

Site-specific nutrient management advice and agricultural intensification in maize-based systems in Nigeria



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Dissertation presented in partial
fulfilment of the requirements for the
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Bioscience Engineering

December 2019

Doctoraatsproefschrift nr. 1605 aan de faculteit Bio-ingenieurswetenschappen van de KU Leuven

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Uitgegeven in eigen beheer, Oyakhilomen Oyinbo, Leuven, Belgium

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Acknowledgements

First and foremost, I am eternally grateful to the Almighty God for the successful completion of my PhD program. I want to return all the glory, honor and adoration to Him for His faithfulness to me and my family throughout the course of my program. At first sight, it may seem as if one can independently go through the challenging moments of a PhD journey. However, it is worth noting that I would not have been able to complete the journey without receiving the support and encouragement of a lot of wonderful people in different ways, directly or indirectly.

At this point, I have a lot of people to appreciate. First of all, I wish to express my heartfelt and profound gratitude to my supervisor, Prof. Miet Maertens. Miet, I want to thank you for giving me the opportunity to undertake a PhD program under your scholarly guidance. Thank you for your patience, enthusiasm, encouragement and strong commitment to my progress from my enrollment into the pre-doc to the doctoral program. Indeed, you have been very supportive all the way, and I am extremely grateful for all the critical comments, valuable suggestions and feedback that you gave me at every stage of my research, which has immensely enriched the respective chapters of this dissertation. Truly, I feel very happy and fulfilled working with you over the period of my program because of the opportunity of learning a lot from you – both in terms of research- and non-research related issues. I am also grateful to you for supporting my participation in academic conferences, for providing me a pleasant working environment at the division, and for making my stay in Leuven worthwhile.

I would like to deeply appreciate my co-supervisors: Prof. Roel Merckx, Prof. Jan Diels and Dr. Jordan Chamberlin. Roel and Jan, I thank you for your scholarly inputs and critical comments, which help to improve the quality of my work, and for keeping track of my progress from the pre-doc up to the defense stage. Jordan, I would like to thank you for being a part of my PhD journey. I am thankful to you for meticulously reviewing my research proposal and the draft papers, and for all the discussions we had, especially about the conceptual framework in chapter four of this dissertation. You have greatly contributed to this dissertation, especially by your unflinching support in the design and conduct of my field activities as part of the Taking Maize Agronomy to Scale in Africa (TAMASA) project implementation in Nigeria. I am very grateful to you for the experience I had in managing the

three rounds of farm-household panel surveys and learning about the whole process in the use of Computer-assisted Personal Interviews (CAPI) for farm-household surveys. I look forward to more collaboration with you. I will like to appreciate Prof. Liesbet Vranken for giving me useful comments and feedbacks on the choice experiments in this thesis and for accepting to be part of my jury. I will also like to deeply appreciate all other jury members: the chairman, Prof. Josse De Baerdemaeker, Prof. Steven Bouillon, Prof. Peter Goos and Prof. Erwin Bulte for contributing immensely to this dissertation through their constructive comments and suggestions.

Despite my quest for a top-notch PhD, I would not have been able to achieve it in KU Leuven without a scholarship. To this end, I wish to acknowledge the Bill and Melinda Gates Foundation [grant number OPP1113374] for the financial support for my PhD through the International Maize and Wheat Improvement Centre (CIMMYT) led project 'TAMASA'. My gratitude goes to the TAMASA project leader, Dr. Peter Craufurd for providing visionary leadership for the project implementation in general and in particular, for giving me valuable comments, suggestions and support for my PhD research activities. Despite your busy schedule, you were able to review a draft paper for me. I am extremely grateful to Dr. Bernard Vanlauwe, who was very supportive, particularly during the discussions about my research proposal and my research stay at the International Institute of Tropical Agriculture (IITA), Kano station with Miet. Thank you for been a source of inspiration to me and many other young African researchers affiliated to IITA and other CGIAR centres. I am extremely grateful to the station representative of IITA, Kano station, Dr. Alpha Kamara for contributing immensely to my PhD program in different ways. In the first place, I would not have embarked on this PhD if you had not motivated me to do so. Thank you for advising and encouraging me to look beyond my comfort zone in Zaria and seek for a better PhD experience elsewhere. I am also grateful to you for supporting my research stay at IITA, Kano station and for the many discussions we had about conducting quality empirical research in IITA. At first, I was very reluctant to stay in Kano but you made me feel comfortable with the idea of staying in Kano, and supported me with a conducive working environment. Apart from that, you were very instrumental to the successful planning and implementation of my field activities. My sincere gratitude goes to Prof. Jibrin M. Jibrin, the director Centre for Dryland Agriculture (CDA), Bayero University, Kano, Nigeria for contributing to my field activities. Thank you for your strong commitment to the conduct of

the three rounds of panel survey by ensuring that CDA was actively involved in the whole exercise.

Many thanks go to TAMASA team members at IITA, Kano station. I would like to thank the TAMASA-Nigeria country coordinator, Prof. Ibrahim Baba for his contributions, particularly in facilitating the logistics for my field activities. Thank you for leading all the discussions we had with other project partners about my field work, and ensuring that I got their continuous support throughout the field activities. I am wholeheartedly grateful to Dr. Julius Adewope, who supported me with the spatial sampling framework of farm-households, and for supervising the production of the maps used in this dissertation. My deepest appreciation goes to Mr. Kamal, who supported me in various ways, including the preliminary visits to the survey communities, the training of enumerators for the farm-household surveys, the training of extension agents for the pilot of Nutrient Expert tool, and the supervision of my field activities. Also, I am grateful to Mrs. Helen Jerome, who was primarily responsible for the production of the maps used in this dissertation, and to Mrs. Princess Ifeanyi, who gave me the necessary administrative support during my field work and my stay in Kano. I will like to thank all other IITA, Kano station staff, especially Mr. Rabo, Dr. Lucky, Mr. Reuben, Mr. Tofa, Mr. Olumide and the IITA postgraduate research fellows for their support and friendship during my stay in Kano.

My profound gratitude goes to all the people and institutions that participated in the planning and conduct of the data collection, and the pilot of Nutrient Expert tool as part of the randomized controlled trial implemented in this dissertation. I deeply appreciate all the well-trained enumerators who diligently participated in the three-period farm-household panel survey and the agricultural extension agents survey. Notable among them are Abu, Atiku, Nura, Salisu, Francis, Kalu, Fidelis, Jamilu, Wilson, Mohammed, Josiah, Richard, Ahmadu, Joel, Desmond, Grace and others. Also, I am grateful to Baba, Ismail, Hailru, Mbavai, Luqman and AY, who supervised the survey teams in the data collection, and made sure the data collection plan was adhered to. My sincere gratitude goes to the agricultural extension agents who contributed to the implementation of the randomized controlled trial by piloting the use of Nutrient Expert tool in the treatment villages, and the field support staff who supervised the exercise. Special thanks go to the following institutions, Kaduna State Agricultural Development Agency (KADA), Katsina State Agricultural and Rural Development Authority (KTARDA), Kano State Agricultural and Rural Development

Authority (KNARDA) and Sasakawa-Global 2000 for their support. I am extremely grateful to the 792 maize farmers and the 320 extension agents who accepted to be respondents for the farm-household and extension agents surveys respectively, and for dedicating their time for the surveys. Also, I will like to recognize the efforts of the community leaders in the survey communities and my contact persons in the extension organizations for their roles in facilitating the field activities.

My PhD experience at the Division of Bioeconomics was truly amazing. Thanks to the many wonderful and helpful colleagues: Erik, Tessa, Frederik, Pieter, Monica, Jana, Bernd, Michiel, Fikadu, Natalia, Teopista, Goedele, Isabelle, Moses, Joseph, Anna, Eewoud, Floris, Kaat, Genaye, Tafesse, Tijstke, Nuria, Cindybell, Karin, Diana, Kewan, Marie, Charlotte, Ashenafi, Iris, Tilahun, Lucia and Kato. Thank you for the scholarly comments and feedbacks during seminar presentations, the insightful methodological discussions, the memorable social events and the moments we shared at the lunch room and the Geo-garden. Also, I would like to appreciate my case administrator at the international office, Heidi, Hilde at the ICT unit and Karlien for their support.

I had an overwhelming support from my friends and family during the course of my PhD program. I am most grateful and indebted to my beloved wife, Grace Oyinbo for her love, prayers, encouragement and invaluable support. It was really difficult but you had the strength to combine family, work and your PhD study during my stay in Belgium. Thank you for taking care of our daughters, Eliora and Aviya throughout this period. I truly owe my PhD success to you. My profound gratitude goes to my parents, Mr. and Mrs. Peter Oyinbo and parents-in-law, Prof. and Mrs. Peter Rekwot for their prayers and moral support. Thank you for your parental love and care to me, and especially to my lovely wife and kids during my stay in Belgium. Also, I am grateful to my siblings and in-laws for their support throughout my study period.

Back in Nigeria, I would like to appreciate my colleagues at the Department of Agricultural Economics and the Department of Agricultural Extension and Rural Development, Ahmadu Bello University, Zaria, Nigeria for their support. Also, I am grateful to the management of the University for giving me study leave to undertake this PhD project.

Oyakhilomen Oyinbo

Summary

Despite the potentially large gains from intensification and agricultural productivity growth in Sub-Saharan Africa (SSA), yields of staple crops, such as maize are far below attainable yields. Depletion of soil fertility associated with low and inappropriate use of nutrients play a crucial role in this. Yet, fertilizer use is low in SSA, which partly relates to information constraints. Relaxing such constraints via agricultural extension interventions is expected to produce positive outcomes but do not always result in the intended effects, which may be connected with the highly heterogeneous smallholder farming systems. Yet, traditional extension systems in SSA countries, including Nigeria, provide general fertilizer use recommendations, which do not account for the substantial variation in production conditions. A potential intervention in this regard is site-specific nutrient management (SSNM) paradigm. In light of the rapid digital transformation, digital decision support tools (DSTs) can be leveraged to allow provision of SSNM extension advice. There are research gaps in the theoretical and empirical literature on design, adoption and impact of DST-enabled site-specific extension services, and in the broader literature related to fertilizer use in maize. This PhD thesis focuses on a nutrient management DST for maize ‘Nutrient Expert’ in northern Nigeria, and addresses some of the gaps.

In chapter 2, I analyze farmers’ preferences for intensification of maize production supported by DST-enabled SSNM recommendations in the maize belt of Nigeria. I use data from a choice experiment (CE) among farmers, and estimate different econometric models to control for attribute non-attendance and account for preference as well as scale heterogeneity. The findings show that overall, farmers have strong preferences to switch from general to DST-enabled SSNM recommendations, which lend credence to the inclusion of digital tools in agricultural extension. Also the findings show two latent classes or preference groups of farmers, early and late adopters of intensified maize production, and the heterogeneous preferences can be related to the farmers’ resource endowment, sensitivity to risk and access to services and institutions. The findings imply that improving the design of DSTs to enable provision of information on the riskiness of expected investment returns and flexibility in switching between low- and high-risk recommendations will help farmers to make better informed farm decisions.

In chapter 3, I analyze preferences of extension agents for the design of a nutrient management DST for extension, and their willingness to use such tool. I use data from a CE among extension agents, and estimate different models to capture preference heterogeneity

and account for attribute non-attendance. The findings show that the extension agents in general have a high willingness to use DSTs for SSNM extension advice, which supports the emerging policy interest in design of such DSTs for maize. They prefer a DST with a more user-friendly interface that requires less time to generate an output but have substantial heterogeneous preferences for other design features. The findings also show two preference groups of extension agents, the more committed agents – who prioritize the effectiveness-related features of DSTs, and the more pragmatic agents – who care more about practical features of DSTs. The differences in observed characteristics between the two groups are very small, which suggests that unobservable characteristics likely play a role in explaining preference heterogeneity. The findings imply that accommodating preference differences may facilitate the adoption of DSTs by extension agents and thus enhance the scope for such tools to impact the production decisions of farmers.

In chapter 4, I analyze the impact of farmers' access to SSNM recommendations for maize enabled by a DST on fertilizer use rates, fertilizer management practices, maize yield and revenue. I implement a randomized controlled trial with two treatment groups, T1 without and T2 with additional information on variability of expected returns and a control group. I use three-period panel data to estimate the impact. The findings show that SSNM recommendations bring about improvements in fertilizer management practices, yield and gross revenue after one-year treatment but not fertilizer use for T1. This suggests that optimal management practices can improve yield and revenue by reducing technical inefficiencies. The findings also show that yield and revenue gains are quite similar for the two treatment groups despite considerable increase in fertilizer by T2 over T1. This suggests that the increase in fertilizer does not result in substantial revenue gains, which may be connected to low yield responses to higher fertilizer levels. The findings also show that SSNM recommendations, combined with additional information on the distribution of expected returns, appears to induce more fertilizer use after one year and foster continued fertilizer investment after two years. In addition, the findings show that there are only gradual increases in investment, maize yield and especially net revenue after two years.

Overall, this dissertation shows that there is high adoption potential of nutrient management DSTs for maize by extension agents, and of extension advice from such DSTs by farmers, which aligns with the widespread interest and investments in site-specific and digital tools for agricultural applications in developing countries. Yet, the findings show economically small but significant effects of DST-enabled SSNM recommendations on intensification of maize production. This underscores the need for more research with longer

periods and with complementary interventions to allow better understanding of the impact of DST-enabled site-specific recommendations in the long run while accounting for other shortcomings.

Samenvatting

Ondanks de potentieel grote winsten uit intensivering en productiviteitsgroei in de landbouw in Sub-Sahara-Afrika (SSA), liggen de opbrengsten van de voornaamste gewassen, zoals maïs, ver onder de haalbare opbrengsten. Uitputting van de vruchtbaarheid van de bodem door het lage en niet-optimale gebruik van meststoffen spelen hierin een cruciale rol. Het gebruik van meststoffen blijft laag in SSA, deels omwille van informatie beperkingen. Het opheffen van dergelijke beperkingen via landbouwadviesinterventies wordt verondersteld een oplossing te bieden, maar heeft niet altijd het beoogde effect. Dit kan gerelateerd zijn aan de diversiteit van kleinschalige landbouwsystemen. Traditionele landbouwadviesinterventies in SSA landen, waaronder Nigeria, geven algemene aanbevelingen in verband met gebruik van kunstmest, die de aanzienlijke variatie in de productieomstandigheden niet in rekening nemen. Een mogelijke oplossing in dit opzicht is het site-specifieke nutriëntenbeheer (SSNM) paradigma. Door de snelle digitale transformatie kunnen digitale beslissingsondersteunende hulpmiddelen (*decision support tools*, DSTs) worden ingezet om SSNM advies mogelijk te maken. Er zijn leemtes in de theoretische en empirische literatuur over het ontwerp, de adoptie en de impact van DST-ondersteunde site-specifieke adviesdiensten, en in de bredere literatuur met betrekking tot het gebruik van kunstmest in maïs. Dit proefschrift richt zich op een nutriëntenbeheer DST voor maïs 'Nutrient Expert' in het noorden van Nigeria, en vult een aantal van de hierboven vermelde onderzoek leemtes.

In hoofdstuk 2 analyseer ik de voorkeuren van landbouwers voor intensivering van de maïsproductie op basis van DST-ondersteunde SSNM aanbevelingen in de maïsgordel van Nigeria. Ik maken gebruik van gegevens uit een keuze-experiment bij de boeren, en schatten verschillende econometrische modellen om te controleren voor attribuut verzuim en om preferenties en heterogeniteit in schaal in rekening te nemen. De bevindingen tonen aan dat boeren een sterke voorkeur hebben om over te schakelen van algemene naar DST-ondersteunde SSNM aanbevelingen, wat wijst op het potentiële succes van digitale hulpmiddelen in landbouwadvies. De bevindingen tonen ook twee latente klassen of voorkeurgroepen van boeren, vroege en late adopters van geïntensiveerde maïsproductie. Deze heterogene voorkeuren kunnen worden gerelateerd aan de beschikbare hulpbronnen, de gevoeligheid voor risico's en de toegang tot diensten en instellingen van boeren. De bevindingen impliceren dat verbeteringen aan het ontwerp van DSTs die voorziening van informatie over de risico's van de verwachte rendementen en flexibiliteit bij het schakelen

tussen lage en hoge risico aanbevelingen mogelijk maken, de boeren zullen helpen om beter geïnformeerde beslissingen te nemen.

In hoofdstuk 3 analyseer ik voorkeuren van landbouwadviseurs voor het ontwerp van een nutriëntenbeheer DST, en hun bereidheid om een dergelijke tool te gebruiken. Ik maken gebruik van gegevens uit een keuze-experiment onder adviseurs, en schatten verschillende modellen om de heterogeniteit in preferenties vast te leggen en attribuuft verzuim in rekening te nemen. De bevindingen tonen aan dat de adviseurs over het algemeen een grote bereidheid hebben om DSTs voor SSNM adviesinterventies te gebruiken, wat de opkomende politieke belangstelling in dergelijke DSTs voor maïs ondersteunt. Ze geven de voorkeur aan een DST met een gebruiksvriendelijke interface die minder tijd vraagt om resultaten te genereren, maar voor andere ontwerpelementen zijn de voorkeuren zeer heterogeen. De resultaten wijzen ook op twee groepen adviseurs, de meer betrokken agenten die prioriteit geven aan de effectiviteit-gerelateerde functies van DSTs, en de meer pragmatische agenten die meer waarde hechten aan de praktische eigenschappen van DSTs. De verschillen in waarneembare kenmerken tussen beide groepen zijn heel klein, wat suggereert dat niet-waarneembare kenmerken waarschijnlijk een rol spelen bij het verklaren van de heterogeniteit in voorkeuren. De bevindingen impliceren dat men het gebruik van DSTs kan vergemakkelijken door rekening te houden met verschillen in voorkeuren bij adviseurs en dat men daarmee het potentieel van dergelijke tools om de productie beslissingen van boeren te beïnvloeden kan vergroten.

In hoofdstuk 4 analyseer ik de impact van de toegang van boeren tot SSNM aanbevelingen voor maïs met behulp van een DST op het gebruik van kunstmest, kunstmest managementpraktijken, de opbrengst van maïs en inkomsten. Ik implementeren een gerandomiseerd onderzoek met controlegroep en twee behandelingsgroepen, zonder (T1) en met (T2) aanvullende informatie over de variabiliteit van de verwachte rendementen. We maken gebruik van panel data over drie periodes om de impact te schatten. De bevindingen tonen aan dat SSNM aanbevelingen leiden tot verbeteringen in de meststof managementpraktijken, in de opbrengst en in de bruto-inkomsten na één jaar behandeling, maar niet in het gebruik van kunstmest voor T1. Dit suggereert dat optimale managementpraktijken de opbrengst en inkomsten kunnen verbeteren door het reduceren van de technische inefficiënties. De resultaten tonen ook aan dat de groei in opbrengst en inkomsten zeer vergelijkbaar is tussen de twee behandelingsgroepen ondanks de aanzienlijke stijging van de meststof gebruik door T2 in vergelijking met T1. Dit suggereert dat een hoger gebruik van kunstmest niet leidt tot een aanzienlijke groei in inkomsten, wat gerelateerd kan

zijn met lage effect van hogere kunstmest niveaus op opbrengsten. De resultaten tonen ook aan dat SSNM aanbevelingen, in combinatie met aanvullende informatie over de verdeling van de verwachte rendementen, meer gebruik van kunstmest blijken te veroorzaken na één jaar en continue kunstmest investeringen na twee jaar blijken te bevorderen. Daarnaast tonen de bevindingen dat er slechts een geleidelijke toename is van investeringen, opbrengst van maïs en in het bijzonder netto-inkomsten na twee jaar.

Tot slot, dit proefschrift laat zien dat er een groot potentieel is van nutriëntenbeheer DSTs voor maïs bij landbouwadviseurs, en van advies uit dergelijke DSTs bij boeren. Dit sluit aan bij de wijdverspreide interesse en investeringen in site-specifieke en digitale hulpmiddelen voor landbouwapplicaties in ontwikkelingslanden. Echter, de bevindingen tonen economisch kleine maar significante effecten van DST-ondersteunde SSNM aanbevelingen op de intensivering van de productie van maïs. Dit onderstreept de noodzaak van meer onderzoek over langere periodes en met aanvullende interventies om tot een beter begrip van de impact van de DST-ondersteunde site-specifieke aanbevelingen op de lange termijn te komen, rekening houdend met de andere tekortkomingen.

List of Abbreviations and Acronyms

4Rs	Right Fertilizer Source, Right Rate, Right Placement and Right Time of Application
AI	Attributes Ignored
AC	Attributes Considered
AIC	Akaike Information Criterion
ASC	Alternative-Specific Constant
ANA	Attribute Non-attendance
BIC	Bayesian Information Criteria
C	Control
CDA	Centre for Dry land Agriculture
CE	Choice Experiment
CIMMYT	International Maize and Wheat Improvement Centre
DiD	Difference-in-Difference
DST	Decision Support Tool
EAs	Extension Agents
FAOSTAT	Food and Agriculture Organization of the United Nations Statistical Database
FDR	False Discovery Rate
FGD	Focused Group Discussion
FAW	Fall Army Worm
GPS	Global Positioning System
Ha	Hectare
HH	Household
ICT	Information and Communication Technology
IID	Independently and Identically Distributed
IITA	International Institute of Tropical Agriculture
IPNI	International Plant Nutrition Institute
ISFM	Integrated Soil Fertility Management
ITT	Intent-to-Treat
K	Potassium
K ₂ O	Potassium Oxide
KADA	Kaduna State Agricultural Development Agency

Kg	Kilogram
KNARDA	Katsina State Agricultural and Rural Development Authority
KTARDA	Kano State Agricultural and Rural Development Authority
LCM	Latent Class Model
LGAs	Local Government Authorities
MRS	Marginal Rates of Substitution
MXL	Mixed Logit
N	Nitrogen
NAERLS	National Agricultural Extension and Rural Liaison Services
NGN	Nigerian Naira
NE	Nutrient Expert
P	Phosphorus
P ₂ O ₅	Phosphorus Pentoxide
QUEFTS	Quantitative Evaluation of the Fertility of Tropical Soils
RCT	Randomized Controlled Trial
SALCM	Scale-Adjusted Latent Class Model
SSA	Sub-Saharan Africa
SSNM	Site-Specific Nutrient Management
Std. Dev.	Standard Deviation
T1	Treatment One
T2	Treatment Two
TAMASA	Taking Maize Agronomy to Scale in Africa
TPP	Total Physical Product
TVP	Total Value Product
USD	United States Dollar

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