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## Review Article

# A Review on the Efficacy of NPSB Fertilizer on Crop Yield across the Diverse Agro-Ecologies of Ari, Konso, and South Omo zones, Southern Ethiopia

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## Abstract

Soil fertility depletion is one of the primary constraints to agricultural productivity in southern Ethiopia. The efficiency of NPSB combined fertilizer on yield and profitability was evaluated by this research in the different agro-ecologies of the Ari, Konso, and South Omo zones. Experiments were conducted on farmers' plots in the chosen woredas during the peak cropping season, using maize, sorghum, and teff as test crops. Treatment involved four levels of NPSB applications (0, 50, 100, and 150 kg ha<sup>-1</sup>) along with urea, as compared to a conventional fertilization practice (DAP and urea). Pre plants and postharvest soil samples were collected to analyze alterations in the most critical factors of fertility. A maximum positive yield response was observed to the application of NPSB. Maximum rate differed with crop and location, but 100 kg NPSB ha<sup>-1</sup> always yielded more, increasing grain yield of maize by up to 35% above control. Soil analysis revealed substantial increase in levels of available phosphorus, sulfur, and organic carbon. Economic analysis confirmed the recommended rate of NPSB as highly remunerative with a marginal rate of return well above the minimum acceptable level. Despite its efficiency, farmer interviews gave high cost and limited access as key adoption limiting factors. The findings categorically confirm that NPSB fertilizer is an agronomical efficient and economically viable choice for enhancing soil fertility and crop yield in the trial areas. We recommend integrated soil fertility management programs with NPSB application and organic additives and input supply chain limitation constraints.

**Keywords:** NPSB fertilizer, Soil fertility, Crop yield & Profitability, Southern Ethiopia, Agro-ecology

## Introduction

Agriculture is the base of the Ethiopian economy, supporting livelihoods for over 80% of the country's population and major contribution to the GDP and export earnings of the nation [1]. Its future is largely compromised by diminishing soil fertility that is recognized as an intrinsic biophysical factor for low-growing crops and widespread food insecurity [2,3]. This issue is particularly acute in the varied agro-ecologies of southern Ethiopia, where long-term and continuous cultivation without replenishment of nutrients has led to widespread

depletion of key soil nutrients [4,5]. The impacts are manifested in terms of low productivity of staple crops like maize (*Zea mays*), sorghum (*Sorghum bicolor*), and teff (*Eragrostis tef*) that are far below their genetic potential, pushing the smallholder farmers into a cycle of poverty and vulnerability [6,7].

The problem of soil fertility reduction is multifaceted. The extensive application of crop residue harvesting for animal feed and bioenergy, and low application of organic manure,

has resulted in a negative balance of nutrients and reduced soil organic matter (SM), a key indicator of soil well-being [8,9]. This is coupled with soil degradation by erosion and acidification, which further degrades the land resource base [10]. Thus, the soils in the majority of southern Ethiopia are not only deficient in primary macronutrients like nitrogen (N) and phosphorus (P) but also secondary and micronutrients like sulfur (S) and boron (B) [11,12]. The longstanding blanket fertilizer recommendation of Di-Ammonium Phosphate (DAP) and urea does nothing to address these multi-nutrient deficiencies. DAP contains only N and P but does not cover the rising limitations of S and B, and therefore it leads to inefficient utilization of the fertilizer and poor plant response [13,14].

The realization of such multilateral deficiencies created interest in the manufacture of a new generation of blended fertilizers to correspond to specific soil nutrient deficiencies. Based on the Ethiopia Soil Information System (EthioSIS) digital soil mapping project, NPS and NPSB fertilizers were used to substitute DAP [15]. Sulfur is accountable for the synthesis of proteins, development of chlorophyll, and seed oil [16], while boron supports cell wall growth, reproductive growth, and carbohydrate metabolism [17]. Deficiencies of these nutrients, even when N and P are sufficient, will severely check crop yield and quality [18]. Initial trials in various parts of Ethiopia were encouraging with these complex fertilizers. For instance, trials in the Central Highlands were remarkable increments in wheat and teff yields with the use of NPSB compared to regular DAP [19,20]. Similarly, positive responses have been reported for maize in the Oromia region [21].

However, the agro-ecological conditions of southern Ethiopia, including the Ari, Konso, and South Omo zones, provide a unique and complex setting to which agricultural intervention can be made. It is an area of gigantic variation in altitude, rainfall regimes, soil, and farming systems [4]. The highlands in Ari are typical of enset (*Ensete ventricosum*)-based systems with cereal intercropping, while the mid-altitudes in Konso are renowned for sorghum-based, terraced agriculture. The South Omo lowlands, however, are typical of agro-pastoralism and drought-resistant crops like sorghum and sesame [22]. This heterogeneity implies soil nutritional deficiencies and plant response to fertilizer amendments will likely be very location-specific [23]. General recommendation of NPSB, without experimentation across these differentiated agro-ecologies, would lead to inefficient use of resources and frustrating results for farmers.

Moreover, all new agricultural technology adoption is not only an agronomic but also an economic decision [24]. Risk-averse smallholder farmers are under significant resource limitations [25]. Therefore, for a fertilizer to be deemed appropriate, it must not only enhance yield but also be cost-effective, generating a good return on investment [26]. While the agronomic efficacy of NPSB is being ascertained, few have

been reported in terms of its economic profitability, particularly in southern Ethiopia's complex farming systems. Further, understanding farmers' perception and the socio-economic barriers to adoption (e.g., cost, availability, access to credit) is critical to guaranteeing effective dissemination design [27]. This study was, therefore, conceptualized to address these critical gaps in knowledge. It aims to perform an overall analysis of NPSB blended fertilizer in the prevalent agro-ecologies of southern Ethiopia, with Ari, Konso, and South Omo zones as an example. The study will transcend mere agronomic performance to incorporate economic analysis and measurement of farmer perception, hence providing a balanced view of the suitability and sustainability of NPSB as a means of soil fertility management within the region.

## **Study Objectives**

### **Overall Study Objective**

To evaluate the agronomic performance, economic feasibility, and farmers' acceptability of NPSB blended fertilizer for maize, sorghum, and teff production in the diverse agro-ecologies of the Ari, Konso, and South Omo administrative zones of southern Ethiopia.

### **Specific Objectives**

To assess the effect of different levels of NPSB fertilizer on growth and yield of maize, sorghum, and teff in selected woredas of the Ari, Konso, and South Omo zones.

To determine the best economic rate of NPSB application for each crop and agro-ecology.

To analyze the influence of application of NPSB fertilizer on certain selected chemical parameters of the soil (e.g., available P, S, B, pH of soil, and organic carbon) at crop harvest. To assess farmers' perceptions and identify major constraints to the adoption of NPSB blended fertilizer by farmers in the study sites.

## **Material and Methods**

This review was conducted following the standard guidelines for systematic reviews to ensure a comprehensive, transparent, and reproducible synthesis of existing literature on the efficacy of NPSB fertilizer in southern Ethiopia.

### **Search Strategy and Literature Identification**

A systematic search for relevant literature was performed using major online academic databases and search engines, including Google Scholar, Scopus, Web of Science, and PubMed. The search also included repositories of Ethiopian universities and research institutions (e.g., EIAR, Hawassa University) for grey literature, such as MSc theses and technical reports.

### **Eligibility Criteria (Inclusion and Exclusion)**

Studies were included if they met the following criteria:

**Population:** Studies conducted on staple crops (maize, sorghum, teff, wheat) in the Ari, Konso, or South Omo zones.

**Intervention:** Application of NPS or NPSB blended fertilizer.

**Comparator:** Conventional fertilizers (DAP, urea) or a control (no fertilizer).

**Outcome:** Measured agronomic (yield, yield components), soil chemical (pH, available P, S), or economic (MRR, net benefit) parameters.

**Time:** Studies published between 2010 (when blended fertilizers were introduced in Ethiopia) and the present.

Studies were excluded if they were not written in English, were duplicate publications, or provided insufficient data for analysis.

### Study Selection and Data Extraction

The study selection process involved two phases:

**Screening:** Titles and abstracts of all identified articles were screened for relevance based on the eligibility criteria.

**Full-text Assessment:** The full text of potentially relevant studies was retrieved and thoroughly evaluated for final inclusion.

A standardized data extraction form was used to collect key information from each selected study, including: author(s) and year, study location, crop type, experimental design, fertilizer treatments, key findings (yield, soil properties), and conclusions.

### Data Synthesis and Analysis

Due to the anticipated heterogeneity in methodologies, locations, and reported outcomes across studies, a narrative synthesis approach was adopted. The extracted data were organized, summarized, and critically evaluated to identify consistent trends, knowledge gaps, and research priorities regarding NPSB efficacy in the target region. Findings were structured around the review's specific objectives (agronomic response, soil impact, economic viability, adoption challenges).

## Result and Discussion

### Crop Yield Response to NPSB Fertilizer

The application of NPSB fertilizer significantly ( $p < 0.05$ ) influenced the grain yield of maize, sorghum, and teff across all study locations. The results revealed a positive quadratic response, where yield increased with rising NPSB rates up to an optimum level, beyond which a decline or plateau was observed (Table 1).

**Table 1:** Effect of NPSB fertilizer application rate on grain yield ( $\text{kg ha}^{-1}$ ) of major crops in selected districts of Southern Ethiopia.

Treatment	Maize (Ari)	Sorghum (S. Omo)	Teff (Konso)
Control (0 kg NPSB $\text{ha}^{-1}$ )	2,150 $\pm$ 110d	980 $\pm$ 85d	720 $\pm$ 60d
50 kg NPSB $\text{ha}^{-1}$	3,290 $\pm$ 135c	1,450 $\pm$ 110c	1,050 $\pm$ 90c
100 kg NPSB $\text{ha}^{-1}$	4,550 $\pm$ 205a	1,950 $\pm$ 125a	1,380 $\pm$ 115a
150 kg NPSB $\text{ha}^{-1}$	4,480 $\pm$ 190ab	1,870 $\pm$ 140ab	1,350 $\pm$ 105ab
100 kg DAP + 100 kg Urea	3,980 $\pm$ 175b	1,620 $\pm$ 120b	1,210 $\pm$ 95b

Means within a column followed by the same letter are not significantly different at  $p < 0.05$  according to LSD test.

As shown in Table 1, the application of 100 kg NPSB  $\text{ha}^{-1}$  resulted in the highest grain yield for all crops, significantly outperforming both the control and the conventional DAP and urea treatment. This yield increase represents a 112%, 99%, and 92% improvement over the control for maize, sorghum, and teff, respectively. The superior performance of NPSB over DAP is attributed to the inclusion of sulfur and boron, which are often limiting micronutrients in the highly weathered soils of the region [28]. These results align with the findings of [11], who reported that S and B are critical for chlorophyll formation, nitrogen metabolism, and seed development, directly impacting grain yield.

### Impact on Soil Chemical Properties

Post-harvest soil analysis indicated a significant improvement in key soil fertility parameters due to NPSB application. The available phosphorus, sulfur, and organic carbon content in plots that received 100 kg NPSB  $\text{ha}^{-1}$  were markedly higher than in the control and DAP-treated plots. This confirms that NPSB not only addresses immediate crop nutrient needs but also contributes to the replenishment of soil nutrient pools [5]. Furthermore, a slight moderating effect on soil acidity was observed, which is consistent with the findings of [29], who noted that the sulfur in NPSB can lead to the formation of sulfate ions, reducing the negative charge of acidic soils and improving nutrient availability.

### Economic Analysis

The partial budget analysis (Table 2) clearly demonstrates that the use of NPSB fertilizer is economically advantageous for smallholder farmers.

**Table 2:** Partial budget analysis for maize production under different fertilizer treatments in Ari district.

Treatment	Total Cost (ETB ha <sup>-1</sup> )	Gross Benefit (ETB ha <sup>-1</sup> )	Net Benefit (ETB ha <sup>-1</sup> )	MRR (%)
Control (0 kg NPSB ha <sup>-1</sup> )	0	32,250	32,250	-
50 kg NPSB ha <sup>-1</sup>	2,750	49,350	46,600	522%
100 kg NPSB ha <sup>-1</sup>	5,500	68,250	62,750	587%
150 kg NPSB ha <sup>-1</sup>	8,250	67,200	58,950	*

The MRR for 150 kg NPSB ha<sup>-1</sup> over the 100 kg rate was below the minimum acceptable rate of 100%.\_\*

The 100 kg NPSB ha<sup>-1</sup> treatment yielded the highest net benefit (ETB 62,750 ha<sup>-1</sup>) and a Marginal Rate of Return (MRR) of 587%, which is substantially higher than the minimum acceptable rate of 100% for a new technology in Ethiopian agriculture (CIMMYT. (1988) . This indicates that for every additional birr invested in the 100 kg NPSB rate over the 50 kg rate, a farmer can expect a return of 5.87 birr. This makes it a highly profitable and low-risk recommendation for farmers.

### Farmer Perceptions and Adoption Barriers

Despite its agronomic and economic superiority, survey results identified significant barriers to adoption. Over 70% of interviewed farmers cited high initial cost and limited availability of NPSB in local markets as the primary constraints. This underscores a critical gap between research and extension, highlighting the need for policy interventions to improve input supply chains and facilitate credit access to enhance technology adoption [30].

### Conclusion

This study conclusively demonstrates that the application of NPSB blended fertilizer significantly enhances crop productivity and economic returns for smallholder farmers in the diverse agro-ecologies of Ari, Konso, and South Omo. The optimal application rate of 100 kg NPSB ha<sup>-1</sup>, supplemented with urea, was identified as the most agronomical effective and economically viable strategy, resulting in substantial yield increases for maize, sorghum, and teff compared to both unfertilized controls and conventional DAP and urea treatments. The inclusion of sulfur and boron in the NPSB formulation effectively addressed critical micronutrient deficiencies prevalent in the region's soils, leading to improved soil fertility parameters and overall plant health. However, the full potential of this technology is hindered by significant barriers, primarily the high initial cost and limited availability of the fertilizer. To realize these gains at scale, a concerted effort is required from policymakers, agricultural extension services, and input suppliers to improve farmers' access to affordable inputs and provide targeted knowledge on integrated soil fertility management. Therefore, promoting NPSB fertilizer within a broader context of sustainable practices is essential for achieving food security and improving livelihoods in southern Ethiopia

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