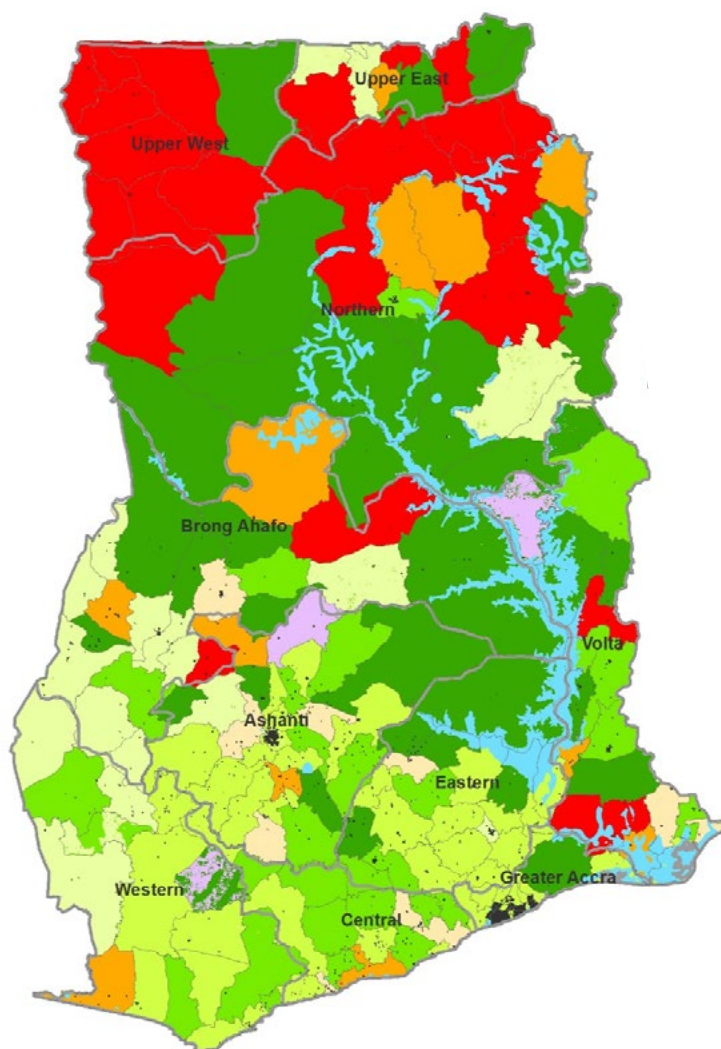


Progress report on Agricultural Typologies Work for the Program of Accompanying Research for Agricultural Innovation (PARI)



The map on the frontcover shows the agricultural typology of crop, livestock, poultry and fishing activities. Further details on the methodology and results are provided in Section 4 of this report.

ACKNOWLEDGEMENTS

The paper was developed within the project “Program of Accompanying Research for Agricultural Innovation” (PARI), which is funded by the German Federal Ministry of Economic Cooperation and Development (BMZ).



Federal Ministry
for Economic Cooperation
and Development



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1. INTRODUCTION

Africa is increasingly emphasizing the role of innovation in development. Innovation for sustainable and high agricultural growth forms an important part of the Science, Technology and Innovation Strategy for Africa 2024 (STI Strategy 2024). The German Government has acknowledged this innovation potential and wants to support the improvement of food and nutrition security and sustainable agricultural value chains through Agricultural Innovation Centers in 12 African countries and in India. ZEF's Program of Accompanying Research for Agricultural Innovation (PARI) offers independent scientific advice to support these Innovation Centers.

PARI's main goal is to contribute to sustainable agricultural growth and food security in Africa and India by supporting the scaling of proven innovations in the agri-food sector in collaboration with all relevant actors. PARI accompanies specified innovations with ex-ante impact research and identifies further innovation opportunities, including those expressed by end users of research in collaboration with the multi-stakeholder innovation platforms. PARI also fosters synergies with and links to existing innovation systems in the respective countries.

Within PARI's work, IFPRI has the task of assisting in the development of a methodology and concept for strategic analysis and visioning by providing economic modelling tools to help understand where the best opportunities for innovation investments in value chains are. For this purpose, rural typologies of micro-regions for the 12 African countries in the PARI project will be constructed to identify micro-regional level opportunities,

bottlenecks and investment gaps based on the concept of the production possibilities frontier applied to farm activities, drawing on highly detailed household-level survey and geospatial data on agro-ecological conditions, accessibility and poverty.

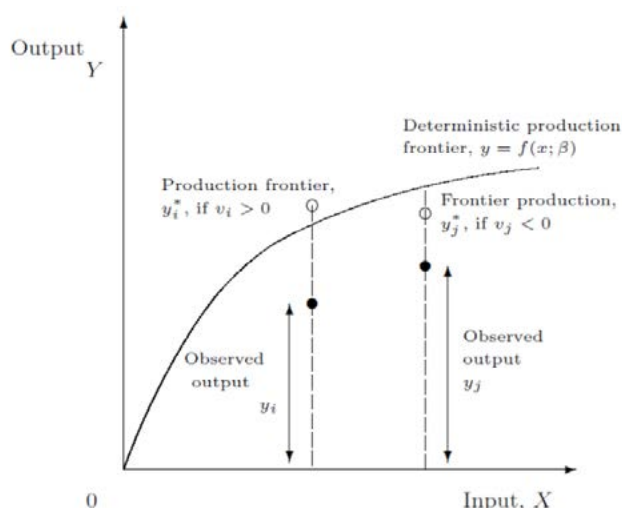
The rest of this report is organized as follows. Section 2 describes the methodology developed by the Markets, Trade and Institutions Division at IFPRI to construct the agricultural typologies. Section 3 details the progress made in securing the necessary data to construct the typologies for all the countries in the study. Section 4 presents preliminary results for Ghana and Malawi, and Section 5 explains the capacity strengthening activities, next steps and concluding remarks.



2. METHODOLOGY

The stochastic frontier approach allows us to explore econometrically the notion that, given the fixed local agro ecological and economic conditions in a micro-region and the occurrence of random shocks that affect agricultural production (weather, prices, etc.), the investment, production decisions and technological innovations a farmer makes translate into higher or lower production and income. In such a context, inefficiency is defined as the loss incurred in by operating away from the frontier given the current prices and fixed factors faced by the household. By allowing us to estimate where the frontier lies, and how far each producer is from it, the stochastic frontier approach enables us to identify local potential and efficiency levels to construct our typology. A graphical depiction of this concept is shown in Figure 1.

Figure 1. Graphic representation of a stochastic production frontier in the single-output, single-input case



We use the basic model proposed by Aigner et al. (1977) and Meeusen & van den Broeck (1977) depicted in Figure 8, where the stochastic frontier production function is defined as:

$$y_i = f(x_i; \beta) \exp(v_i - u_i) \quad (1)$$

where y_i is the possible production for farmer i ,

$f(x_i; \beta)$ is an adequate function of inputs x and parameters β ,

v_i is a random error with zero mean, associated with random factors that are not under the farmer's control, and

u_i is a non-negative random variable associated with factors that prevent farmer i from being efficient.

Then the possible production y_i is bounded by the stochastic quantity $f(x_i; \beta) \exp(v_i)$. It is assumed that the stochastic errors v_i are i.i.d. random variables distributed $N(0, \sigma^2)$, and independent from u_i . A farmer's technical efficiency is defined as the fraction of the frontier production that is achieved by his current production. Given the frontier production of farmer i is $y_i^* = f(x_i; \beta) \exp(v_i)$ then his technical efficiency can be defined as:

$$TE_i = \frac{y_i}{y_i^*} = \frac{f(x_i; \beta) \exp(v_i - u_i)}{f(x_i; \beta) \exp(v_i)} = \exp(-u_i) \quad (2)$$

Caudill & Ford (1993) and Caudill et al. (1995) showed that the presence of heteroskedasticity in u_i is particularly harmful because it introduces biases in the estimation of β and technical efficiency. This is very likely to occur if there exist sources of inefficiency related to factors specific to the producer. In this case



the distribution of u_i will not be the same for all the observations in the sample and a correction for heteroskedasticity needs to be made by modelling the variance of u_i :

$$\sigma_{u_i}^2 = \exp(z_i \delta) \quad (3)$$

where z_i are farmer-specific factors affecting his technical efficiency.

In order to estimate the model expressed by equations (1)-(3) we need to address the fact that farms are multi-output production units. So we need to move from a production function to a profit function approach. The stochastic frontier profit function can be expressed as (Kumbhakar & Lovell, 2000):

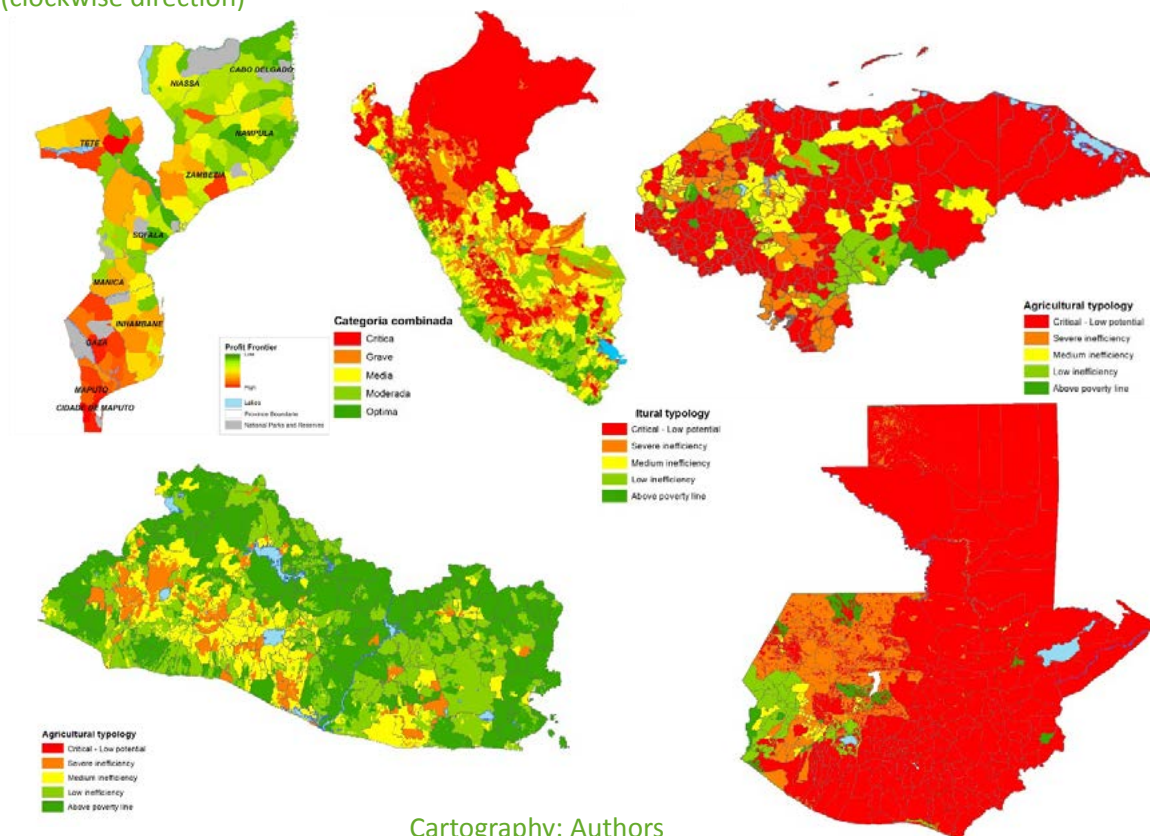
$$\pi_i = f(p_i, w_i; \beta) \exp(v_i - u_i) \quad (4)$$

where p_i and w_i are output and input price vectors, respectively.

With the estimation approach described above we can obtain parameter estimates that will allow us to predict or extrapolate agricultural income potential and efficiency measures at the regional level, which we can then group and classify into types to construct the typology. The typology then allows us to identify types of regions with extremely different needs, bottlenecks and opportunities, which in turn will result in a different set of investment recommendations for development in each type of region, including decisions regarding investments in agricultural innovation.

IFPRI has developed similar typologies and program targeting systems to the one proposed here for several countries: Ecuador, El Salvador, Honduras, Guatemala, Mexico and Peru in Latin America; Morocco, Mozambique and Uganda in Africa, and Vietnam

Figure 2. Examples of typologies for Mozambique, Peru, Honduras, El Salvador and Guatemala (clockwise direction)



Cartography: Authors



and Cambodia in Asia. In the case of Peru, Honduras and Guatemala the typologies are a component of a larger toolkit designed to aid government and donor agencies in selecting their investment portfolios towards poverty alleviation in rural areas, with the Peruvian government already incorporating the toolkit in their decision-making process for public in-

vestment budgets with regional governments and public offices for the 2015 fiscal year ([Government announcement](#) and [law](#)). Figure 2 shows examples of the rural typologies constructed for Mozambique, Peru, Honduras, El Salvador and Guatemala using this methodology.

3. DATA GATHERING EFFORTS

To build the typology maps, we first need to construct an accessibility model for each of the 12 countries in the study. The accessibility model allows us to estimate the time costs of accessing the closest market from any point in the map, where we can define “market” as actual markets to trade agricultural outputs, or as town or cities of certain size that generate high levels of demand for those products. To calculate this model we use global geographic data on water, roads, railroads, topography and natural barriers publicly available from DIVA-GIS. We also use GIS land cover type data as an explanatory variable in the stochastic frontier estimation from NASA and the USGS.

For each specific country, we also need a recent and nationally representative rural household survey with a detailed agricultural production module. The main challenge in obtaining these datasets is that to improve the precision of the typology maps we need access, when possible, to the GPS coordinates of the households in the survey sample, which is confidential information not released in the publicly available data files. We have signed a Data User Agreement with the World Bank LSMS (Living Standards Measurement

Surveys) group to access the GPS data for four countries included in the PARI project (Ghana, Malawi, Nigeria and Ethiopia) and we are currently in the process of securing the necessary data for the rest of the countries in the project. The household surveys we already have full access to are listed below.

Ghana Living Standards Survey Round 6 (GLSS6), 2012/2013: The GLSS6 was conducted by the Ghana Statistical Service (GSS) from October 2012 to October 2013 and covers a sample of 16,772 households (9,327 in rural areas) representative at the national, urban/rural, regional and district levels.

Malawi Integrated Household Survey (IHS) 2010/2011: Conducted by the Malawi National Statistics Office (NSO) and part of a regional project titled the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) implemented by the World Bank and the Bill and Melinda Gates Foundation. While there is also a panel component of this survey, we are using the larger cross-section that consists of 12,272 households. It is representative at the national, urban/rural, regional and district levels.



Nigeria Generalized Household Survey (GHS)
2012/2013: This survey was conducted by the Nigeria National Board of Statistics (NBS) and consists of 5,000 households, for which detailed agricultural information and also part of the LSMS-ISA project. It is meant to be representative at both the national, urban/rural and zonal levels and is a subsample of the larger GHS cross-section.

Ethiopian Socioeconomic Survey (ESS)
2013/14: Conducted by the Central Statistics Agency of Ethiopia (CSA) in partnership with the World Bank LSMS-ISA project. The wave we are using covers both urban and rural areas, includes 5,262 households, and is representative at the urban/rural and national levels.

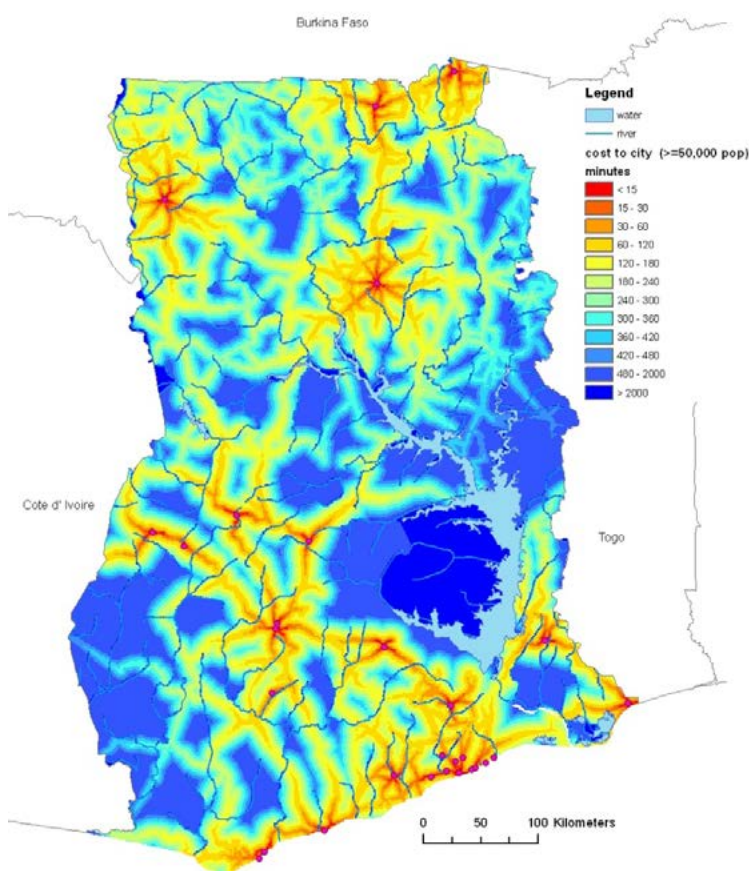
4. PRELIMINARY RESULTS¹

Ghana

The map in Figure 3 shows the results of the accessibility model calculated as the time it takes to get from any point in the map to the closest city of at least 50,000 inhabitants. Only the areas in colors ranging from red to yellow are within three hours of a major city, and hence a dynamic market for agricultural outputs. While the regions in the Southern coast (Greater Accra, Central and Western) are fairly well connected, the rest of the country shows large areas in blue, which denotes relatively poor accessibility. For any farmer in these areas getting to an attractive market to sell outputs or buy inputs would be extremely costly. Increasing agricultural productivity in these regions, for instance, would have a limited impact on incomes and livelihoods of rural households unless market access costs are reduced.

Figure 4 shows the 2015 poverty map elaborated by the GSS. The information on the poverty map helps us construct our final typology.

Figure 3. Ghana: Access to cities of 25,000 inhabitants or more

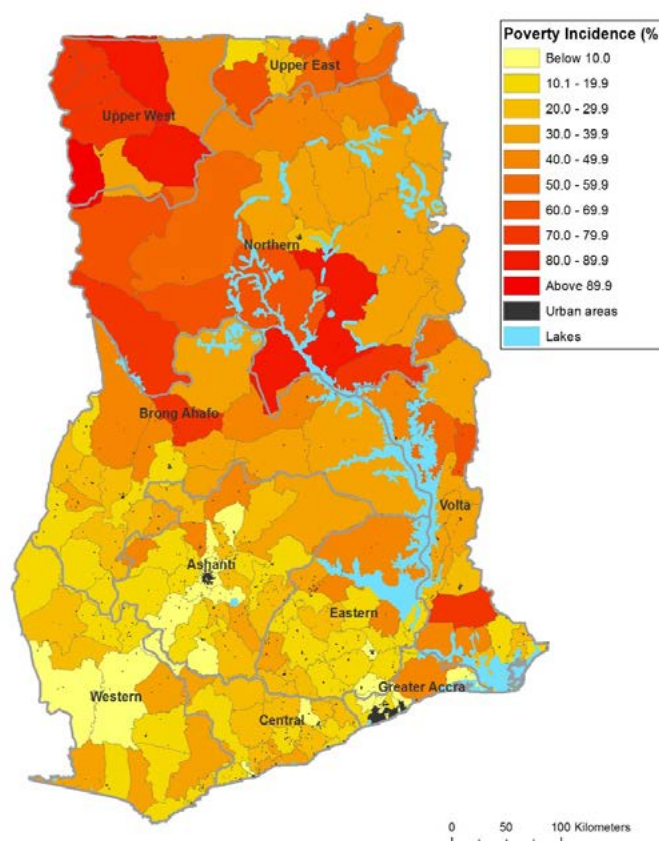


Cartography: Authors

¹ These results are pending validation from local experts, please do not cite.



Figure 4. Ghana: 2015 Poverty map (GSS)



Cartography: Authors. Data Source: Ghana Statistical Service (GSS)

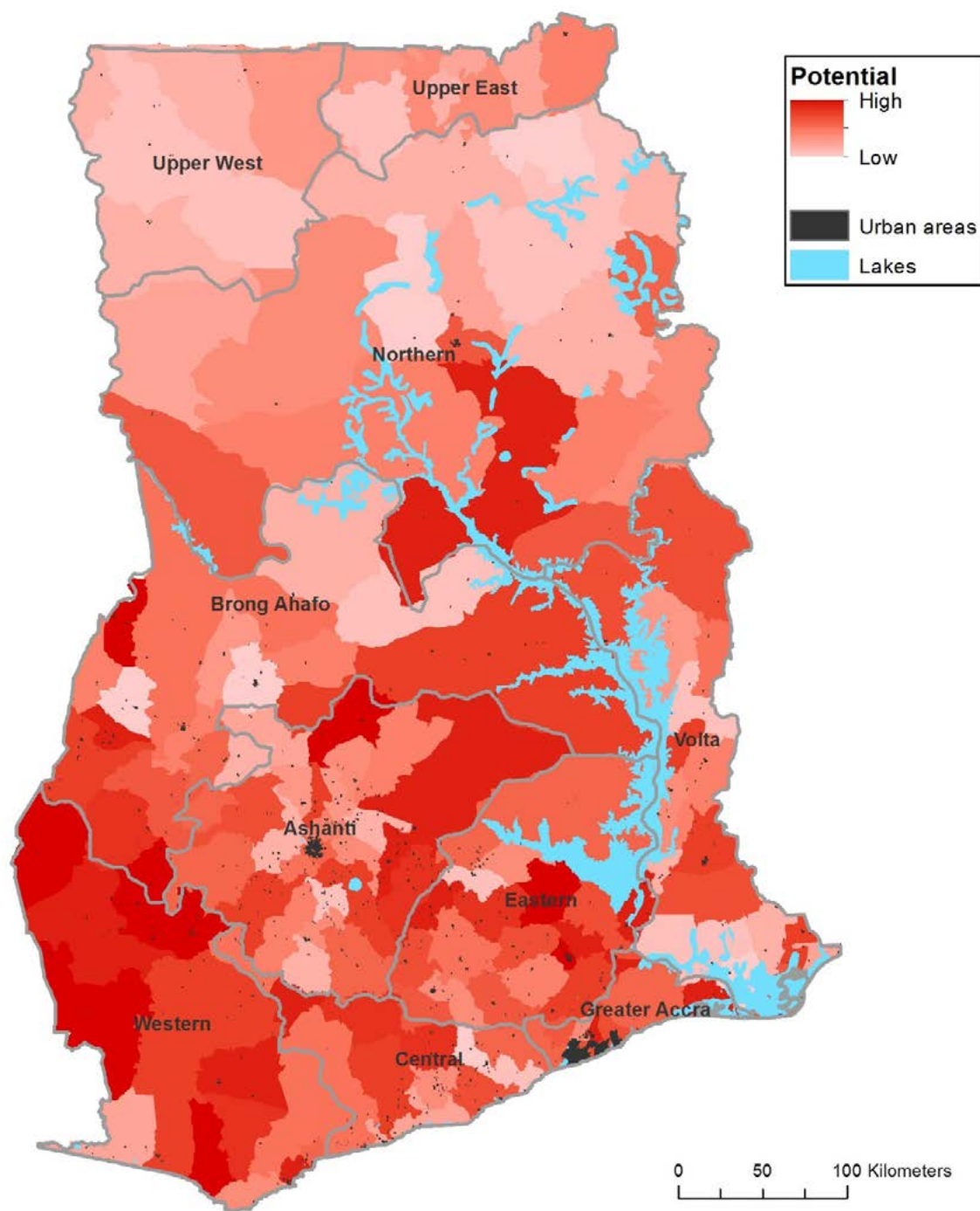
logy: while the regional agricultural potential and efficiency estimates help decide what type of intervention is better suited for the local productive and economic characteristics, local poverty rates help establish a priority of where investments are needed the most.

The regional extrapolation of the stochastic frontier estimation results show that the poorer areas in the Upper West region and Northern region have low agricultural potential (Figure 5) in spite of medium to high efficiency levels (Figure 6), indicating that agricultural investments in these areas might not yield high returns in the short term without considerable investments in infrastructure and technological change. Results for the Brong-Ahafo region are more encouraging, with areas suffering from medium to high poverty rates show significant agricultural potential, indicating that there are still considerable productivity gains to be achieved

by investing in reducing inefficiencies in the agricultural sector in these areas. This is also shown in the map in Figure 7 which presents the agricultural typology that results when the agricultural potential and efficiency estimates are combined with the poverty data. Areas in dark and medium green in the typology are regions where investing in reducing inefficiencies in the agricultural sector can yield significant benefits in terms of increasing incomes of the rural poor. Areas in red are labeled as critical because they have high poverty rates but low agricultural potential, so development policies in these areas should concentrate in social safety net programs and human capital enhancing policies such as conditional cash transfers in the short term, and in large infrastructure development (such as investments in rural roads and electrification) and technological innovation and R&D in agriculture in the long term.



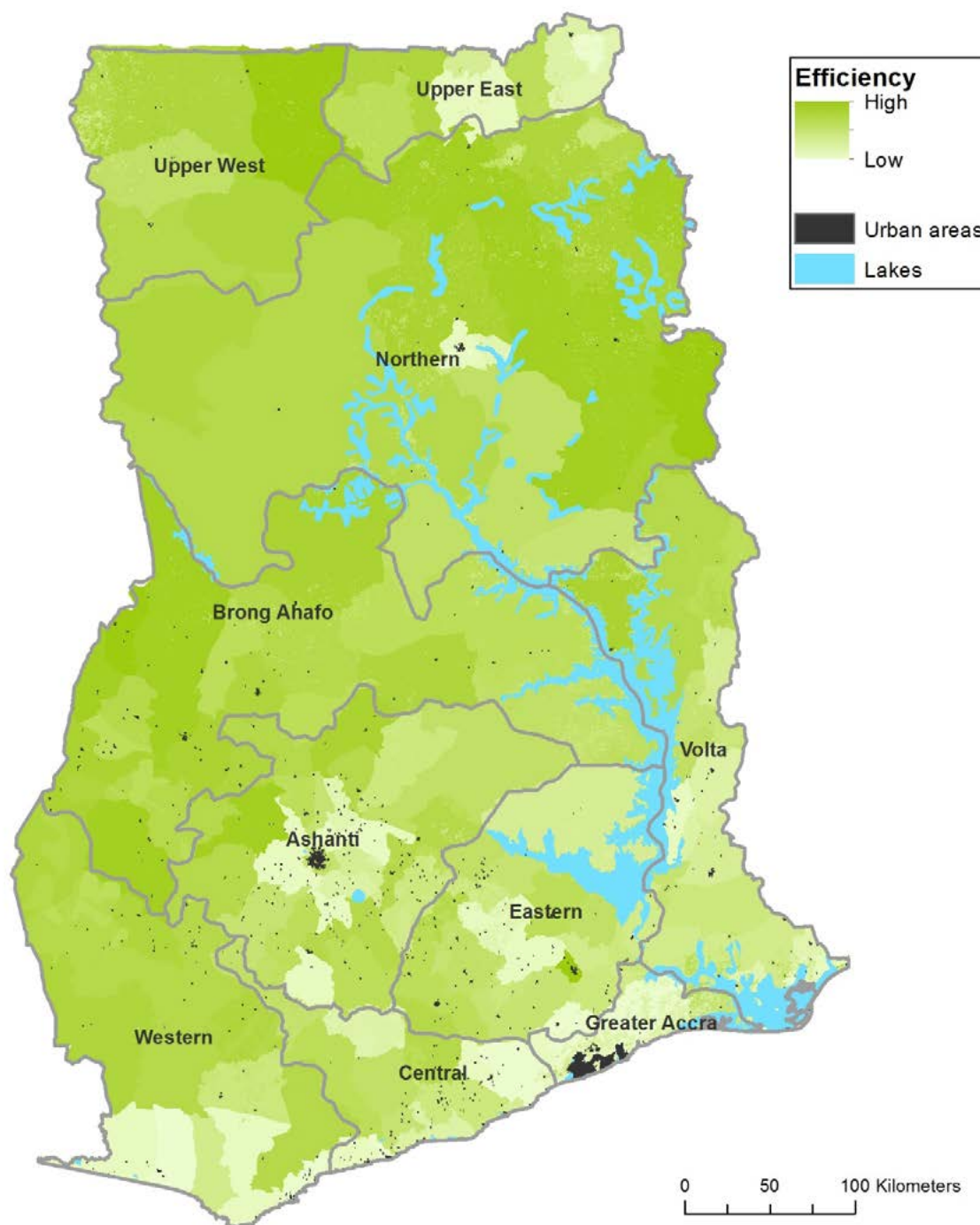
Figure 5. Ghana: Agricultural potential for crop, livestock, poultry and fishing activities



Cartography: Authors



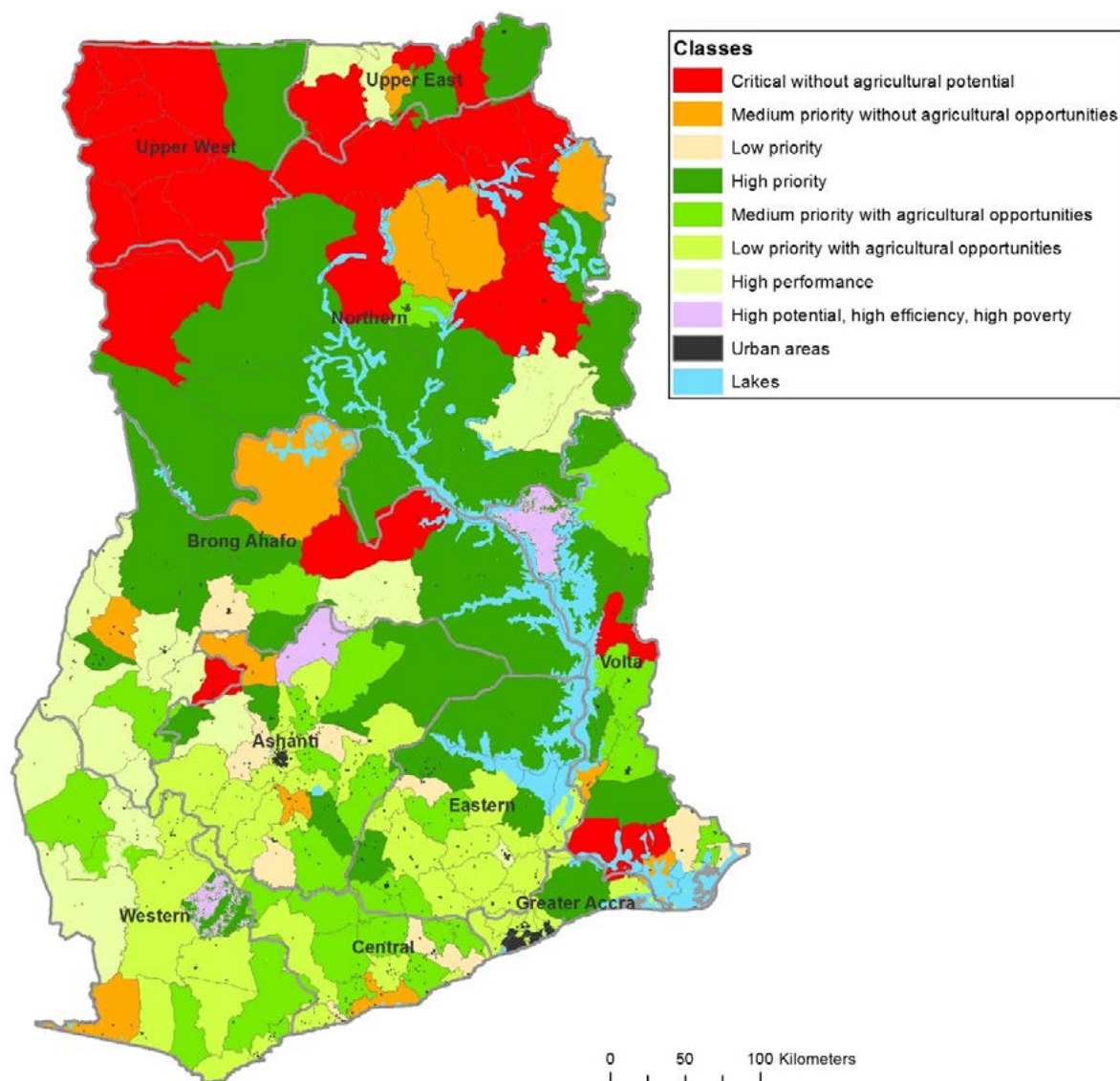
Figure 6. Ghana: Agricultural efficiency crop, livestock, poultry and fishing activities



Cartography: Authors



Figure 7. Ghana: Agricultural typology of crop, livestock, poultry and fishing activities



Cartography: Authors



Malawi

The preliminary results for Malawi are shown in the maps in figures 8, 9, and 10. The accessibility model shows fairly high levels of accessibility to local markets, except the areas near Mzimba in the Northern region of the country, which is also an area of low agricultural potential. The Central region and

the district of Chitipa on the north of the Northern region concentrate well connected areas with high agricultural potential. The district of Kasungu, for example, shows both high agricultural potential and efficiency, as well as a good connection to markets. Most of the Southern region, on the other hand, shows low agricultural potential.

Figure 8. Malawi: Access to markets

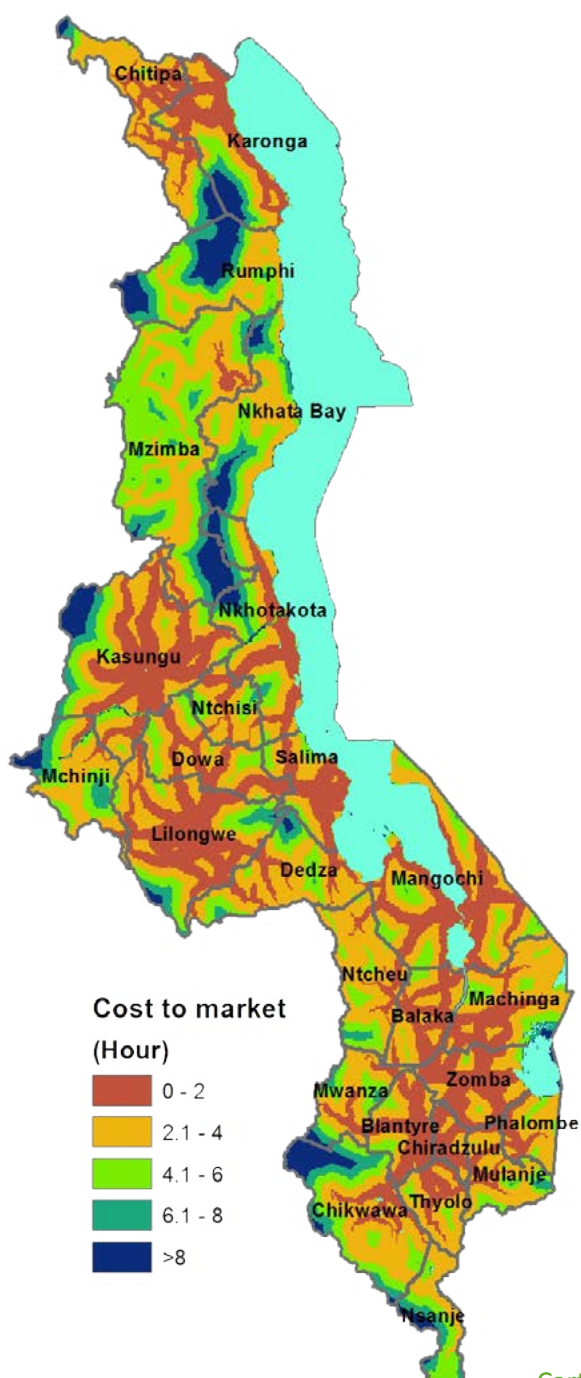
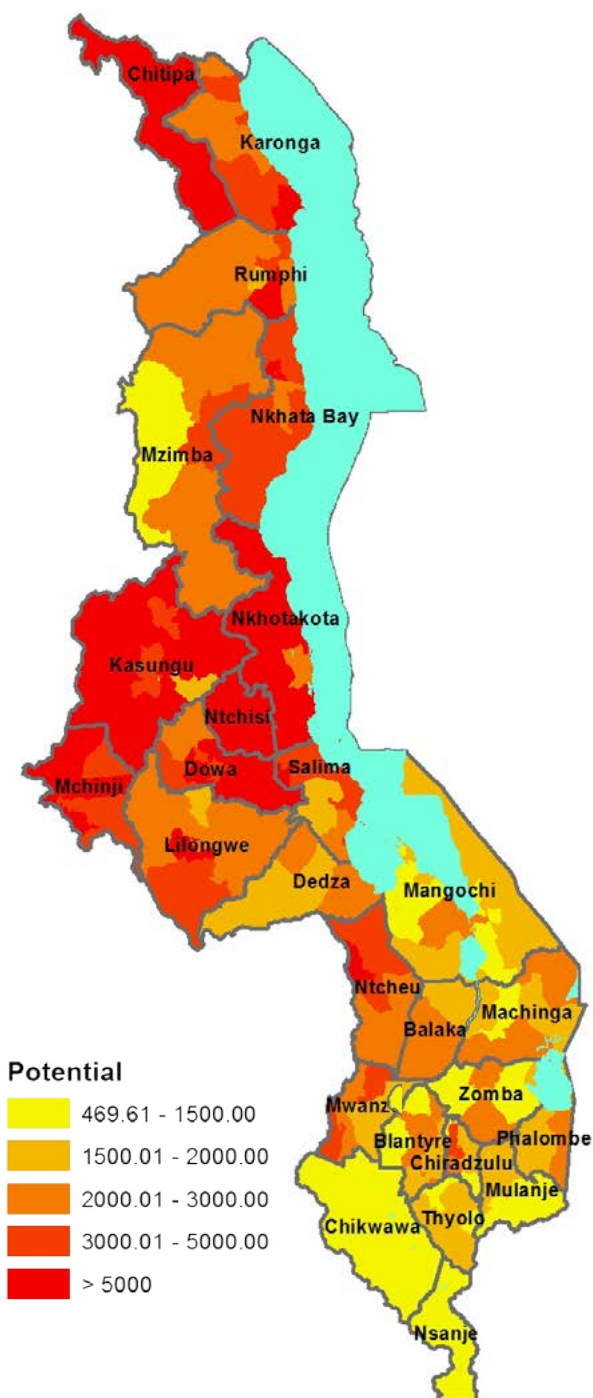


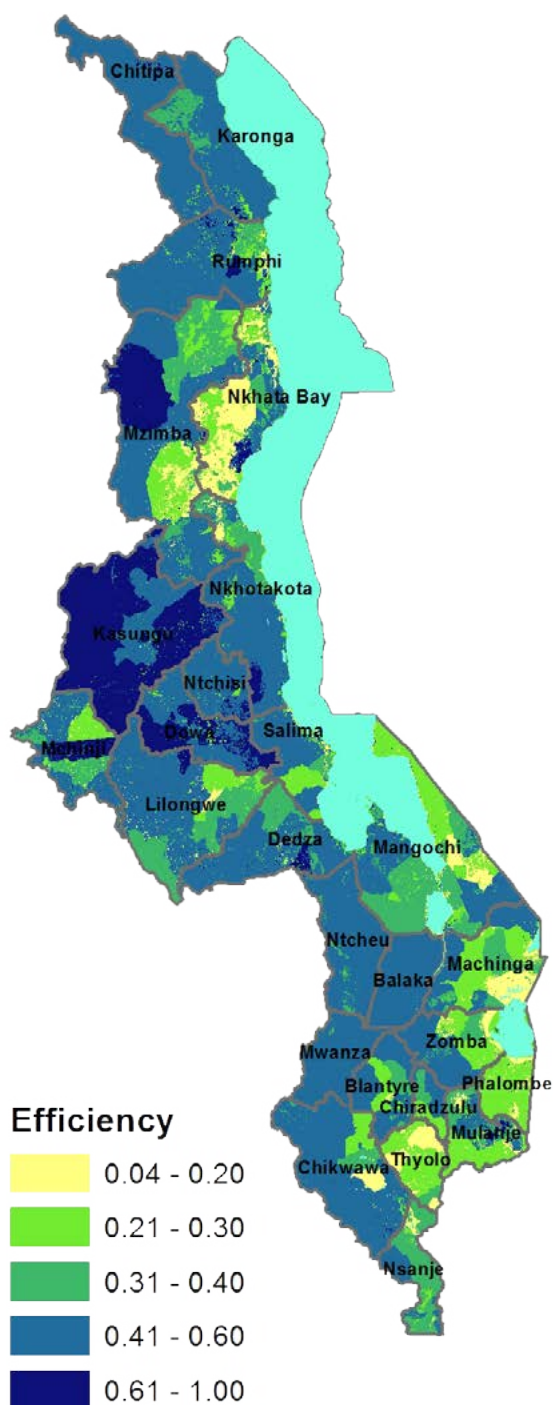
Figure 9. Malawi: Agricultural potential



Cartography: Authors



Figure 10. Malawi: Agricultural efficiency



Cartography: Authors

5. CONCLUDING REMARKS

We are currently working on completing the typology for Malawi, and developing the ones for Nigeria and Ethiopia, while securing reliable household survey data for the remaining PARI countries. Once completed the typology maps are validated against land use and agricultural production maps from different sources, as well as through reviews from local experts. Once the validation is finalized, the data will be uploaded and made publicly available through the E-Atlas.

As part of the capacity strengthening activities of the project, we have also recruited two African-based researchers, Abdoulaye Seck and Francis Mulangu, recommended by Christopher Parmeter, Associate Professor in the Department of Economics at the School of Business Administration of the University of Miami, and instructor of the AGRODEP course on Productivity Analysis (which focused on stochastic frontier estimation). Abdoulaye Seck is an Associate Professor at the Faculty of Economics and Business of Cheikh Anta Diop University in Dakar, Senegal, and Francis Mulangu is an Agricultural Economist at the African Center for Economic Transformation in Accra, Ghana. Both of them were invited to IFPRI headquarters in Washington, DC, to attend a one week long training course on constructing agricultural typologies during the month of March, and are now supporting the project doing data analysis.



REFERENCES

- Aigner, D. J., Lovell, C. A., & Schmidt, P. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of Econometrics*, 6, 21-37.
- Caudill, S. B., & Ford, J. M. (1993). Biases in Frontier Estimation Due to Heteroskedasticity. *Economic Letters*, 41, 17-20.
- Caudill, S. B., Ford, J. M., & Gropper, D. M. (1995). Frontier Estimation and Firm-Specific Inefficiency Measures in the Presence of Heteroskedasticity. *Journal of Business and Economic Statistics*, 13, 105-111.
- Kumbhakar, S. C., y C. A. K. Lovell (2000). *Stochastic Frontier Analysis*. Cambridge University Press.
- Meeusen, W., & van den Broeck, J. (1977). Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. *International Economic Review*, 18, 435-444.



