Farm Size and Agricultural Productivity of Nutritious Foods

Evidence from Ethiopia's Vegetable VC survey

The Nutrition Challenge in Sub-Saharan Africa

Africa's agriculture is transforming rapidly through policy changes, infrastructure development, and urbanization. While food security has improved, **nutrition security remains a critical concern**. Low diet diversity stems from limited availability and high prices of nutrient-rich foods like vegetables and fruits.

Ethiopia exemplifies this challenge: agriculture accounts for 35% of GDP, yet the country has among the poorest diet diversity in Africa. Understanding how to boost production of nutritious foods is essential for combating hidden hunger and micronutrient deficiencies.

Research Focus: A Critical Knowledge Gap

What We Know

Past research focused heavily on staple crops like grains and maize during agricultural transformation. The "inverse farm size-productivity" relationship suggested smaller farms were more efficient.

What's Missing

Little is known about how production of **nutritious foods** – vegetables – is changing. Are small farms or large farms more productive in producing high-nutrient foods?

Study Objective

Examine farm size versus productivity in vegetable production in Ethiopia using unique large-scale survey data that includes both smallholders and commercial farms.

Key Findings at a Glance

2-4×

Productivity Gap

Larger farms achieve 2 to 4 times higher output, value, and profit per hectare compared to small farms.

12 ha

Optimal Size

Peak productivity for vegetables occurs around 11-12 hectares, with diminishing returns beyond this point.

91%

Market Orientation

Surveyed vegetable farmers sold over 91% of their output, indicating highly commercial production systems.

Why Farm Size Matters: Theoretical Framework

Traditional View

Small farms use intensive family labor with tight supervision, achieving higher yields per hectare in imperfect markets.

Modern Reality

High-value crops require purchased inputs and technology. Larger farms with better credit access can invest more effectively.

Scale Economies

When markets function well, more efficient farms grow larger – similar to manufacturing firms.

In transforming agricultural systems with improving market access, we expect a **positive farm size-productivity relationship** for commercial vegetables, as larger farms can deploy inputs more effectively.

Ethiopia's Agricultural Transformation

Sector Significance

Agriculture accounts for 35% of GDP – much higher than the 20% Sub-Saharan Africa average.

Recent Changes

Major increases in fertilizer use, improved seeds, and expansion of agribusiness over the past decade.

Nutrition Gap

Despite progress, diet diversity remains poor with widespread micronutrient deficiencies.

Data Collection: Vegetable Farm Survey

01

Strategic Sampling

2020 survey in Central Rift Valley targeted both smallholders and large-scale vegetable farmers**, ensuring inclusion of commercial farms often missed in typical surveys**.

02

Comprehensive Coverage

Four districts with >100 ha irrigated land; 37 villages; ~22 farmers randomly sampled per village, yielding 805 completed surveys.

03

Key Crops

Tomato, onion, cabbage, green pepper, Ethiopian kale – all providing crucial micronutrients like vitamin C, folate, iron, and calcium.

04

Detailed Metrics

Land area, yields, input use (fertilizer, seeds, labor, irrigation), farming practices, output quantities, and prices by crop.

Measuring Productivity: Three Key Metrics

1

Yield

Crop output per hectare – the fundamental measure of physical productivity.

2

Value of Output

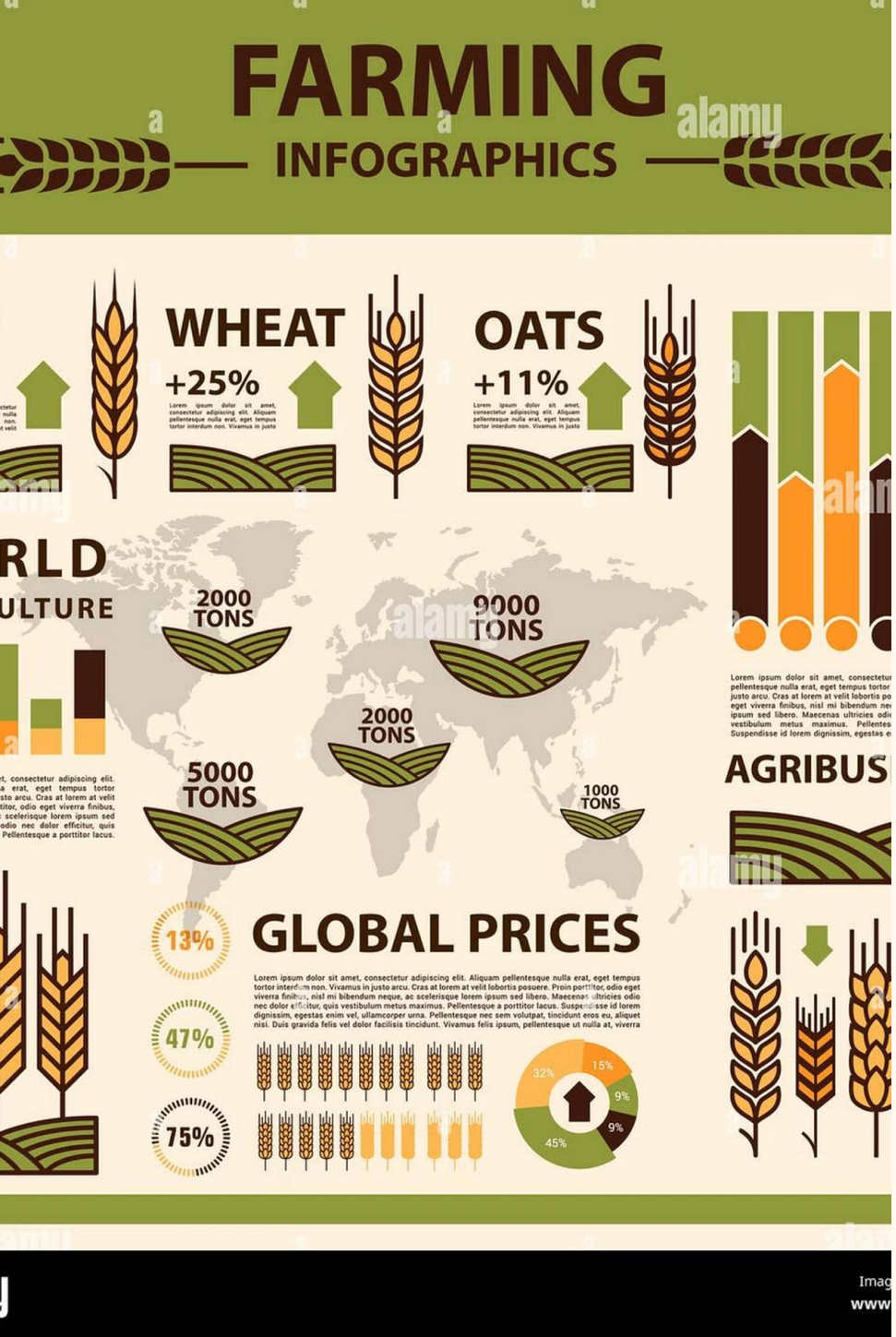
Monetary value of production per hectare – capturing both quantity and market prices.

3

Profit

Revenues minus input costs per hectare – the bottom-line measure of economic performance.

These partial productivity indicators capture different aspects of vegetable farm performance. Farm size equals total cultivated area (hectares). The study covers a wide range of vegetable farms, from ~0.1 to 16+ hectares.



Analytical Approach: Visualizing the Relationship

1

Step 1: Visual Exploration

Non-parametric regressions plot productivity versus farm size, revealing the shape of relationships without assumptions.

2

Step 2: Statistical Modeling

Quadratic regression captures potential increasing then decreasing returns: Productivity = $\beta_0 + \beta_1(\text{Size}) + \beta_2(\text{Size}^2) + \varepsilon$

3

Step 3: Robustness Checks

Control for farmer characteristics, remove outliers, and test sensitivity to unobserved factors.

Vegetables: Bigger Farms Dramatically Outperform

Why Large Vegetable Farms Excel

Input Intensity

- Far higher fertilizer use
- Greater irrigation access
- More hybrid seed adoption
- Modern technology deployment

Crop Choices

- 60% of large farm area in tomatoes (high-value crop)
- Only 28% of small farm area in tomatoes
- Strategic focus on profit-maximizing crops

Labor Efficiency

- Less labor per hectare than small farms
- Hire workers vs. intensive family labor
- Achieve scale efficiencies

Market Access

- Closer to input suppliers and markets
- Shorter transport distances
- Sell slightly higher share of output (>91%)

When input usage variables are added to regressions, the farm size advantage shrinks – confirming that **large farms' higher productivity stems largely from greater use of inputs and technology**, not inherent size effects alone.

Vegetable Farming: A Consistent Pattern

Vegetables

2-4× productivity advantage for large farms; optimal size ~12 hectares

Vegetable farming shows a **positive farm size-productivity relationship** – contradicting the traditional inverse relationship. The classic assumption that smaller farms are more efficient does not hold for vegetables in Ethiopia's commercializing context.

For vegetable farming, large farms' advantages stem from **greater input intensity and modern practices**. Once controlling for inputs (fertilizer) and technology (seeds), the pure size effect diminishes. This means the productivity gap is bridgeable: if smallholders gain access to similar resources, they can improve substantially.

Robustness: Testing the Findings

1

Outlier Removal

Removing the smallest and largest vegetable farms (bottom and top 2%, 5%, 10%) strengthened rather than weakened the positive size-productivity relationship for vegetable production.

2

Measurement Error Analysis

If anything, small vegetable farms' data may be less reliable (over-reporting yields), meaning the true size advantage in vegetable production could be even larger than observed.

3

Unobserved Factors

Sensitivity analysis shows hidden variables would need implausibly large effects to overturn the findings for vegetable farming. The relationship is robust.

Key Insight: Ethiopia's restrictive land policies limit farm expansion, reducing concerns that only the most productive farmers acquired larger farms. For vegetable farming, the size effect appears genuine rather than spurious.

Challenging Conventional Wisdom

Traditional View

"Small farms are more efficient due to intensive family labor and careful management. Policies should favor smallholders."

New Evidence

"In commercializing contexts with modern inputs, larger farms can outperform. The inverse relationship isn't universal – context matters."

This study aligns with recent research finding U-shaped or positive size-productivity relationships when including medium and large farms. The findings are consistent with standard market equilibrium models: in functioning markets, more efficient producers expand. As regions develop, advantages of scale and investment appear to trump traditional small farm benefits.

> "The debate shifts: instead of assuming small is always beautiful, we should ask under what conditions do small farms shine, and when do larger farms take the lead."

Why Can't Small Farms Compete? Market Constraints

Credit Access

Banks more willing to finance larger, established farms. Smallholders face credit constraints limiting input purchases.

Land Markets

Ethiopia's restrictive land policies (state ownership, limited rental) trap efficient smallholders at tiny scales.

Labor Dynamics

Large farms efficiently hire and manage workers. Small farms rely on intensive family labor but can't easily expand.

Knowledge & Management

Large farms often have specialized knowledge or professional managers. Small farms rely on general extension advice.

Many advantages of large farms result from **overcoming factor market constraints** that plague smallholders. By having means to hire labor, rent land, obtain credit, and purchase inputs, larger farms escape the low-productivity trap. Improving market access for smallholders could help them approximate large farm performance.

NatuField
AGRICULTURE

Fresno, CA 93711
inquire@natufield.mail
222 555 7777
Template.net

Agriculture Policy Development Guide

Prepared by: June Reed

Policy Implications: A Dual Approach

Leverage Scale for Supply

- Support emerging commercial farms or farmer cooperatives
- Enable land consolidation where appropriate
- Encourage responsible investment in larger enterprises
- Rapid gains in nutritious food supply and lower prices

Empower Smallholders

- Improve access to credit and modern inputs
- Facilitate contract farming and cooperatives
- Support technology dissemination
- Create rural non-farm job opportunities

Boosting production of vegetables may require leveraging larger-scale farms to increase supply and lower consumer prices – improving access to vitamins and proteins for vulnerable populations. However, **inclusive transformation** ensures smallholders aren't left behind through collective action, input support, and livelihood diversification.

Key Takeaways

1 ## Farm Size Matters in Context

In commercializing settings with modern inputs and markets, larger farms achieve 2-4× higher productivity per unit than smaller farms for vegetables.

2 ## Non-Linear Relationship

Benefits taper off at higher scales (~12 ha for vegetables). Moderately large farms outperform very small ones, but infinite scaling isn't beneficial.

3 ## Input-Driven Advantage

Large farms' superior performance stems from higher input use and technology adoption, not inherent efficiency. The gap is bridgeable with proper support.

4 ## Dual Policy Approach Needed

Support commercial farms for quick supply gains while empowering smallholders with inputs, credit, and market linkages for inclusive transformation.

Application to Papua New Guinea: Study Design Recommendations

01

Inclusive Sampling Strategy

Ensure representation across farm scales – include smallholders, medium producers, and any commercial operations or cooperatives. Avoid sampling bias that misses "big players."

02

Comprehensive Data Collection

Gather detailed yields, input use, costs, and market access data. Use Ethiopian questionnaires as models while adapting to PNG's context and recall-based reporting.

03

Geographic Stratification

Account for PNG's diverse geography – compare remote highland smallholders with farmers near urban centers. Market access likely influences size-productivity dynamics.

04

Factor Market Analysis

Investigate credit access, input availability, labor markets, and knowledge gaps. Understand constraints preventing smallholders from adopting productive practices.

05

Value Chain Linkages

Connect farm productivity to market outcomes and dietary impact. Will scaling up vegetable production meaningfully improve affordability for consumers?