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Impact of Grain Subsidy Policy on Agricultural Ecological Efficiency: Evidence from Pakistan

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Abstract

The complex relationship between grain subsidy programs and agricultural ecological efficiency in Pakistan is becoming increasingly important in sustainable agriculture and environmental preservation. This study uses a quasi-experimental methodology. SPSS software was used to conduct the statistical analysis. Descriptive statistics were initially calculated for each variable. This study analyses grain subsidy policies using modern literature and empirical data, acknowledging government interventions' crucial significance in agricultural practices in Pakistan. The results show that, firstly, grain subsidy a siginfance positive relationship with ecological efficiency. Secondly the nagtive grain subsidy effect on soil health and soil pH(Avg.change). One consequence of such projects is boosting food production and supporting farmers economicallyThe study recommends legislative changes that balance agricultural productivity and environmental protection. These include promoting sustainable farming, reforming subsidy programs to encourage ecological practices, and incorporating environmental factors into agricultural legislation.

Keywords: Agriculture, Environmental Sustainability, Ecological Efficiency, Grain Subsidy

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Contents

Abstract

The complex relationship between grain subsidy programs and agricultural ecological efficiency in Pakistan is becoming increasingly important in sustainable agriculture and environmental preservation. This study uses a quasi-experimental methodology. SPSS software was used to conduct the statistical analysis. Descriptive statistics were initially calculated for each variable. This study analyses grain subsidy policies using modern literature and empirical data, acknowledging government interventions' crucial significance in agricultural practices in Pakistan. The results show that, firstly, grain subsidy a siginfance positive relationship with ecological efficiency. Secondly the nagtive grain subsidy effect on soil health and soil pH(Avg.change). One consequence of such projects is boosting food production and supporting farmers economicallyThe study recommends legislative changes that balance agricultural productivity and environmental protection. These include promoting sustainable farming, reforming subsidy programs to encourage ecological practices, and incorporating environmental factors into agricultural legislation.

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Introduction

Agriculture has been a cornerstone of human civilization for millennia, providing nutrition, livelihoods, and economic stability to communities around the world. But, as the world's population continues to grow, so does the demand for agricultural products, which places a great deal of pressure on the agricultural industry to

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increase output. Even though they are necessary for food security, too large yields and too great efficiencies have generated several environmental and ecological problems in Pakistan.

Intensification of agricultural practices in Pakistan including the use of chemical fertilizers, pesticides, and monoculture cropping has resulted in environmental deterioration, land degradation, water pollution, and loss of biodiversity. These practices became the subject of both regulatory and encouraging government policies.

Grain production subsidies are essential for promoting and providing grain production and food security (Kong et al., 2021). This paper examines, as a result, the impact of agricultural subsidies on grain production in main grain-producing regions. Agricultural subsidies can increase household income (Han & Chen, 2021) by promoting the growth of cultivable land, and by increasing cereal manufacturing. For the longer term, fittingly China's cereal production thus far has been consistently depended upon as the force behind small households (Jiang et al., 2021).

Since grain subsidy programs may offer economic help for farmers and consumers, but may also be used for maintaining environmentally harmful activities, the impact of the grain subsidy on agricultural ecological efficiency has become a matter of interest. Balancing food production and environmental conservation requires first understanding the interplay between these programs and ecological efficiency. A multifaceted research framework is proposed to investigate resource utilization, environmental sustainability, as well as biodiversity, and the evolution, objectives, and implementation methods of grain subsidy policies (Ke et al., 2015). Therefore, income-based subsidies are an effective way of promoting grain production (Yu et al., 2017).

Grain subsidy policy on agricultural ecological efficiency is a research topic as it is of relevance to a number of significant spheres such as public health, environmental sustainability, and economics. In many countries, grain subsidies form a major part of agricultural policy, playing a significant role as far as economic sustainability of cultivation and therefore, the food security of the country are concerned. Therefore, it is critically important for agricultural sector stakeholders, policymakers, and economists to understand the impact of these subsidies on agricultural practices and yields. This subsidy consequently leads to improvement in agricultural productivity and the level of agricultural mechanization since the runaways specialize in other things (Rahman et al., 2020). However, one advantage to rural households is that subsidies to agricultural machinery purchases will boost both the quantity and quality of machinery (Tong et al., 2020) that the households can acquire. When using agricultural machinery, they can produce cereal with higher efficiency and have a lesser amount of labor on an acre (Huo et al., 2022)

This research explores the influence of grain subsidy on agricultural ecological efficiency, with the desire to reconcile environmental stewardship with agricultural productivity. It shows that local and central governments should provide necessary incentives to residents to buy onboard advanced agricultural machinery (Zou et al., 2019).

The impact of grain subsidy policy on agricultural ecological efficiency, that is, the carbon footprint, biodiversity impacts, and use of resources is studied. The research analyzes environmental metrics and agricultural outputs by using subsidies, using statistical computations. In addition, public health is considered, as cultivation methods and commodity variety determine food availability and quality. The research seeks to enhance the policy choices for environmentally sustainable and economically feasible health-conscious agricultural practices.

It aims to investigate the effect of grain subsidy policy on agricultural ecological efficiency. We have developed the following specific research objectives to attain this overarching goal:

1. With the aim to investigate grain subsidy policies' historical evolution in different regions of Pakistan.
2. To estimate the effects of these policies on Pakistan's agricultural practices, such as crop selection, input use, and land management.
3. Environmental impacts of grain subsidy policies in Pakistan, for example on soil health, water quality, and biodiversity are explored.
4. It seeks to identify potential tradeoffs and compensation between food security and environmental sustainability of these changes in Pakistan. Cultural practices, including crop selection, input use, and land management in Pakistan.

Grain Subsidy Policies Affecting Agricultural Ecological Efficiency in Pakistan: implications for Soil, water, and biodiversity conservation is the focus of this research. It attempts to educate politicians, practitioners, and academics about the complicated connection between many policymakers or interventions and ecological consequences with the goal of directing policymakers toward sustainable agriculture policies to solve food insecurity and more ecologically pleasing agriculture.

In this study, "Impact of Grain Subsidy Policy on Agricultural Ecological Efficiency: In the paper, 'The Grain Subsidy Schemes Evidence from Pakistan' the complex link between the grain subsidy scheme and agricultural efficiency in Pakistan is examined. The complex relationship between agricultural ecological efficiency and the grain subsidy regime is studied for the target of 2019–2023. First, descriptive statistics are used in SPSS to understand each variable and to start an investigation. A t-test for independent samples is performed to test the significance in terms of the control and treatment groups, taking significance as p less than 0.05. Ethical standards and data integrity were maintained—educated consent was sought and strong anonymization was utilized to preserve privacy for farmers throughout this research. This developed investigation examines the effect of grain bonuses on how activities and results of Pakistan's agriculture industry ecological practices.

Literature Review

Agricultural ecological efficiency (AEE, the coordinated development of agricultural productivity, resources, and the environment) is an important indicator (Ren et al., 2023). AEE is aimed at producing the most agricultural output possible with the least amount of resources and the least environmental pollution under a specific combination of agricultural inputs (Hu et al., 2023; Ma et al., 2017), integrating agricultural production efficiency and environmental benefits.

In recent years, scholars have paid much attention to research on AEE (Scuderi et al., 2021). Guo and Liu (2021) indicate that agricultural production's economic and environmental benefits can be taken into account by AEE. Though the AEE of the agricultural economy develops rapidly, it should be improved generally, leading to the urgent need for new stimuli for the promotion of agricultural green production (Wu et al., 2022). Various studies have demonstrated that agricultural mechanization level, regional economic growth, urbanization process, agricultural financial expenditure, natural disasters, and so on will all impact AEE (Li et al., 2021). Subsidies for agricultural supplies that are comprehensive primary target inputs utilized in cereal production, including pesticides and fertilizers(Zou et al., 2019). We are all aware that agricultural subsidies can assist rural households in main producing regions in covering a portion of their expenses. As a consequence of the augmented budget allocated to fertilizer and pesticides, household utilization patterns will undergo modifications (Pan et al., 2022).

In the absence of subsidies, grain-producing rural households are obligated to bear the costs associated with fertilizer and pesticides. Consequently, they have a tendency to acquire inexpensive or mono-compound fertilizers (Li & Wu, 2021), which leads to compromised water resources and contaminated soil quality (Arrueta et al., 2022). However, they may alter their decision if the government provides subsidies for agricultural supplies to households. If prudent rural households are involved, the expected rate of return will be either maximized or minimized. As an effective strategy to handle hazards associated with cereal production and weather unpredictability in rural areas where acreage is usually limited, fertilizers and pesticides are used (Mozumder & Berrens, 2006).

In order to influence fertilizer application decisions, agricultural supplies must be subsidized (Tigre & Heshmati, 2022). Subsidizing more efficient fertilizers gives rural households access to them and prevents soil degradation. As such, it bolsters soil quality and provides assured sustainable land occupancy in substantial agricultural zones which, in turn, increases cereal production (Jaksomsak et al., 2016).

But farmers also have their responsibility to encourage agricultural green output. The knowledge, skills, and production conceptions affect their production behavior which in turn affects agricultural production input and output. This results in the important influence of AEE in RHC (Zhang, 2017). The discussion will still need improvement in this part of the extant papers. Past research was primarily concentrated on the influence of RHC on AEE, which is applied via the education dimension (F. Liu & Lv, 2021). With improvements in farmers' education level, their production skills are also improved, which can take full advantage of the input elements to promote AEE improvement. (Z. Liu et al., 2023). Moreover, farmers know very little about environmental protection has come to some certain level, which is beneficial to the promotion of AEE (Yang et al., 2021). According to other experts, on the other hand, the RHC has practically no effect on agricultural economic growth (Attanasio et al., 2017).

The history of the grain subsidy goes back as far as the civilizations of antiquity. Grain subsidies were used extensively by nations around the world in the past, like Egypt and Rome, where they served to stabilize food prices, providing food security and boosting the agricultural industry(Zhu et al., 2022). Many of these early subsidies were essential in preventing famine, and in helping to maintain social stability.

From the medieval period, monarchs or municipal authorities in Europe on occasion gave subsidies for grain to ensure a constant food supply. Usually, these subsidies were connected with feudal institutions when the landowners were rewarded for their loyalty and participation in grain production (Peng et al., 2022). Due to the Industrial Revolution, there was great urbanization, which additionally pushed demand for grain. Because of this, European and North American governments started to implement grain subsidy programs to help farmers as well as to promote a steady supply of food for the growing urban population. The intention of these subsidies has been to find a balance between agricultural sustainability and urban nourishment (Anderson, 2022).

For grain subsidy policies, the watershed experience was the Great Depression in the United States. The Agricultural Adjustment Act (AAA) was passed in 1933 to deal with falling agricultural incomes and the problem of crop surpluses. These subsidies aimed at reducing the surplus and increasing farmer's economic well-being show how the grain subsidies transformed to cope with modern economic problems (K. Chen & Wang, 2022).

Following WWII, numerous other countries maintained the grain subsidy for fiscal policy of their agricultural policies. Ensuring food security and providing an income for farmers, who were the backbone of the national economy, were the principal objectives (Martínez-Moreno et al., 2022).

The Green Revolution, which occurred in the mid-twentieth century, introduced new agricultural technologies and methods that raised grain production dramatically. Governments in poor nations frequently employed grain subsidies to stimulate the adoption of these inventions, increasing food production and improving food security (Shideler, 2022). History has been open to disputes about grain subsidy policies. They became a focus of international trade negotiations, with trade treaties such as the General Agreement on Tariffs and Trade (GATT) and the World Trade Organization (WTO) trying to control agricultural subsidies, especially for grains, to maintain fair global trading practices (Martínez-Moreno et al., 2022).

Currently, grain subsidy policies among countries are very different. Yet some countries have continued with extensive grain subsidies to support farmers and to guarantee food security, and others have switched to market-oriented agricultural policies. The use of these policies continues to be debated as useful or not useful as well as their consequences by policymakers, economists, and agricultural specialists.

One important way that agricultural practices change in response to subsidy policies is that farmers have the option of choosing which crop to plant. Specific crop subsidies may lead to a shift of production toward those crops. For instance, the Farm Bill in the U.S. played a major role in offering large commodities subsidies, in particular for corn and soybeans (Attanasio et al., 2017). So, farmers can end up preferring to plant some crops as opposed to others, which in turn, leads to monoculture farming techniques and no agricultural diversification.

It could also have an effect on the environment. Subsidies for such crops as those that require much water or chemicals contribute to environmental degradation. The European Union's Common Agricultural Policy (CAP), for instance, has been reproached for subsidizing intensive agricultural practices that destroy soil and pollute water (Morri & Santorini, 2021). The ecological sustainability of subsidy programs is one thing these environmental consequences highlight for policymakers to consider. An additional benefit is that agricultural apparatus can operate in various locations and aid in the mitigation of agricultural catastrophes (Weerasekara et al., 2021). As a result of reducing time and space constraints, sophisticated apparatus increases production efficiency. The second benefit pertains primarily to the production of grains. Advancements in agricultural mechanization will serve as intermediaries between humans and more environmentally sustainable agricultural technologies. Equipment such as subsoilers, which loosen and enhance soil fertility (Ning et al., 2022) construct irrigation and water conservation systems, and manage diseases and pests are a few examples. In addition to mitigating human-induced errors, these agricultural technologies will enhance cereal production efficiency and sustainably increase grain output.

However, subsidy policies most often provide vital income support to farmers. Farmers can be protected through subsidies they receive for reducing financial risks and ensuring farmers have live symptoms. They also found in China, that subsidies had an enormous positive impact on farmers' income, especially for smallholders (Zhang, Wang, and Bai 2019). One of the more controversial issues with subsidy policies is the potential they have to distort agricultural markets. Overproduction of particular crops as a result of subsidies can lead to falling prices, while cutting farmers' competitiveness in other regions or countries (Han et al., 2021). It is a hot topic in the trade treaties of the World Trade Organization (WTO), for example.

Agricultural policies, particularly subsidy policies, play an enormous role in how agriculture is practiced with implications on crop selection, the environment, farmer income, and market dynamics. Although they are a vital service to the agricultural industry, the impact these companies are sure to have on water in the region needs to be carefully considered. The aim of the subsidy program should be to combine economic support and environmental responsibility through the integration of sustainable agricultural practices and environmental protection in the subsidy program design.

The paper is organized as follows: The second section reviews the existing evidence on the research question and brings forth a set of hypotheses. Data and methodology are described in Section 3. In Section 4, I analyze the empirical findings. In section 5, directions for future work are outlined. Section 6 concludes.

Methodology

The study uses a quasi-experimental methodology in order to assess the impact of agricultural subsidies on various environmental factors including soil health, water use, and fertilizer use. An experimental design was selected due to ethical, as well as practical, considerations that prevent the implementation of a proper experimental approach in a real farming situation. In different parts of Pakistan, two groups of farmers, the treatment group which received subsidies, and a control group which did not, were studied.

Sampling

A stratified random sampling procedure was used to select two hundred farms from each of these two groups. The stratification was by the size of the farm, the crops grown, and the location. We created this strategy to ensure the sample was representative.

Data Collection

Data was gathered using organized questionnaires through field trips and farmer interviews. The field trips also required the observation of and evaluation of farming practices using observation, water sampling, and soil testing. Interviews were conducted by enumerators with training who had been able to communicate well with the local respondents in either the regional languages they spoke or who had culturally informed them on agricultural practices in the study area. The statistical analysis was done on SPSS software. First, descriptive statistics were calculated on each variable. T-test for independent samples was used as the statistical technique to compare the control group with the treatment group. For all analyses, a p-value of ≤ 0.05 was considered statistically significant. Each of the participants gave their informed permission before enrolling in the clinical experiment. Therefore procedures of anonymization were performed in order to protect the personal information of the farmers and protect their privacy. The study was meant to understand comprehensively subsidies impact on agricultural practices in Pakistan through use of rigorous methodology. A specific focus was proposed on the environmental contrast of the country's extant applications in the field of agriculture and the evaluation of their effectiveness.

Data Analysis:

Environmental viability of grain subsidy policies

The environmental sustainability of grain subsidy programs is evaluated via a few ecological efficiency indicators such as water use efficiency, carbon footprint, biodiversity impact, energy efficiency ratio, and nutrient use efficiency, in this study.

Table 1

utilization of subsidies

Parameter	Without Subsidy	With Subsidy	P-value
Soil Health	72%	65%	0.045
Water Usage	4000m^3	5200m^3	0.031
Fertilizer Use	200 kg	270 kg	0.027
Yield	1.5 tons	2.0 tons	<0.001

Author's Calculations

These metrics provide a useful set of intuition about the complex ecological impacts of these rules and give a broad picture that makes it easier to improve and restructure future agricultural subsidy regulations in this area.

Soil Health

Using subsidies was shown to dramatically reduce soil health, measured as a decrease in the indicator of soil health from 72% to 65% (P-value 0.045). The health of the soil was measured by different soil quality indicators, including pH level, organic matter content, and erosion susceptibility. It means that while subsidies increase yields, they encourage development that is negative for long-term soil sustainability. Further analysis of Table 2 shows that this decrease in health is consistent across all the phenotypic sub-metrics of soil health, such as pH and organic matter.

Water Usage

In the subsidized scenario, water use increased, going from 4000 m3 to 5200 m3 (P-value = 0.031). A deeper look at Table 3 reveals that increased groundwater extraction is the leading cause of this increase. This conclusion is alarming because excessive groundwater consumption can cause aquifers to be depleted, which would affect long-term water supplies. According to the findings, while subsidies may help raise immediate grain yield, they may also unintentionally encourage patterns of water use that are unsustainable.

Use of Fertilizer

Another criterion where the analysis discovered a considerable impact from subsidies was the use of fertilizer. When subsidies were used, use rose from 200 kg to 270 kg (P-value = 0.027). Table 4's additional breakdown reveals that other fertilizers, including those containing nitrogen, phosphorus, and potassium, were also used more frequently. It may result in an imbalance of soil nutrients and may have a role in problems like eutrophication in surrounding bodies of water.

Yield

In the subsidized scenario, the yield parameter significantly increased from 1.5 tons to 2.0 tons (P-value 0.001). Although this demonstrates the remarkable effectiveness of subsidies in boosting grain output, the advantage comes at the expense of the environment due to decreased soil health, increased water use, and increased fertilizer use, as shown by the other criteria studied.

Table 2

Soil Health Metrics

Soil pH	Organic Matter	Soil Erosion	Without Subsidy	With Subsidy	P-value
6.5	5%	Low	6.2	6.0	0.039
6.8	7%	Moderate	6.5	6.3	0.054

Author's Calculations

Table 2 was developed to deconstruct the several sub-metrics of soil health, including soil pH, organic matter, and soil erosion levels, in order to explain better how grain subsidies affect soil health. This additional level of research improves our comprehension of the precise way in which subsidies might influence soil quality.

pH of the soil: The study discovered that when subsidies were used, soil pH levels slightly decreased. Notably, the pH levels decreased to 6.0 and 6.3 in areas where the soil pH was initially 6.5 and 6.8, respectively. In the first scenario, the drop in pH levels was statistically significant (P-value =

0.039), indicating a possible negative impact of subsidies on the health of the soil.

Organic Substance: A further crucial indication of soil health, organic matter, was displayed as percentages. Organic matter P-values are not included in Table 2. However, their inclusion as a parameter of interest suggests the necessity for additional research to look into any potential drop brought on by subsidies.

Earth Erosion: There are two categories for soil erosion: "Low" and "Moderate." While the study lacks precise data as to how much and how fast soil erodes under the production of subsidies, it establishes a background for considering soil erosion as part of soil health. Because agricultural practices that intensify farming also produce high rates of erosion, it is important, nonetheless, to consider this problem in light of grain subsidies.

Table 3

Water Usage by Source

Source	Without Subsidy	With Subsidy	P-value
Groundwater	2200m^3	3000m^3	0.042
River/Lake	1800m^3	2200m^3	0.056

Author's Calculations

Use of Water: Table 3 provides a more detailed perspective of water use by grain source from which we can gain a more complete picture of the environmental consequences of grain subsidies. Table 3 shows that there are two major watering sources, groundwater and river/lake water. This specialized approach allows for a more complete assessment of the role that subsidies will play in sustainable water management of agriculture.

Groundwater: The study showed that the introduction of subsidies considerably increased groundwater use from 2200 m3 to 3000 m3 (P value = 0.042). An increase like this given the likelihood of groundwater depletion and the long-term effects such an increase is likely to have on the human population and biological systems is alarming.

River/Lake: The amount of water consumed by rivers and lakes also rose from 1800 m3 to 2200 m3. Although the P-value, 0.056, still did not reach the standard 0.05 threshold for statistical significance. But even this small increase can have an effect on neighborhood ecosystems in places where water bodies are already stressed. In particular, because fertilizers represent a key input into agricultural production and productivity, the subsidies can shed light on how effective they are at providing an ecological service. To provide a more detailed understanding of how subsidies affect fertilizer application, Table 4 divides fertilizer usage into three categories: The principal ones are nitrogen, phosphorus, and potassium.

Table 4

Fertilizer Types and Usage

Type	Without Subsidy	With Subsidy	P-value
Nitrogen	80 kg	120 kg	0.029
Phosphorus	50 kg	70 kg	0.034
Potassium	70 kg	80 kg	0.061

Author's Calculations

Nitrogen: The study found that when subsidies were used, nitrogen-based fertilizer usage significantly increased from 80 kg (nitrogen) to 120 kg (nitrogen) ($P = 0.029$). Other environmental problems from nitrogen overuse include runoff polluting waterways, greenhouse gas emissions, and others.

Phosphorus: Just as with nitrogen, the amount of phosphorus usage increased statistically significantly (P-value = 0.034) from 50 kg to 70 kg with the implementation of subsidies. Phosphorus in excess can end with eutrophication, a phenomenon that diminishes water quality by inducing toxic algal blooms.

Potassium: Although the amount of potassium consumed increased with subsidies, from 70 kg to 80 kg, this increase was not statistically significant at the standard 0.05 level (P-value = 0.061). However, even a slight increase can have an impact on the environment, particularly when paired with alterations in the application of other fertilizers.

Equation model: Based on the data and the hierarchical categorization from Class 1 to Class 3, let us break down the impact of the grain subsidy policy on different agricultural metrics hierarchically.

Class 1 (Overall Agricultural Metrics): This is the highest-level category that summarizes the impact of subsidy on overarching agricultural parameters.

Given by: $\boldsymbol{Y_1} = \boldsymbol{\beta_{10}} + \boldsymbol{\beta_{11}} \times \boldsymbol{Subsidy} + \in_1$

Where:

$\boldsymbol{Y_1}$Represents overall agricultural metrics (like Soil Health, Water Usage, Fertilizer Use, and Yield).

$\boldsymbol{\beta_{10}}$ It is the intercept.

$\boldsymbol{\beta_{11}}$ Is the coefficient representing the effect of subsidy.

$\in_1$ This is the error term for Class 1.

Class 2 (Detailed Soil and Water Metrics): This class goes into detail about soil health and water usage parameters.

Given by: $\boldsymbol{Y_2} = \boldsymbol{\beta_{20}} + \boldsymbol{\beta_{21}} \times \boldsymbol{Subsidy} + \in_2$

Where

$\boldsymbol{Y_2}$Represents specific metrics within Soil and Water usage (like Soil pH, Organic Matter, Groundwater Usage, and River/Lake Usage).

$\boldsymbol{\beta_{20}}$It is the intercept.

$\boldsymbol{\beta_{21}}$Is the coefficient representing the effect of subsidy.

$\in_2$This is the error term for Class 2.

Class 3 (Fertilizer Types and Usage): This class focuses on specific fertilizer types and their usage.

Given by: $\boldsymbol{Y_3} = \boldsymbol{\beta_{30}} + \boldsymbol{\beta_{31}} \times \boldsymbol{Subsidy} + \in_3$

Where

$\boldsymbol{Y_3}$Represents metrics related to different fertilizer types (like Nitrogen, Phosphorus, and Potassium).

$\boldsymbol{\beta_{30}}$It is the intercept.

$\boldsymbol{\beta_{31}}$ Is the coefficient representing the effect of subsidy.

$\in_3$This is the error term for Class 3.

This equation model offers a hierarchical approach to understanding the impact of grain subsidy on various agricultural metrics. At the top level (Class 1), the effect on general agricultural outcomes is captured. As we move to Class 2 and Class 3, the details get finer, looking into specific metrics within broader categories. The coefficients (β) in these models capture the magnitude of the subsidy's effect on each metric. These effects are ideally determined by fitting these models to individual observational data. The approach provided here offers a structured framework for such an analysis.

Regression Analysis

The change in each metric (dependent variable) is utilized to construct the regression model table in which the introduction of the subsidy (independent variable) is reflected. A table of regression models based on the metrics supplied is presented below:

Table 5

Regression analysis model

Dependent Variable	Independent Variable (Subsidy)	Coefficient (β)	P-value
Soil Health	With vs. Without Subsidy	-7%	0.045
Water Usage	With vs. Without Subsidy	$1200m^3$	0.031
Fertilizer Use	With vs. Without Subsidy	70 kg	0.027
Yield	With vs. Without Subsidy	0.5 tons	<0.001
Soil pH (Avg. Change)	With vs. Without Subsidy	-0.2	~0.0465
Groundwater Usage	With vs. Without Subsidy	$800m^3$	0.042
River/Lake Usage	With vs. Without Subsidy	$400m^3$	0.056
Nitrogen Use	With vs. Without Subsidy	40 kg	0.029
Phosphorus Use	With vs. Without Subsidy	20 kg	0.034
Potassium Use	With vs. Without Subsidy	10 kg	0.061

*Notes: *** $p < 0.01$, ** $p < 0.05$, * $p < 0$.*

The coefficient in this table represents the variation in the dependent variable during the change from the "Without Subsidy" to the "With Subsidy" scenario. The P-value provides insight into the magnitude of this change. Statistical significance is generally denoted by a P-value less than 0.05, which suggests that the observed change cannot be attributed to random variation.

The study meticulously constructs a regression model table to show how agricultural metrics and subsidy regimes are related. This table, "Table 05: Regression analysis model," quantifies and explains how subsidies affect agriculture. All dependent variables are essential ecological efficiency and farming metrics. This includes soil health, water, fertilizer, yield, pH, groundwater, river/lake, and nitrogen, phosphorus, and potassium consumption. The independent variable in each model is 'With vs. Without Subsidy.' All rows in the table reflect regression models, with the Coefficient (β) column indicating the effect of subsidies on the dependent variable. A -7% coefficient for Soil Health suggests a 7% decrease with subsidies, while a $1200m^3$ rise in Water Usage indicates a significant increase. These coefficients measure the subsidy's agricultural impact. Analysis of the statistical significance of changes requires the P-value column. Changes with P-values < 0.05 are statistically significant. Water usage increases significantly with subsidies (P-value 0.031). A close P-value of 0.056 for River/Lake Usage does not meet the significance level, requiring further careful analysis. The bottom notes explain P-values, with asterisks signifying significance. These levels quickly identify data-supported adjustments' strength.

Discussion

Grain subsidies have received a lot of attention in policy and scholarly circles on how they affect agricultural practices. The grain subsidy program in a country like Pakistan, where agriculture is a large share of GDP can have implications on something as overarching as economic development. One crucial area of these subsidies influenced by them is agricultural ecological efficiency which represents the sustainable use of environmental resources in agricultural production. This study aimed to analyze the planned and unplanned results of Pakistan's grain subsidy policy in terms of agricultural ecological efficiency.

Using Subsidy Programs to Promote Agricultural Sustainability in Pakistan

When it comes to boosting sustainability, Pakistan's agricultural policy has always included subsidy programs. The purpose of these initiatives is to reach a peaceful equilibrium between the adamant need to protect the environment and the most immediate problems in the food production challenge. Implementation of different techniques which achieve this equilibrium may include incentives to encourage conservation activities. One illustrative example of a measure to abate soil erosion and enhance soil quality is conservation tillage. Because they reduce the probability of disease and insect infestation, thus reducing the need for chemical pesticides, crop rotation strategies are advocated. However, the study has produced a host of revelations about the effectiveness of Pakistani subsidy programs.

Subsidy Programs' Unintended Effects on Environmental Health

The study shows some amazing findings regarding the impact of subsidy programs on the environment. This study pinpoints that subsidies have a large negative impact on soil health. This is confirmed by a reduction in soil health indices from 72% to 65% (P-value = 0.045). For the study, the fertilizer consumption shows a very significant increase of about 200 kg to 270 kg (p-value 0.027). Furthermore, water consumption also increased significantly, growing from 4000 m3 to 5200 m3 (P = 0.031). The above findings illustrate the unnoticed impact of subsidies, including ecologically sound agriculture and agriculture with sustainable practices.

Impact on Yield: Complexity of Effect

Interestingly, the study also documented a variation in crop production under subsidized input ranging from 1.5 tons to 2.0 tons (Pvalue 0.001). Although this may seem like a good thing on the surface, sustainability cannot be looked upon from a short-term viewpoint. It reveals how the degraded soil quality, and increased water use coupled with increased fertilizer consumption contribute to a sacrifice of longer-term environmental health in pursuit of short-term output gain. In this complex scenario, subsidies are compared with short-term agricultural advantages (long-term environmental hazards), questioning the overall effectiveness of subsidies as instruments in support of sustainable agriculture.

Policy and Practice Implications

The results of the study indicate that Pakistan should urgently review its system of agricultural subsidies. Subsidy programs should be very well thought out and closely monitored to avoid inadvertently working against the very same objectives they were meant to serve. This would require a multi-faceted strategy of rigorous scientific studies, and stakeholder engagement to produce a more efficient and environmentally conscious subsidy system.

Recommendations

- The ecological balance promoting programs should be prioritized like soil health and conservation of water.
- Subsidies can be created to subsidize farmers that use less damaging fertilizers and pesticides. onservation.
- Create subsidies to encourage farmers to use less damaging fertilizers and pesticides.
- Education and Training: Education and training programs can help farmers to understand and execute sustainable farming techniques.
- Set up a sophisticated monitoring and evaluation system to be used to evaluate subsidy policies and make on-the-job adjustments.
- By subsidizing water-efficient irrigation technologies and practices. In addition, they are asked to implement soil health restoration programs such as organic farming and crop rotation subsidies.
- Take the cash from harmful subsidies and put it into sustainable agriculture.

- Greater scientific research and development into the methods, and use, of sustainable farming.
- Farmers, professionals, and environmental groups to make sure that subsidy policy involves all these three.
- That subsidy policy should include farmers, professionals, and environmental groups to make sure that it is economically and environmentally balanced.
- Make it public how you are allocating the subsidy and hold violators accountable. Soil health and water conservation.

Conclusion

Agriculture subsidies in Pakistan influence deeply rural as well as agricultural issues like production, conservation, and community well-being. In general, they stabilize earnings, ensure economic resilience, and build necessary infrastructure and services for agriculture. The proclaimed purpose of these subsidies is to strike a balance between food security and environmental sustainability; however, they also create unexpected environmental effects. A key for Pakistan's agriculture sector to be long-term viable and sustainable is a balanced approach that takes into account both economic and environmental factors. The expected ecological impacts of agricultural subsidies could be counteracted and the advantages maximized via a multifaceted strategy with sufficient plans of execution and control.

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