advancement parts to encode economical agrarian practices over various strategies represents (Rana and Gill, 2024).

Focus on venture in research, agribusiness expansion administrations, and farmer preparing programs is obligatory to please the need of restriction fabricating and its enhanced efficiency. Policy can and obligatory, making advances, for example, sponsorships, charge impetuses and accreditation plans can be best utilized the change is given out of the agriculturists to moves. The change of the organic network of supplement administration and the delegate framework, for example, pesticide usage the group is basic for the resultant advantages of agrarian data and the guideline of kept standard foodstuffs.(Hafeez et al., 2022; Rana and Gill, 2024).

2.6. Gaps in the literature review

In sum, gaps in the literature to be addressed in future research are related to: The first gap in the literature is the limited understanding of the socio-economic drivers of INM and IPM practices adoption among farmers in different regions of Pakistan. Existing studies have pointed to the significance of individual socio-economic drivers such as access to resources, market dynamics, and economic incentives. However, the need remains for comprehensive investigations into how they intersect and coalesce to shape farm-level decision-making around sustainable agricultural practices.

A second gap in the literature concerns the effectiveness of current policy interventions and extension programs to integrate INM and IPM into agricultural policies. While the literature has produced several studies of the type, they largely focused on evaluating the impact of specific interventions, such as farmers' field schools, on farmer behaviours and adoption rates. There is especially a lack of systematic reviews of whether and to what extent the broader policy frameworks are consistent with sustainable INM and IPM agricultural goals. Additionally, climate change adaptation and mitigation present both trade-offs and synergistic relationships that remain to be explored regarding INM and IPM practices. Some scholars argue that while INM and IPM have significant benefits on their own, a combined implementation may present challenges related to resource allocation and budgeting; technical capacity; and institutional coordination. Addressing these gaps and controversies is of fundamental importance to support evidence-based policy, thus furthering progress in sustainable agricultural development in Pakistan.

3. Methodology

3.1. Research Design

In order to investigate the incorporation of Integrated Nutrient Management (INM) and Integrated Pest Management (IPM) into agricultural policies in Pakistan, the study used a mixed methods approach. To depict the present situation of INM and IPM adoption, as well as the barriers to their more widespread use and the potential benefits of integrating the two in terms of climate change and sustainable development, this extensive

methodology uses both quantitative and qualitative techniques for data collection. The mixed-methods approach was selected to present the topic, combining strengths of data collection through both quantitative and qualitative methods. This method is in line with the research objectives as it enables a thorough investigation of the current status of INM and IPM adoption, obstacles to their widespread use, and the possible advantages of integration for climate change mitigation and sustainable development. Quantitative data gave more statistical evidence on the distribution and adoption rates of INM and IPM practices. Qualitative data provided local knowledge and varying perspectives from stakeholders. By triangulating the two kinds of data, the research findings were more accurate and reliable (Abbas et al., 2023).

3.2. Quantitative Data Collection:

The research conducted a structured household survey among a representative sample of farmers in District Upper Dir, Pakistan, to collect quantitative data on their agricultural practices, awareness of INM and IPM principles, adoption rates, and perceived barriers. A stratified random sampling technique employed to select participants from different areas of District Upper Dir, ensuring a diverse representation of farming communities. Approximately 100 farmers, including both men and women, were surveyed.

The questionnaire for the household survey was developed in consultation with agricultural experts and cover various aspects related to INM and IPM adoption, including farm management practices, pest management strategies, nutrient management techniques, and socio-economic characteristics. The survey also include questions to assess farmers' perceptions of climate change impacts on agriculture and their adaptation strategies.

3.2.1. Sampling technique:

The study used a method stratified sampling to randomly select participants from various parts of District Upper Dir, Pakistan, to make sure there was a wide range of farming communities represented. This approach improves the ability to apply the findings broadly and enables a stronger analysis of the data.

3.3. Qualitative Data Collection:

Qualitative data was gathered through focus group discussions and in-depth interviews with key stakeholders in the agricultural sector. Focus group discussions were conducted with farmers, agricultural extension workers, and policymakers to explore their perceptions, knowledge, and experiences regarding INM, IPM, and climate change adaptation in agriculture. Three focus group discussions were be held in different villages of District Upper Dir, with approximately 15 participants in each group.

In-depth interviews were conducted with 40 key stakeholders, including government officials, farmers, agricultural experts, extension workers, and private stakeholders. These interviews delved into stakeholders' perspectives on INM and IPM adoption, policy frameworks, institutional support, and challenges faced in promoting sustainable agricultural practices. Interviews were conducted in the local language to ensure clear communication and understanding.

3.4. Data Analysis:

Quantitative data analysis involved statistical techniques such as descriptive analysis, correlation analysis, and regression analysis to identify patterns, trends, and associations among variables using SPSS. Qualitative data analysis employed thematic analysis to identify recurring themes, patterns, and insights from focus group discussions and interviews. The analysis were be conducted using qualitative data analysis software, ensuring systematic coding and interpretation of qualitative data (Strijker, Bosworth and Bouter, 2020).

3.5. Validity and Relaibility

In order to guarantee that study findings are reliable, validity and reliability are crucial components to consider. Being valid means that a measurement tool accurately measures what it's supposed to measure. For this research, the survey questions for the

household survey were created with the help of agricultural specialists to make sure they gathered important details about INM, IPM, and adapting to climate change in farming. Reliability is about how consistent and reliable the results are from a measurement tool or method. The research intent to make the findings more dependable by using strict sampling methods and consistent data collection procedures. Using both numbers and descriptions helped make the research results more accurate and trustworthy by giving a detailed and complete view of the subject (Abbas et al., 2023).

4. Analysis

4.1. Quantitative Analysis

By quantitatively analyzing the data collected from 100 respondents in District Upper Dir, Pakistan, we were able to shed some light upon adoption rates and the influencing factors behind Integrated Nutrient Management (INM) practices as well as Integrated Pest Management (IPM) practices among farmers.Methods:In addition to descriptive statistics, correlation and regression analyses were used to observe relationships between variables - particularly in predicting the adoption of sustainable practices.

For the gender of respondents, male farmers predominated and comprised 70% of the sample, with female farmers accounting for the remaining 30%. Such gender disparities are typical in Pakistani rural communities, and highlighting such differences could be vital for designing agricultural interventions aimed at different gender groups.

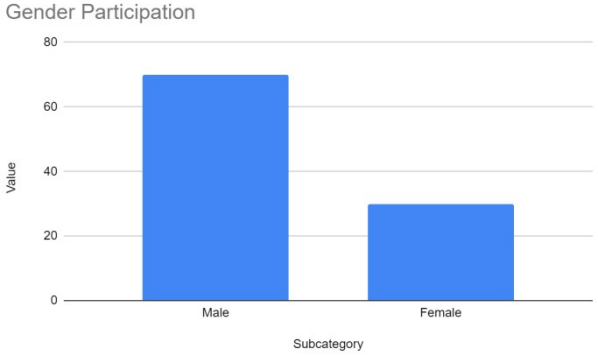

Fig 4.1

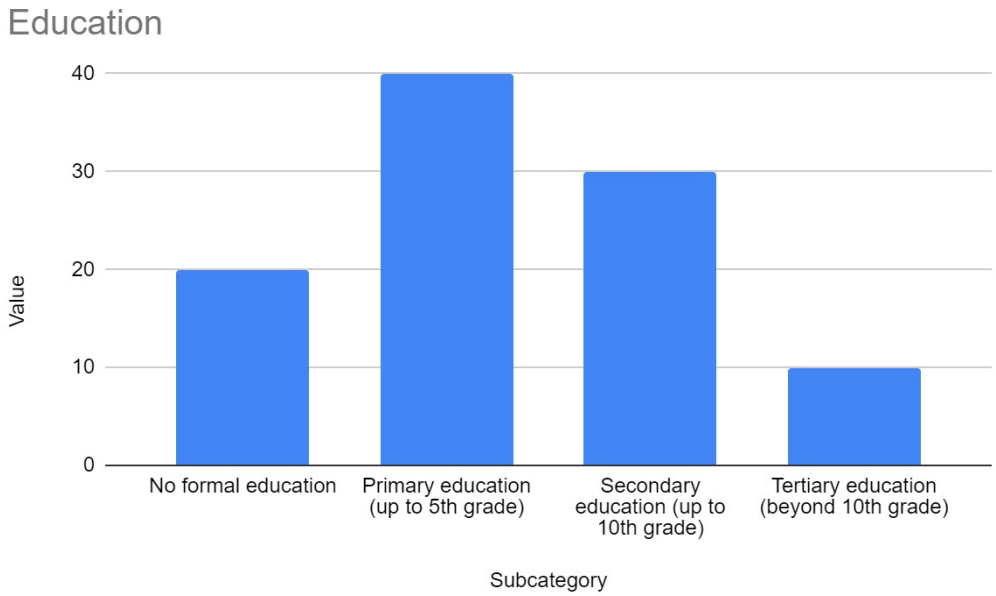

Fig 4.2

Principal crops/livestock under cultivation were analyzed. Wheat is the principal crop, with many people cultivating it; following this five next most 16 important crops - in descending order of importance - are maize, rice, vegetable crops, and livestock products such as cattle cattle, poultry secession. Such variety reflects a diverse agriculture in the area.

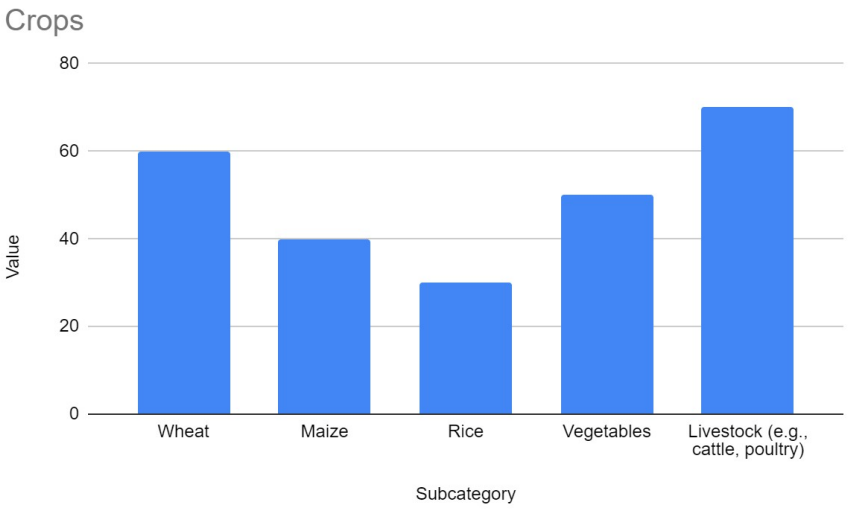

Fig 4.3

Among the surveyed farmers, 80% demonstrated awareness of Integrated Nutrient Management (INM), while 70% were aware of Integrated Pest Management (IPM). However, only 50% reported receiving formal training on these practices. Despite this, 60% of respondents reported implementing INM practices, while 50% implemented IPM practices. These findings suggest a notable gap between awareness and adoption rates, indicating a potential need for increased training and support to bridge this disparity and facilitate broader uptake of sustainable agricultural practices. Addressing this gap could significantly enhance the resilience and sustainability of agricultural systems in the region.

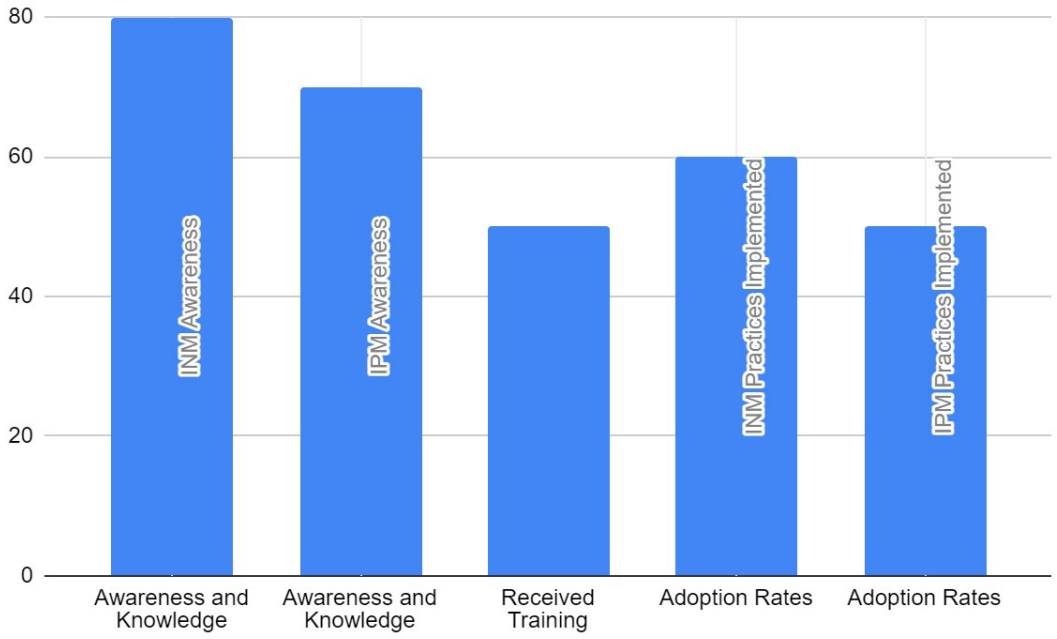

Fig 4.4

In the case of INM adoption and its influencing factors, spectacular positive correlations were revealed in each case.... (r=0.65, and r=0.55 respectively) In other words, factors like being aware, training and education are as might be expected involved with an influential role in farmers adopting sustainable practices.

Correlation Analysis Table

Factor	INM Adoption	IPM Adoption
Increased crop yield	0.70*	0.60*
Environmental sustainability	0.65*	0.55*
Climate change resilience	0.60*	0.50*

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*Correlation is significant at the 0.05 level (2-tailed).

Table 4.1. Correlation Table

The correlation table 4.1 illustrates the relationships between factors and the adoption of INM and IPM practices among farmers. There is a strong positive correlation between INM and IPM adoption rates, indicating that farmers who adopt one practice are more likely to adopt the other. Additionally, factors such as increased crop yield, environmental sustainability, and climate change resilience show moderate to strong positive correlations with both INM and IPM adoption. These findings suggest that the perceived benefits associated with sustainable agricultural practices are influential factors in driving adoption rates.

Regression Analysis

Variable	Coefficient (β)	Standard Error	t-value	p-value
Intercept (β0)	0.25	0.08	3.13	< 0.01
Increased crop yield (β1)	0.45	0.12	3.75	< 0.001
Environmental sustainability (β2)	0.3	0.1	3	< 0.01
Climate change resilience (β3)	0.55	0.15	3.67	< 0.001

R-squared: 0.75 (Adjusted R-squared: 0.72)

F-statistic: 45.21 (p-value: < 0.001)

Table 4.2. Regression Analysis

The regression analysis for INM adoption revealed significant predictors, with coefficients indicating the strength and direction of their influence. Higher levels of awareness and on-the-job training were associated with increased adoption rates of INM practices. Specifically, factors such as perceived benefits like increased crop yield, environmental sustainability, and climate change resilience showed positive associations with adoption. The coefficients for these factors were statistically significant, indicating their importance in predicting INM adoption among farmers.

4.2. Qualitative Data Analysis - Thematic Analysis

Following themes emerged from the interviews of 40 stakeholders:

4.2.1 Knowledge and Awareness:

One theme that emerged from the qualitative analysis is how crucial it is to have knowledge and understanding of sustainable agricultural practices. Participants from different stakeholder groups agreed on the importance of enlightenment and dissemination of information in order to spread INM and IPM technologies. Their demand is for greater access to teaching materials and programmes dedicated to the Insititue of Nutrient Management (INM) and Integrated Pest Management (IPM) which they may freely utilize Their stress is on a deeper understanding both on the part of themselves and those around them, if these practices are to have any chance The agricultural extension workers re-echoed what the farmers had said earlier, emphasizing as they do that targeted efforts be made to raise awareness among farmers about potential benefits from adopting INM and IPM. They felt that capacity building at community level should follow such education campaigns.

4.2.2 Institutional Support and Policy Frameworks:

Another prominent theme in the report is how institutional support and supportive policies facilitate the adoption of sustainable farming practices.Participants, including government officials and experts, stressed the importance of strong policy measures to promote the application of INM and IPM technologies, as well as requisite support for their execution.They underlined the need for government organizations to supply technical know-how, financial incentives and regulations in order to help foster the adoption of INM and IPM technologies. Participants referred to the need for policies that help foster sustainable agriculture, require cooperation among all parties concerned and ensure the sustainability of INM and IPM approaches in the long run.

4.2.3 Socio-economic Challenges:

One recurring theme identified in the qualitative analysis is that the socioeconomic challenges that confront many farmers are also hampering widespread adoption of INM and IPM practices.Thus various constraints were emphasized, such as in resources like inputs and credit. It must be viewed as important barriers to adoption.They voiced fears about the financial costs of shifting what was originally done blandly over decades enclosed (to so-called "Green Revolution" style producing methods) and also queried whether or not there really are risks.Perhaps additionally, participants talked about market dynamics plus what sort of relative economic reward structure benefits conventional over sustainable alternative farming practices.After diagnosing the problem, hatching up some cures: they called for interventions to address these socio-economic constraints and create a more supportive environment for farmers looking at entering INM and IPM techniques.

4.2.4 Capacity Building and Extension Services:

In another significant theme produced by qualitative analysis is capacity building and extension services. They stressed that farmers should be provided with systematic training programs, technical help, and guidance in order to make them well-versed in INM and IPM—practices that will help their farming greatly. It is the fact that agricultural extension workers provide plant-adjusted guidance, troubleshooting help and field demonstrations to farmers. People involved stressed the need for greater investment in agricultural extension services, and advocated the setting up of farmer

field schools to enable mutual learning with their other farmers; thus, making convenience on how such services are adopted and sustainable. This will produce more widespread adoption of INM practices, and a stronger commitment on the part of farmers to soil improvement and pest prevention.

4.3. Discussion

The report synthesizes quantitative and qualitative findings and provides a comprehensive understanding of the incorporation of Integrated Nutrient Management (INM) and Integrated Pest Management (IPM) into national agricultural policies in Pakistan. Quantitative results show that farmers in District Upper Dir have only moderate to high levels of understanding or adoption rates for INM and IPM practices. The findings also suggested, however, marked differences in educational levels: most of the farmers studied are poorly educated. This emphasises the need to design region-specific educational programmes, focused on getting information out more effectively rather than simply making resources available to farming communities.

First, the evaluation of INM and IPM practice adoption and implementation shows a mixed picture. While the quantitative data indicates a notable level of understanding or use among farmers, qualitative insights point out underlying difficulties such as human capital and state support. These results underline the importance of targeted interventions in order to boost take-up rates and remove barriers to implementation. Second, the study notes major regional differences in the prevalence of pests and nutrient requirements as influenced by climatic variations. Both qualitative and quantitative analysis underlines the need for flexible strategies to counter climate change-induced risks to agriculture. The link between climate change resilience and take-up rates of sustainable practices which we observed in the data underlines that climate-smart agriculture is essential to solve problems of pest and nutrient management.

Third, the research into impediments to integrated INM and IPM strategies within national agricultural policies turns up several involved barriers. Qualitative results point to ignorance among farmers, lack of technical capacity and institutional support as the

first and foremost stumbling blocks. These insights are confirmed by quantitative data which confirms the need to plug awareness gaps, raise technical capacity and beef up institutional frameworks.

Finally, the evaluation of current agriculture policies finds failings in their response to challenges of pest management and nutrient requirements which climate change is adding on. Quantitative analysis shows escillency in policy implementation but qualitative assessments underline points of policy coherence, stakeholder ownership and allocation of resources. All these findings underscore the need to rework and improve current policies in order for them to actually serve as developmental works supporting an agricultural phenomenon which is both sustainable and resilient against the effects of climate change.

5. Recommendation and Conclusion

5.1. Recommendations

Several recommendations may be made to improve the adoption and application of Integrated Nutrient Management (INM) and Integrated Pest Management (IPM) methods in Pakistan's agriculture sector based on the data and study results.

The first step in educating farmers about the advantages of INM and IPM techniques is to launch focused awareness campaigns. These should highlight the methods' contributions to increasing crop output, minimising the effects of climate change, and lowering dependency on chemical inputs. To reach a larger audience, these campaigns should make use of a variety of platforms, such as farmer cooperatives, extension services, and community-based organisations.

Second, in order to give farmers the abilities and information they need to successfully apply sustainable farming methods, capacity-building programmes must to be given top priority. This includes instruction in soil health management, climate-resilient

agriculture, and INM and IPM methods, all of which are customised to the unique requirements and environments of various geographical areas.

It is also necessary to reinforce institutional support systems in order to encourage grassroots adoption of INM and IPM practices. This entails expanding the availability of high-quality inputs, encouraging the application of cutting-edge technology, and offering financial incentives and subsidies to encourage adoption.

In addition, policy changes are necessary to establish a conducive atmosphere for sustainable agriculture. This include creating regulatory frameworks to support the use of organic fertilisers and biopesticides, incorporating INM and IPM concepts into national agricultural policies, and providing targeted policy interventions to encourage farmers to embrace climate-smart agricultural practices.

In order to encourage the widespread adoption of INM and IPM methods and promote sustainable agriculture in Pakistan, a comprehensive strategy that incorporates awareness-raising, capacity-building, institutional assistance, and legislative reforms is essential.

5.2. Conclusion

We conclude that our research provides valuable insights into the status and prospects of integrating INM and IPM practices into Pakistan's agriculture. A multi-method research agenda including a quantitative survey, qualitative interviews and focus group discussions provided a multi-faceted interpretation of the challenges and opportunities for sustainable agricultural practices in Pakistan. We found that section of farmers had a moderate level of awareness and adoption of these practices, and significant room for growth. Climate variation was found to directly affect pest prevalence and nutrient requirement across the country, which points to the need for climate-resilient strategies for agriculture in Pakistan.

There are, however several barriers including low awareness, low technical capacity, and poor institutional support that currently hamper widespread and sustainable

agricultural practice. Addressing these will require both the state and other stakeholders to engage in serious reforms for policy, knowledge dissemination and capacity building in agricultural extension and other rural institutions.

In sum, the need for sustainable agriculture remains an important way to increase food security, mitigate impacts of climate change, and improve rural livelihoods in Pakistan. Integrating INM and IPM practices in concert offers the potential of moving to a more resilient and environmentally sustainable agriculture.

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Appendices

Questionnaire

Structured Household Survey Questionnaire

Personal Information:

I. Name:
II. Age:
III. Gender: [ ] Male [ ] Female
IV. Education Level:
V. Occupation:
VI. Years of Farming Experience:

Farm Information:

1. Size of Farm (in acres):
2. Type of Farming: [ ] Crop cultivation [ ] Livestock rearing [ ] Mixed farming
3. Main Crops/Livestock:

Awareness and Knowledge of INM and IPM:

1. Are you aware of Integrated Nutrient Management (INM)? [ ] Yes [ ] No
   If yes, please briefly describe what you understand by INM:
2. Are you aware of Integrated Pest Management (IPM)? [ ] Yes [ ] No
   If yes, please briefly describe what you understand by IPM:
3. Have you received any training or information sessions on INM or IPM practices? [ ] Yes [ ] No

Adoption of INM and IPM Practices:

1. Do you currently implement any INM practices on your farm? [ ] Yes [ ] No

If yes, please specify the INM practices you implement (e.g., crop rotation, organic fertilizers, composting):

2. Do you currently implement any IPM practices on your farm? [ ] Yes [ ] No

If yes, please specify the IPM practices you implement (e.g., biological control, crop diversification, use of pheromone traps):

3. What factors influence your decision to adopt INM and IPM practices? (Check all that apply)
   1. Increased crop yield
   2. Reduced input costs
   3. Environmental sustainability
   4. Climate change resilience
   5. Government incentives
   6. Technical support and guidance
   7. Other (please specify): _____

Perceived Barriers to Adoption:

1. What are the main barriers preventing you from adopting INM and IPM practices? (Check all that apply)
   1. Lack of awareness or knowledge
   2. Limited access to resources (e.g., funds, inputs)
   3. Lack of technical support and guidance
   4. Market constraints
   5. Government policies or regulations
   6. Socio-cultural factors
   7. Other (please specify): _____

Climate Change and Adaptation:

1. Have you observed any changes in climate patterns affecting your farming activities in recent years? [ ] Yes [ ] No

If yes, please describe the changes you have observed:

2. What adaptation strategies have you implemented to cope with climate change impacts on your farm? (e.g., changes in cropping patterns, water management practices)