Predicting Agronomic Boundaries of Future Fertilizer Needs in AgriStats

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Predicting fertilizer consumption for a given crop and country is challenging. In this article, we explore an agronomic model based on yield gap analysis, fertilization for attainable yield, and area growth featuring case studies from Indonesia.

Predicting fertilizer requirements is of interest to both public and private sector players involved in fertilizer production, distribution, or market development activities. Key challenges in anticipating fertilizer use include limitations in available agricultural statistics on current fertilizer use by country and crop and uncertainties in quantifying the complex nature of factors affecting future nutrient needs. In this paper, we describe components of an agronomic model used in AgriStats, a database on agricultural statistics at the International Plant Nutrition Institute (IPNI), to generate realistic scenarios of fertilizer consumption.

The model is based on a robust yield gap analysis using estimates of actual, attainable, and potential yield. By estimating the fertilizer requirements necessary to overcome existing nutrient limitations of a crop in a specific region, scenarios of fertilizer use can be constructed for the three yield levels. We have purposely excluded economics in our analysis and focus on the inherent agronomic constraints and projected advances in knowledge and technological adoption. In the following, we describe the model in greater detail before presenting a case study from Indonesia on current and future fertilizer use in rice and oil palm.

Actual, Attainable, and Potential Yield

The conceptual framework for the identification of yield gaps is given in **Figure 1**. The yield potential (Yp) is the theoretical maximum yield of a crop in any given season

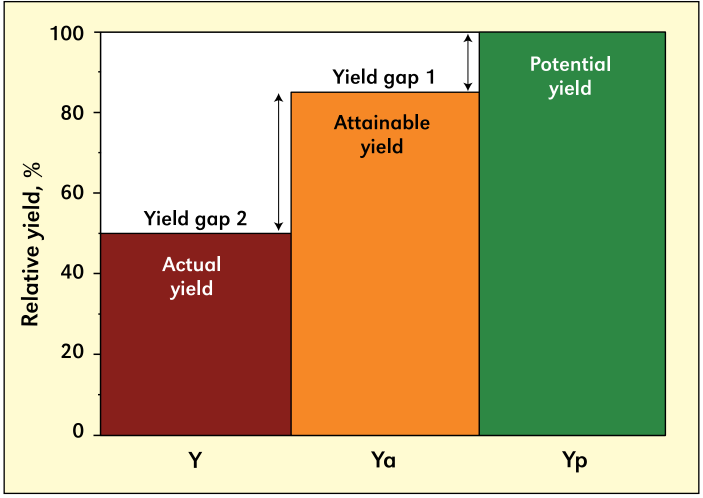

Figure 1. Conceptual framework for the identification of exploitable yield gaps.

Abbreviations: N = nitrogen; P = phosphorus; K = potassium; M t = million metric tons.

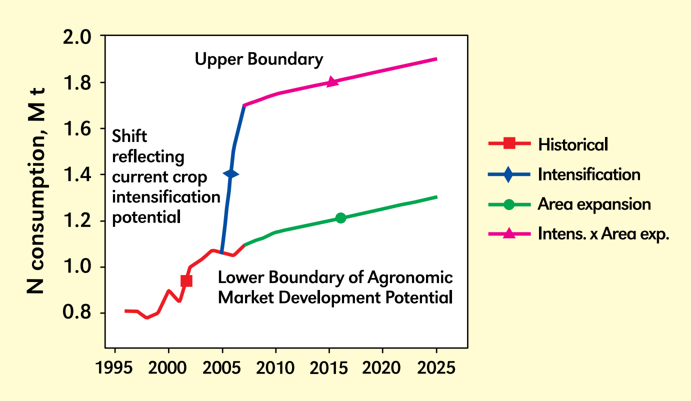

Figure 2. Idealized graph of agronomic market development scenarios.

determined solely by climate and germplasm. By definition, water and nutrients are not limiting yield and yield-reducing factors such as pests and diseases are absent. Yp is commonly estimated using plant growth models and would follow the year-to-year variation in climate.

The attainable yield (Ya) is defined as the yield achieved in farmers' fields with best management practices including water, pest, and general crop management where nutrients are not limiting. Soil constraints or water availability may limit Ya. The attainable yield varies – like the yield potential – from season to season and year to year depending on climate. A meaningful yield target is often closely associated with attainable yield. The maximum attainable yield in any given season could be close to the yield potential, if management is excellent and weather conditions are very favorable. Investments in knowledge or infrastructure (e.g. irrigation facilities) or soil improvement measures could substantially increase attainable yield. It is usually not economical to aim at fully reducing the difference in potential and attainable yield (Yield gap 1) because of the large amounts of inputs required and the high risk of crop failure and profit losses.

The actual yield (Y) in farmers' fields is often lower than the attainable yield due to constraints like poor crop and nutrient management practices that may also enhance pest and disease pressure. The difference between actual and attainable yield (Yield gap 2) is the realistically exploitable yield gap. New technologies and implementation of best management practices can significantly narrow this yield gap. Statistical services (e.g. FAO, USDA) usually provide historical estimates of actual yield for a given crop and country or region

Agronomic Boundaries of Fertilizer Use

In AgriStats, fertilizer use by country and crop is calculated using application rate (kg/ha), total cropped area (ha), and

Table 1. Actual and attainable rice and oil palm production and fertilizer use in Indonesia.

Parameter	Unit	Rice		Oil-Palm	
		Actual	Attainable	Actual	Attainable
Yield[1]	t/ha	4.7	5.7	16.8	25.0
Area	M ha	12.1	12.3	5.5	6.8
Production	M t	57.2	70.0	92.0	170.0
Fertilizer N	kg/ha	100	120	90	90
Fertilizer P_2O_5	kg/ha	25	30	45	55
Fertilizer K_2O	kg/ha	20	35	160	200
Area fertilized N	%	90	90	80	90
Area fertilized P	%	90	90	70	90
Area fertilized K	%	40	70	70	90

[1]Oil palm yield refers to fresh fruit bunches, assuming an oil extraction rate of 21%.
Data sources: current yield, area, and production for rice, FAO, 2007 (http://faostat.fao.org); current yield, area (assuming 80% of total 6.8 M ha under mature palms), and production for oil palm by IOPRI, 2008 (http://iopri.org); fertilizer rates and area fertilized, IPNI AgriStats (http://agristats.ipni.net).

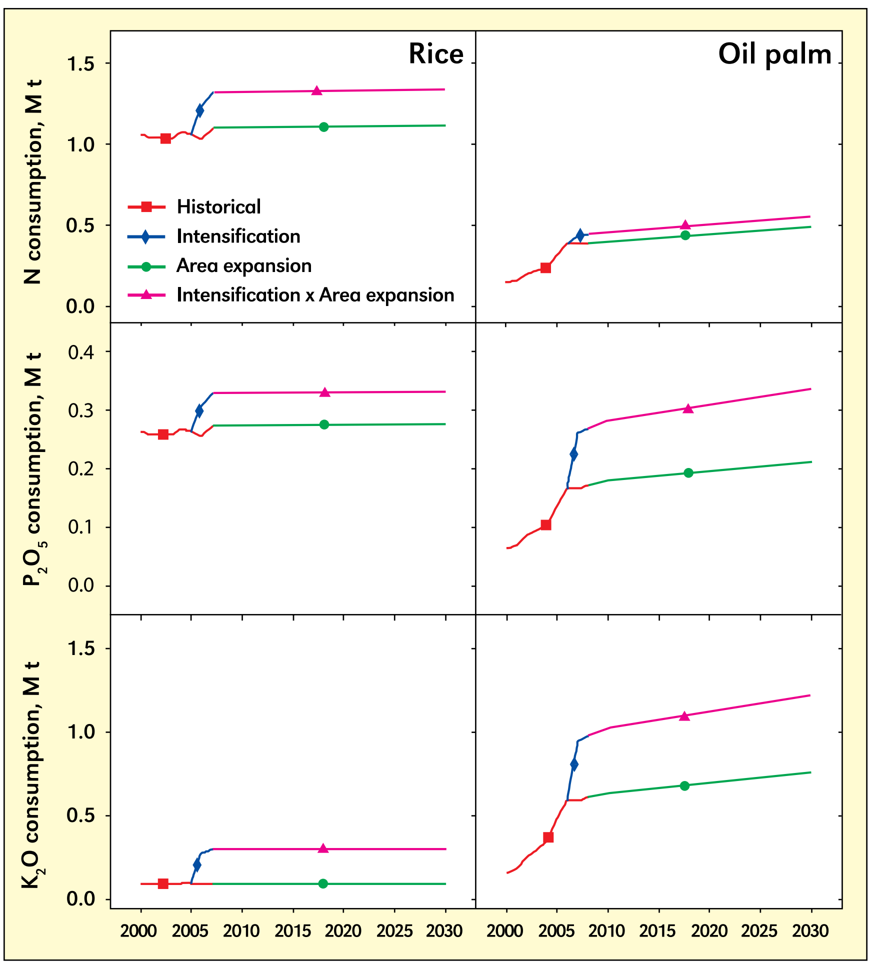

Figure 3. Projections of NPK consumption for rice (left) and oil palm (right) in Indonesia.

the percentage of cropped area that is fertilized. Agronomic boundaries of future fertilizer use are then modeled for any given crop and region based on historical/current consumption trends and realistic expectations of medium to long-term changes in these factors **(Figure 2)**.

- The historical consumption (red line) refers to historical fertilizer use based on estimates of actual yield and corresponding historical rates of fertilization, historical harvested area, and historical percentage of fertilized area.
- The intensification potential (blue line) is based on current harvested area and realistic estimates of changes in percentage of fertilized area and fertilizer use to reach the attainable yield. This scenario portrays the current market development potential.
- The area expansion model (green line) portrays future estimates of consumption based on current fertilization practices and realistic expectations for future harvested area.
- The intensification x area expansion model (purple line) depicts future estimates of consumption based on attainable improvements in fertilizer use and expected changes in harvested area.

The two latter projections of future fertilizer consumption delineate the most likely lower and upper boundaries of potential agronomic market development. It should be noted, however, that unfavorable economics (e.g. commodity prices), resource availability (e.g. fertilizer), or poor technology adoption limit the agronomic market development potential. The actual market development, therefore, is expected to take place between the portrayed boundaries of area expansion and intensification x area expansion.

Case Study – Fertilizer Consumption of Rice and Oil Palm in Indonesia

In the following, we explore the concept of fertilizer use scenarios for rice and oil palm, two of the most important agricultural crops in Indonesia. Most fertilizer in the country is consumed by these two crops. Among the Southeast Asian countries, Indonesia is the top producer of rice while Malaysia and Indonesia dominate the oil palm sector. The actual and attainable production characteristics and fertilizer use in rice and oil palm given in **Table 1** were used to develop fertilizer use scenarios depicted in **Figure 3**.

Production Characteristics and Fertilizer Use

Rice is characterized by moderate opportunities for yield increases, mainly because of limitations in attainable yield **(Table 1)**. A large area is currently cropped to rice, but the scope for further expansion of rice-growing areas is small and there is loss of agricultural land to urbanization, land conversion, and industrialization. Future fertilizer rates corresponding to the attainable yield for rice are projected to be slightly higher than actual rates **(Figure 3)**. Rice farmers in Indonesia generally apply adequate amounts of fertilizers, although overuse of fertilizer N is common in intensively cropped areas. Future fertilizer use assumes improved crop and nutrient management to reach the attainable yield. The proportion of cropped area fertilized with N and P

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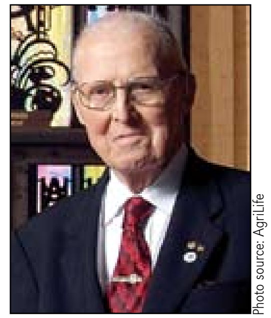
In Memoriam: Dr. Norman Borlaug, 1914-2009

The IPNI Board of Directors issued a brief statement honoring the legacy of Dr. Norman Borlaug, who passed away on September 12 in Dallas, Texas, at the age of 95.

The message of the IPNI Board of Directors states: *We join with millions of people around the world in expressing appreciation and admiration for the great achievements of Dr. Norman Borlaug. His dedication to science in agriculture is responsible for improving the lives of individuals around the world over the past 50 years and into the future. In an amazing journey from his Iowa farm roots to world recognition as a Nobel Peace Prize laureate, he never lost sight of the importance of global food security and the power of science through agriculture. Dr. Borlaug was considered by many as the father of the 'Green Revolution' as his early work in plant breeding led to great increases in harvests of cereal crops in Mexico, India, Pakistan, and other countries. His phenomenal success in breeding high-yielding varieties of wheat, rice, and other crops evolved into broader initiatives in training young agricultural scientists, educating audiences around the globe, and furthering important humanitarian causes. The International Plant Nutrition Institute extends its condolences to the Borlaug family and to his many friends and colleagues. While we are saddened by the loss of this innovative scientist and beloved leader, we believe his vision and accomplishments will serve as inspiration to future generations to continue the quest for world food security.*

Dr. Borlaug in field plots.

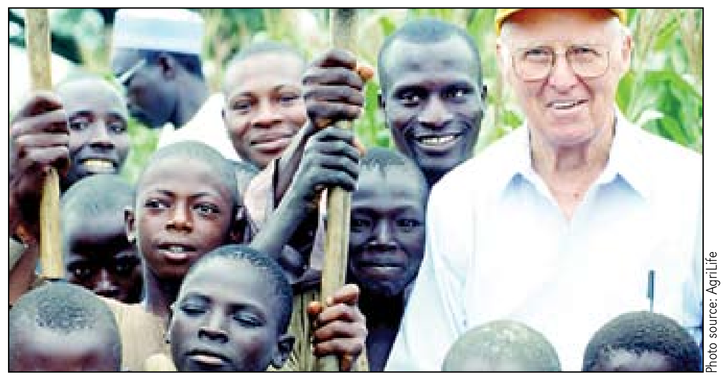


Dr. Norman Borlaug

"Dr. Borlaug was one of those rare individuals who made the most of his fame and influence to champion the cause of applying science for humanitarian benefits," noted IPNI President Dr. Terry Roberts. "He recognized the role of fertilizer in producing the world's food and took every opportunity to remind policymakers and the public that fertilizer is a critical component of global food security."

In July 2007, Dr. Borlaug received the Congressional Gold Medal, the highest honor given by Congress.

A public memorial at Texas A&M University on October 6, 2009, celebrated the life and work of Dr. Borlaug. About 1,000 people attended the service. To learn more about his vision and legacy, visit the website of the Norman Borlaug Institute for International Agriculture: >http://borlaug.tamu.edu<. BC



Bringing the Green revolution to Africa was one of Dr. Borlaug's goals.

AgriStats… *from page 17*

is likely to remain constant in the future, while area fertilized with K is expected to slightly increase as yields increase.

Oil palm production in Indonesia is projected to significantly increase because of both area expansion and opportunities for yield intensification. To meet the nutrient requirements at higher yield and considering lower soil fertility of available land for oil palm, fertilizer P and K use is expected to increase. Fertilizer N rates may remain the same assuming advancements in N management leading to greater efficiency.

Fertilizer Use Scenarios

Future fertilizer use in rice largely depends on farmers' ability to intensify production considering limitations in area expansion **(Figure 3)**. As a result, the upper and lower boundaries of future fertilizer use in rice do not show much change with time. In contrast, the expected increase in area under oil palm will likely result in an increase of fertilizer consumption (lower green boundary), while opportunities for yield intensification are associated with increased fertilizer use, particularly of P and K. Comparing the two crops, rice will remain to be the larger consumer of fertilizer N, while fertilizer P consumption in oil palm may reach the levels observed in rice depending on future yield intensification. Oil palm will continue to consume more fertilizer K than rice and this gap is likely to widen in the future.

Conclusions

Boundaries of future fertilizer use scenarios for a given crop and region can be estimated using current knowledge on yield gaps and realistic expectations on crop intensification and area expansion. It is understood that any economic constraints of the day will combine with agronomic constraints to modify the likelihood of achieving the full extent of the shifts in crop intensification that are indicated.

By employing the concepts of yield gap analysis and future fertilizer use scenarios within AgriStats, we have begun to build a global database with analytical tools able to construct comparisons across countries and crops. The overall goal is to systematically improve our understanding of attainable yield and crop production in a given country or region, providing further guidance on knowledge gaps to be addressed through field research and crop modeling. BC

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Note to Readers

AgriStats is currently a private service available to members of IPNI. Inquiries may be sent to gsulewski@ipni.net.