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Fertilizer profitability in East Africa: A Spatially Explicit Policy Analysis

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Abstract

Even though it is clear that Substantial growth in inorganic fertilizer use is a prerequisite for sustained agricultural growth in Africa, fertilizer use is still one of the factors explaining lagging agricultural productivity growth in SSA. High transport costs and less policy support pose a significant barrier to make fertilizer application profitable in Africa. This paper is aimed to identify organizational and institutional changes that could reduce fertilizer transport costs and their impacts on profitability of fertilizer application. A model is constructed to simulated transport costs from ports to farm-gate at pixel level based on the knowledge of road network condition, surface land cover type, slope, imported fertilizer price at the port, storing fee, handling fee and regulation fee. Furthermore, farm-gate fertilizer price, maize price and VCR (value cost ratio) are calculated. To test the impacts of different policies and strategies to fertilizer profitability, several scenario simulations are developed to visualize them. There are five scenarios considered in the paper including: a) Baseline scenario b) Reduce fertilizer price at port by 20 and 50% c) Transport cost reduce by 20% and 50% d) Reduce country crossing cost by 20% and 50% e) combination of b, c, and d. The research indicated that fertilizer price varies from space. Impacts of scenarios and their severity vary spatially also. There are opportunities to reduce domestic farm-gate fertilizer price if appropriate policy and strategies are made to lower fertilizer transport costs such as improving road condition, decrease handling fee and applying supporting policies and strategies are decreased. Price reduction would increase farmer's effective demand for fertilizer and make fertilizer application profitable. With high incentives of fertilizer consumption, local farmers could increase agriculture production in the end.

Keywords Fertilizer profitability, Value cost ratio, transport cost, East Africa

Introduction

Agriculture often serves as the engine of growth during the early stages of a country's economic development. It plays a key role because the sector typically accounts for a high share of economic activity in developing countries and because agricultural activities tend to have powerful growth linkages with the rest of the economy. Agriculture-led growth tends to be especially pro-poor when it is fueled by productivity gains in the small-scale family farming sector when these productivity gains result in lower prices for food staples consumed in large quantities by low-income groups (Byerlee, D., X.Diao, and C.Jackson, 2005).

The performance of the agricultural sector in Sub-Saharan Africa has been unsatisfactory for the past several decades. It is widely understood that farm productivity growth is a precondition for broad based economic development in most of developing world. There is a consensus that increased use of quality seed and fertilizers is an essential ingredient in any plan for African economic development and food security (Rosegrant, M.W., Paisner, M.S., Meijer, S., , 2001). Based on several studies, Fertilizer together with improved seed are two critical and most important factors to drive yield growth (Anderson, J.R., R.W. Herdt, and G.M.Scobie., 1985; Anderson, J.R., R.W. Herdt, and G.M.Scobie., 1988; Tomich, T.P., P.Kilby, and B.F.Johnston., 1995). According various researches in Asia, fertilizer usage contributes one third increase of cereal production. Researches indicate that fertilizer could bring similar productivity gains to Africa and indeed strong yield growth led by improving or increasing fertilizer usage.

Even though numerous researches have proved that achieving productivity is likely to involve substantially increased use of fertilizer, fertilizer use is still one of the factors explaining lagging agricultural productivity growth in SSA. Currently, fertilizer use in Sub-Saharan Africa averages 9 kg per hectare, the lowest of any developing country by far (FAO(Food and Agriculture Organization), 2004). Even when countries and crops in similar agro-ecological zone area compared, the rate of fertilizer use is much lower in SSA than in other developing regions and crop yields are correspondingly lower. The striking contrast between the limited use of fertilizer in Africa and the much more extensive use of fertilizer in other developing regions has stimulated not only considerable discussion about the role of fertilizer in the agricultural development process but also debate about what types of policies and programs are needed to realize the potential benefits of fertilizer in Africa agriculture. Apparently, the old fertilizer promotion strategy that designed with a “one size fits all” philosophy is failed to recognize the diversity of production systems and the range of farmers’ needs.

Researchers and experts try to figure out the reasons that cause the low fertilizer input in Africa. Generally, evidence explains the low use of fertilizer in Africa in two sides: demand side as well as supply side. On the demand side, 1) Incentives to use fertilizer are undermined by the low level and high variability of crop yield 2) High fertilizer price 3) less market information 4)low credit to support fertilize purchase 5)lack knowledge on how to use fertilizer. On the supply side: 1) High transport cost 2) trade barriers 3) low market size 4) weak business finance and risk management. As described by Yanggen et.al (Yanggen, D., V. Kelly, T.Reardon, A. Naseem, M. Lundberg, M. Maredia, J. Stepanek, and M. Wanzala., 1998), the first and most obvious factor that could explain low fertilizer use relates to profitability. Economists started to use Value Cost Ratio which is simply the ratio of the technical response to fertilizer use and the nutrient/output price ratio to explain the fertilizer use in Africa. In many African countries, fertilizer price to output price ratios are higher than those observed elsewhere in the developing world, reflecting the region’s often difficult production environments on the one hand and it’s poorly developed marketing systems on the other. Based on a large number of observations across countries, researchers and experts have some key findings. Firstly, there is no clear evidence supporting the

acclamation that soils in Africa are inherently less fertile than soils in other regions. On the other hand, crop response varies considerably between sites and across seasons in Africa. This finding emphasized the higher risks of using fertilizer in Africa.

These types of analysis have usually been done in country or sub-national levels because fertilizer prices and crop prices can be easily collected (T.S. Jayne, J. Govereh, M. Wanzala, M. Demeke, 2003; Maria Wanzala, T.S. Jayne, John M. Staatz, Amin Mugeru, Justus Kirimi, and Joseph Owuor, 2001). In the real world, Fertilizer price, as well as crop prices, can vary significantly across space. Within the same country, the crop price that is relevant for any given household depends on whether that household is a net seller of the crop, a net buyer, or neither. Fertilizer price highly depends on so many factors such as how far the household is from the Market and how good the road conditions are. There is a dearth of fertilizer profitability analysis in a spatial disaggregated level. This report is motivated by such potentials and tries to answer the same questions by bringing analysis into a finer pixel level resolution. Furthermore, VCR can be developed at the farm-gate level also. It brought us a chance to carry out quantitative profitability analysis instead of current studies that remain descriptive and lack empirical content due to insufficient data. Profitability remains one of the key factors determining the quantity of fertilizer used. Farmers will not use fertilizer if it is not profitable.

Spatial disaggregated fertilizer price, production price and VCR give us a close look of these economical factors and their spatial distributions but there is a more important question for agricultural policy makers which is whether there are feasible changes in policies and/or investment strategies that can be reduce the farm-gate price of fertilizer and make fertilizer application profitable. To test these hypotheses, several scenario simulations are developed to visualize the impacts of possible policy or regulation on farm-gate fertilizer price and profitability. There are five scenarios considered in the paper including: a) Baseline scenario b) Reduce fertilizer price at port by 20 and 50% c) Transport cost reduce by 20% and 50% d) reduce country crossing cost by 20% and 50% e) combine of b, c, and d. The spatially Explicit Policy Analysis helps us to identify organizational and institutional changes that could reduce fertilizer market costs, and simulate the effects of these potential cost reductions on the profitability of using fertilizer on crop production.

Conceptually, it is not hard to calculate the increase in fertilizer use needed to achieve a certain specified increase in agricultural production. Furthermore, Pixel level fertilizer price and crop price can be calculated also. In practice, however, calculating the needed in profitability analysis is challenging. It is necessary to specify an appropriate target because different crop have different prices and the same to fertilizers. Assuming that a target can be defined, data availability is likely to pose a major problem also. After evaluation of fertilizer data in Africa, maize and urea has been picked as the targets for this paper. Although it is often said that in Africa much more fertilizer is applied to high value or export crops than to staple food crops, it is not true. Based on a study covering 12 countries that jointly accounted for 70-75 percent of fertilizer consumption in Africa during the late 1990s, FAO report (FAO, 2002) determined that maize was the principal

crop fertilized (40 percent of consumption in the countries covered), followed by other cereals including sorghum and millet.

The objective of this paper is to set up a framework to examine spatial fertilizer profitability across countries at pixel levels. It first developed a method to disaggregate economic data from administration unit to farm-gate pixels. Meantime, it provides a detailed look of the factors that affecting fertilizer price and production price at the same scale. Lastly, drawing from the foregoing, the impacts of the possible policy changes on fertilizer price, production price and VCR at farm-gate level are examined. Due to the data availability and work resources, the work focus on east Africa which covers Tanzania, Uganda, Kenya, Burundi, and Rwanda. The framework can be further break down into details as below:

- 1) Yield response at difference fertilizer applications (N application at 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, and 50 kg/ha)
- 2) Transport cost estimation at pixels level in East Africa
- 3) Spatial farm-gate fertilizer price calculation
- 4) Spatial farm-gate maize price calculation
- 5) Maize market shed allocation at pixel level
- 6) Farm-gate fertilizer strategy analysis including four scenarios : a) Baseline scenario b) Reduce fertilizer price at port by 50% c) Transport cost reduce by 20% d) reduce country crossing cost by 50% e) combine of b, c, and d
- 7) Analysis of VCR changes in various scenarios and its possible impacts on farmer fertilizer application, maize production and profitability

Methodology and analysis

1. Construct transport cost surface

High transport costs pose a significant barrier to fertilizer use in Africa. As explain above, transport costs are one of the reasons to keep the high fertilizer price. In order to successful estimate transport cost at pixel level, factors that are account for total transport cost need to be investigated. First of all, we need to define what transport costs are. Transport costs specifically depend on road condition, on/off road transport, distance of transport and slope of the roads. On the other hand, Transport costs are, in a broad sense, the costs involved with the movement of commodities. When this movement takes place within the borders of a particular country, the costs are often described as domestic transport costs, whereas when goods cross borders, there is an additional element of international transport costs. International transport costs comprise all the costs involved in the movement of goods from an exporter to an importer, typically including the cost of handling and bagging, of freight, offloading, uploading and of insurance.

When the transport costs are disaggregated into pixel levels, both of the costs need to be considered. To simplify the variables to construct the transport cost surfaces, the specific transport cost is the function of four variables which are on/off roads, land cover types, fertilizer import locations and slope of the lands. In the broad sense, the handling fees, storage costs, removal fees and border crossing costs are considered. The total transport costs are the combination of both of them .

More specifically, a cost layer is firstly constructed by taking account all the cost variables listed above. A cost layer is a pixel-level layer that each pixel value represents the unit transport costs in a specific pixel when merchandises are transport through it. It not only represents favorability to transport in a pixel level, but also calculate how much it will cost if transport happens in that pixel. Except Kenya and Tanzania, all the other countries are landlocked countries and the fertilizers are heavily depended on importers. To simplify the case, one assumption has been made that all the fertilizers are imported from the ports of Mombasa, Kenya and Dar Es salaam, Tanzania. The transport calculation could be explained by the formula below.

$$C_{pk} = \sum C_{pr} + C_{pl} + C_{ps} + C_{pb}$$

$$C_t = \sum_{k=1}^n C_{pk}$$

Where C_p is the pixel cost

C_{pr} is the on-road transport costs at the pixel

C_{pl} is the off- road transport cost at the pixel

C_{ps} is the additional transport cost due to the land slope

C_{pb} is the border cost if the pixel is on at the border

C_t is the total transport costs from Mombasa or Dar Es Salaam.

C_{pk} is transport cost of k^{th} path pixels that when transport happens

n is the total pixels that passed if fertilizer is transported from Mombasa or Dar Es Salaam

The transports cost in the major corridor roads data is collected from Trade Africa (www.tradeafrica.org) and summarized as below:

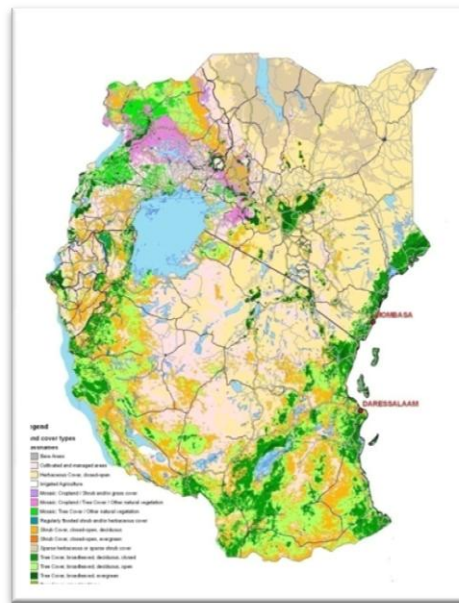
- First level roads: 0.00012\$ kg/km
- Second level roads: 0.0003\$ kg/km
- Other roads: 0.0006\$ kg/km

With the help of ArcGIS spatial analysis extension, the least cost distance module has been applied to development fertilizer transport cost surfaces. The programs are used to generate

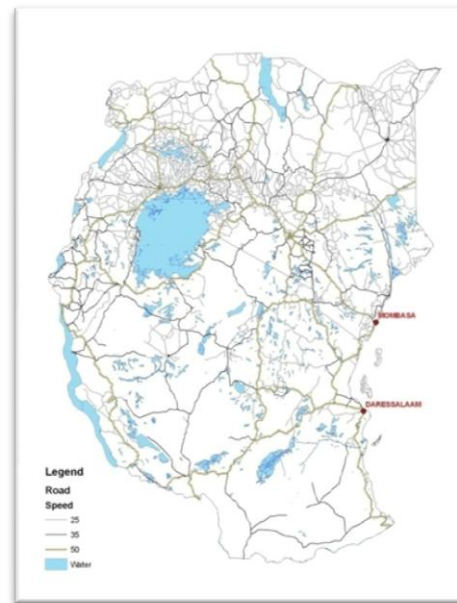
the least transport cost path from the ports to each of the destination pixels and calculate the total transport costs through the path pixels by adding up the costs of the path pixels. The input data and output data display as below. The total transport costs from Mombasa and Der Es Salaam to each of the pixels in the maps has been calculated with the unit of U.S. Dollars/Metric ton.



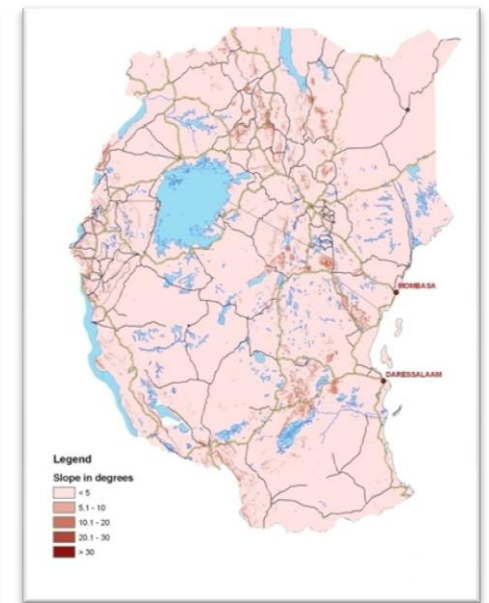
Ports and country boundary



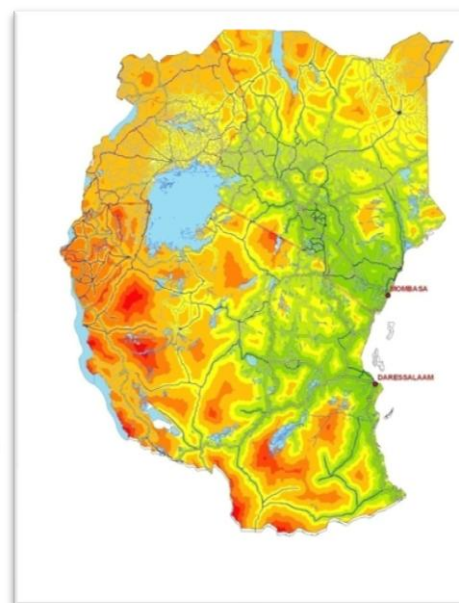
Land cover types



Road networks

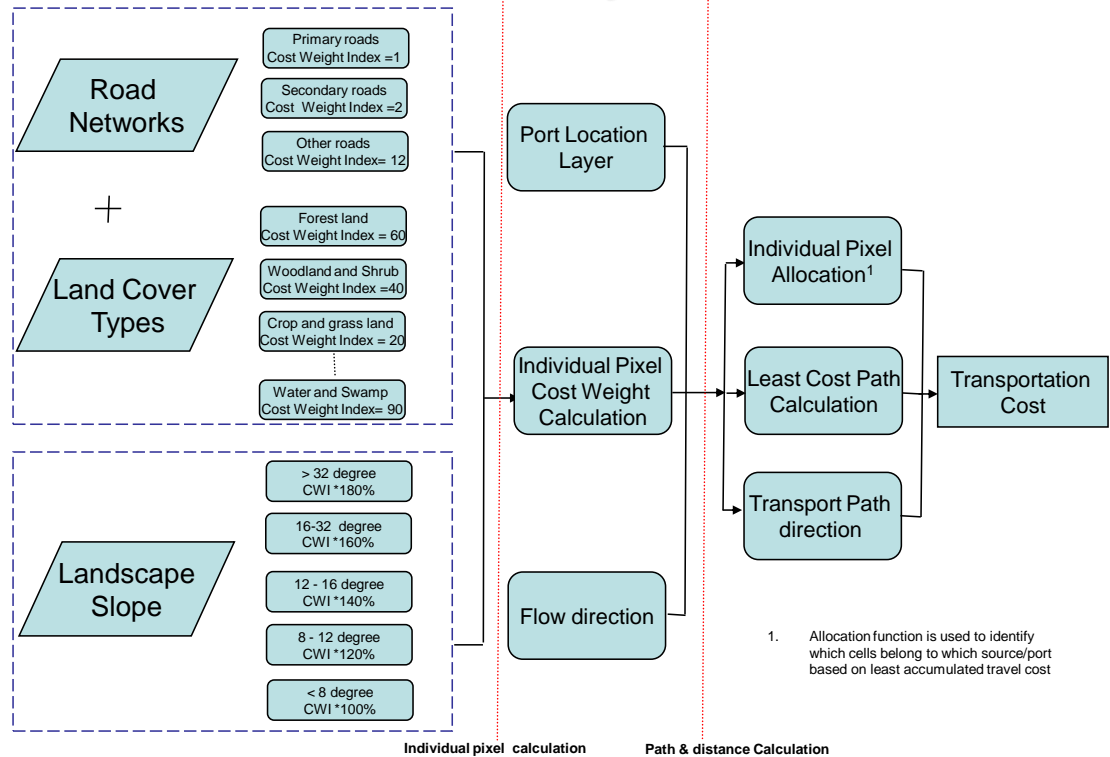


Slopes



Legend
Road
Speed
25
35
50
Transportation cost U.S. \$/MT
< 10
11 - 30
31 - 100
101 - 150
151 - 200
201 - 300
301 - 400
401 - 500
> 500

Overall Schematic Analysis



2. Urea price disaggregation

Based on the transport cost calculation surface, it would be possible to calculate unit urea delivery cost. Based on the report from International Fertilizer Development Center (IFDC, 2005; FAO., 2005) , the landed urea price can be easily obtained. The landed urea price is not equal to the price when the urea leaving the ports. There are a couple of additional fees attached. From the East Africa government report (Regional Agricultural Trade Expansion support, 2006), the transaction fees at the port can be categorized into 5 items and are summarized into the table below:

U.S. \$/kg	Wharfage/St evedore	Handling	Removal Charges	storage /day	Terminal handling
Kenya	0.008	0.006	0.002	0.0005	0.008
Uganda	0.008	0.006	0.002	0.0005	0.008
Tanzania	0.005	0.004	0.004	0.0005	0.008
Rwanda	0.005	0.004	0.004	0.0005	0.008
Burundi	0.005	0.004	0.004	0.0005	0.008

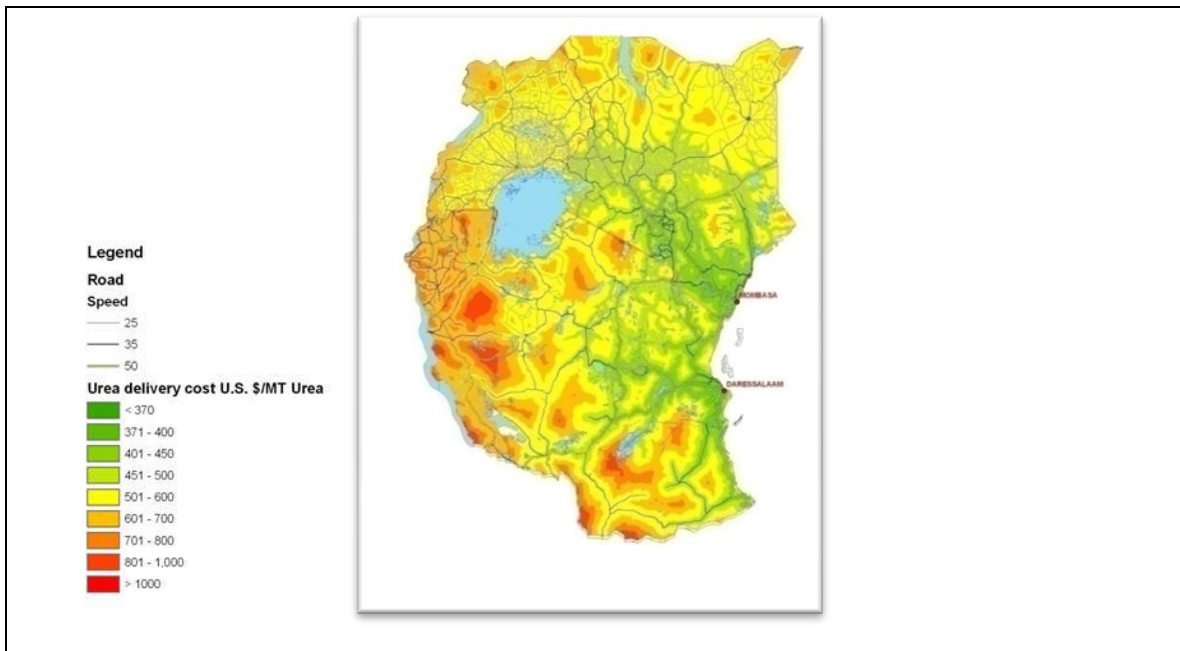
Mathematically, urea delivery price in each pixel can be calculated using the formula below:

$$P_i = C_{ti} + C_o$$

Where P_i is the Urea price at pixel i

C_{ti} is the total transport costs at pixel i

C_o is the total transition costs at the port when the Urea is ready to leave the Port including wharfage, handling, removal charges, storage, and Terminal handlings.



Up to now, Urea prices at pixel level have been developed. Each individual pixel in the map has a urea unit price associated its geographic locations.

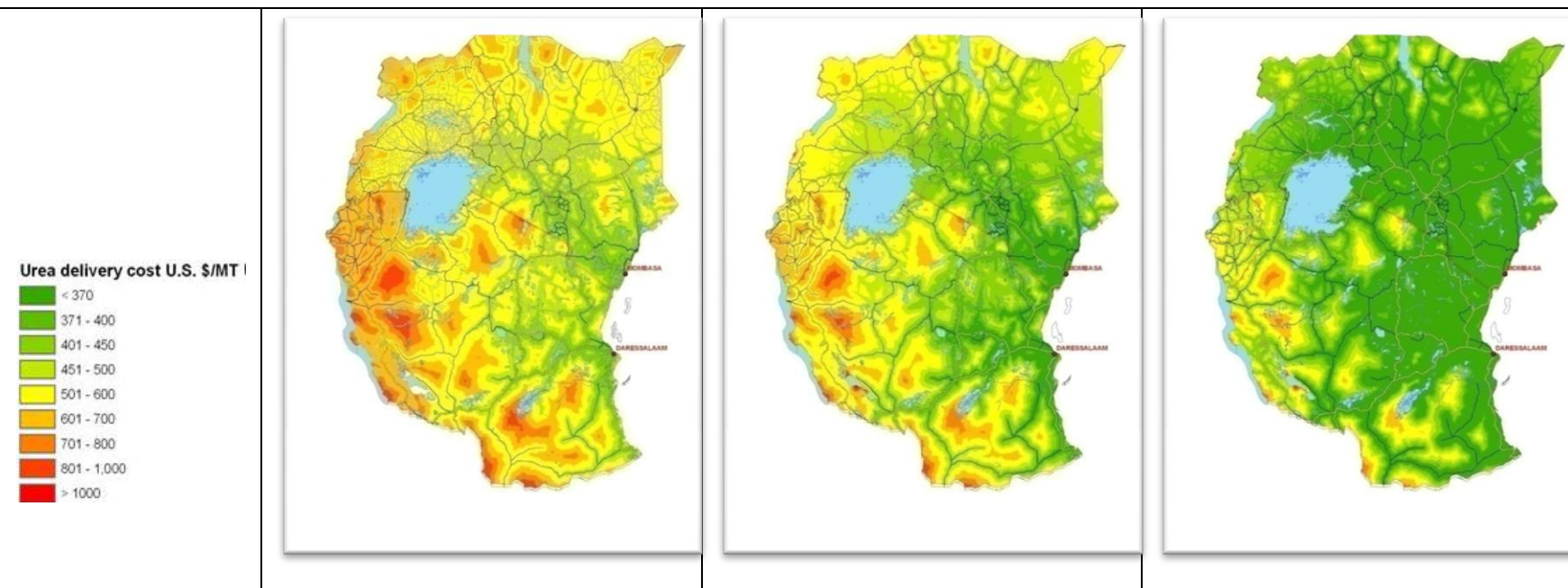
3. Urea delivery cost scenarios

An important question for agricultural policy is whether there are feasible changes in policies and/or investment strategies that can reduce the farm-gate transport costs and hence reduce price of fertilizer. This section reports results of sensitivity analysis on the price of Urea delivery, reflecting several scenarios that are envisioned to reduce farm-gate prices. These scenarios are:

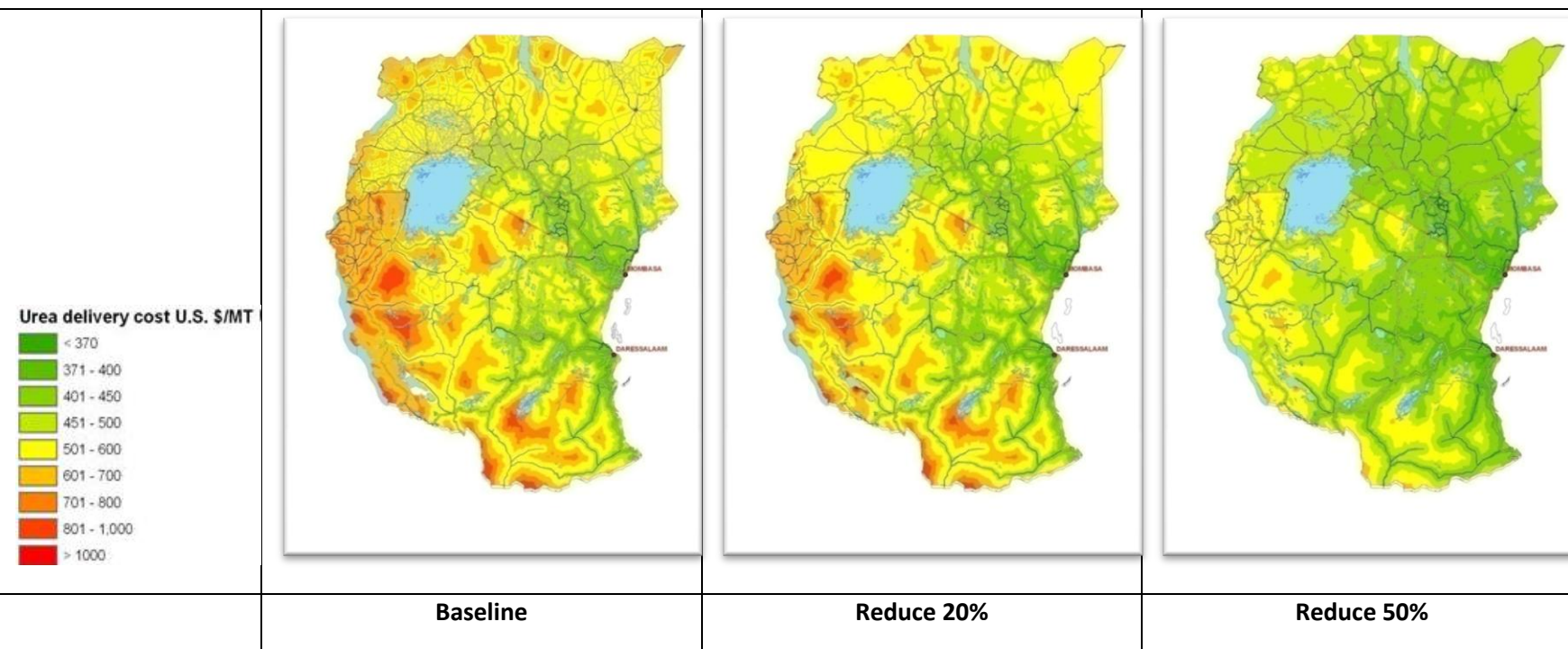
- Reduce landed urea price at the port for 20 and 50%
- Reduce road transport cost at 20 and 50%
- Reduce border crossing cost at 20 and 50%
- Combination of all three scenarios

The maps results are displayed as below:

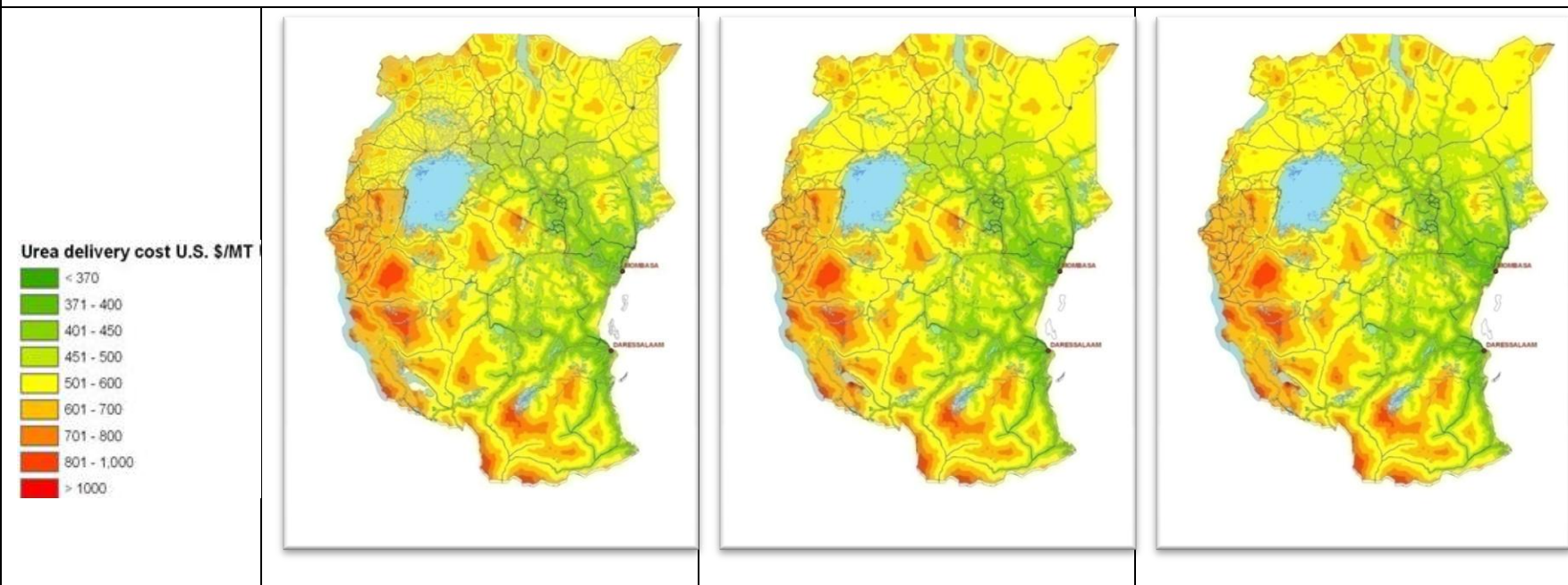
Scenario 1 : Reduce port landed urea price by 20 and 50%



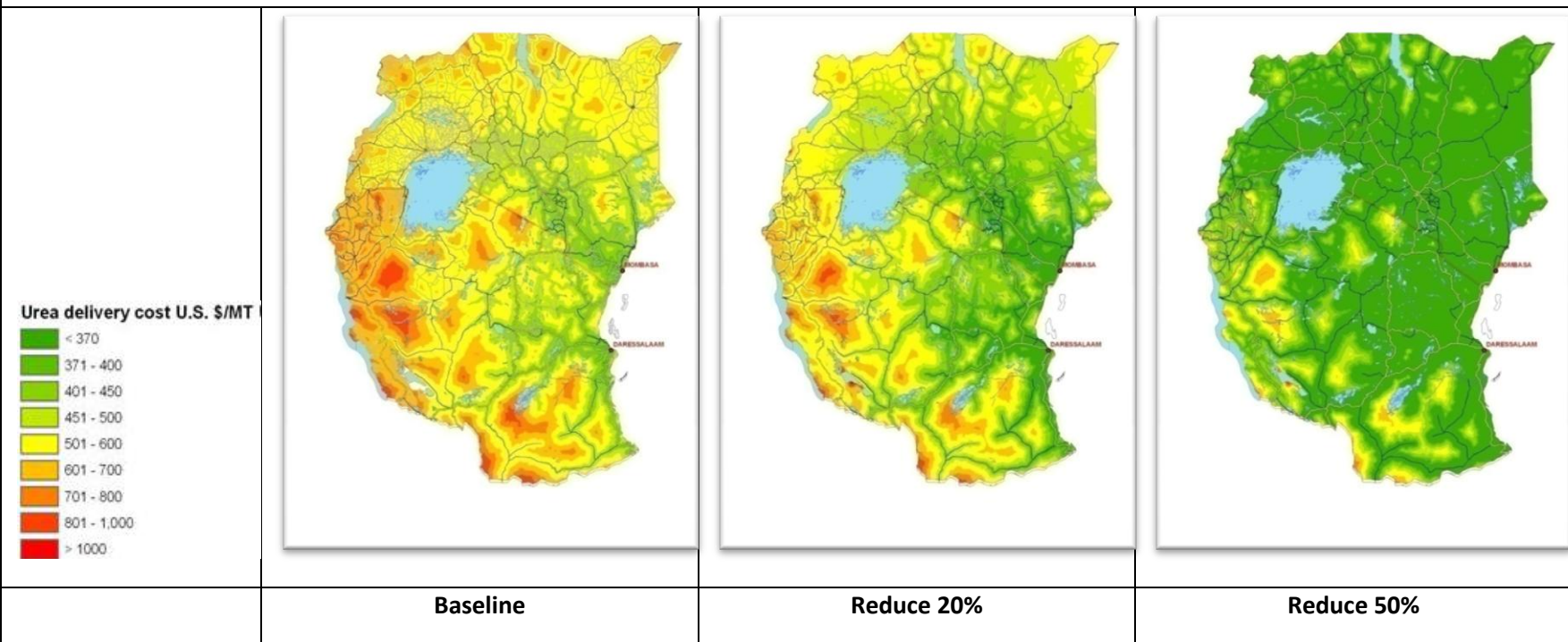
Scenario 2 : Reduce road transport costs by 20 and 50%



Scenario 3 : Reduce border crossing costs by 20 and 50%



Scenario 4 : Combination of all 3 scenarios

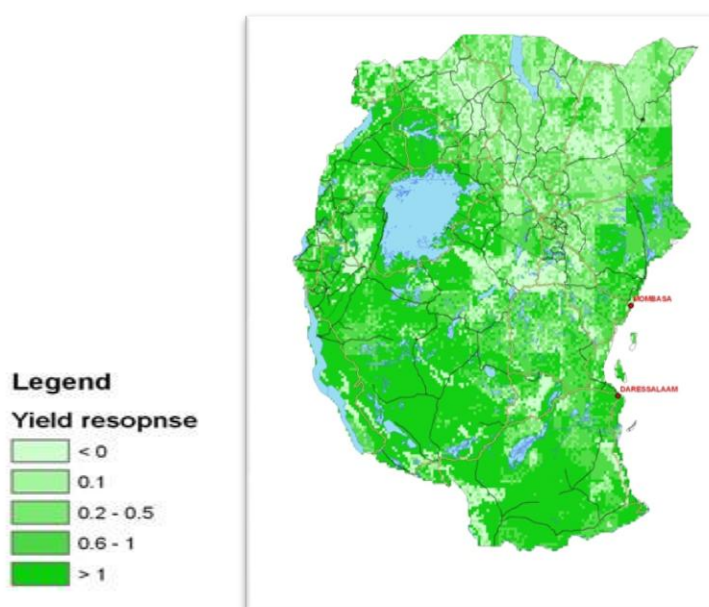


As shown in the maps, urea unit price could drop dramatically if price at port could be cut by 20% or 50%. The decrease of the unit price is relatively happened in a broad scale regardless the distance to the ports. In scenario 2, when road transport cost decreased which means better road quality and road services, less transport taxes, the urea price also drops but it is more concentrate at the place have better road networks and high accessibility. The urea price at or close to roads have large effects than the pixels that are far away from it. In Scenario 3, while border crossing cost reduced, it has biggest impacts on Rwanda than any other countries. There are no effects to Kenya and Tanzania because fertilizer is transported at their own ports. In scenarios 4, which is the adding-ups of all 3 scenarios of course, has the strongest decrease as to urea price. Even though reducing costs apparently lower the urea price but it does not mean all the locations will have reasonable prices. It is clearly displayed that there are spatial discrepancies among locations. Places that have better accessibility are the pro-locations to the strategy changes but locations such as western Tanzania, Northern Uganda have fewer benefits from the strategy changes. Further analysis is discussed in the next section.

4. Maize price disaggregation

With the cost side disaggregated, the benefit side needs to be aggregated also. As discussed in the introduction part, maize, a typical staple crop in Africa consume about half of the fertilizer regularly are used in this prototype research. First of all, the question that how much gain can be obtained after urea applications needs to be answered. Secondly, market maize price need to be collected and calculated. Finally, the farm-gate maize price can be calculated.

DSSAT crop growth model brings us a unique and powerful tool to simulate crop production at different N level applications. Keeping all other biophysical variables the same, N levels at 0, 5, 10, 15, 20,, 50 kg/Ha are applied to DSSAT model. Then, simulated maize productions at each N level are generated after evaluations. Yield response can be calculated as the difference between production at baseline and production at various N levels. One of the results is displayed as below.

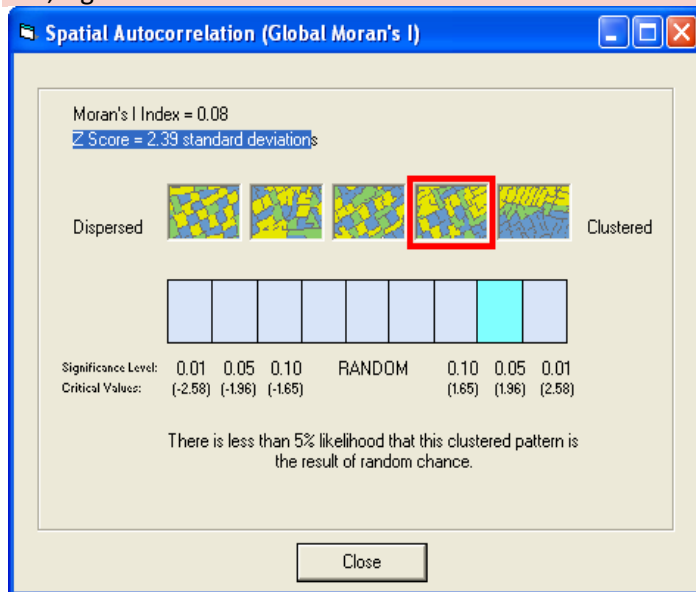


Yield response at 35kg/Ha N application

In order to calculate maize price at pixel level, the maize flow need to be determined first. Presumably, in order to get benefit from maize production gain, maize needs to be transport to the closest market and traded in the market. Forty major cities with population greater than 20,000 are identified and located as major trade market cities. Major cities maize prices are collected from RATIN (Regional Agricultural Trade Intelligence Network) website monthly and then aggregated to year datasets. Cross correlation methods are used to fill in the missing price for certain months. Because maize price are considered relatively depends on relative distance between markets in the same country, spatial auto-correlation weighted with road network method is applied to evaluate the accuracy of the estimation from correlation statistics. The high global moran's I value (Z score =2.39) assure that the estimation are closed enough to the real value. The maize price is displayed in the table below with the results of Moran test.

Market, Country	Price (USD/t)		
	2004	2006	2008
Migori, Kenya	219	224	396
Kitale, Kenya	153	153	271
Eldoret, Kenya	207	191	310
Nakuru, Kenya	219	170	267
Nairobi, Kenya	219	225	294
Kisumu, Kenya	224	224	395
Mombasa, Kenya	211	217	291
Kitui, Kenya	245	221	348
Busia, Kenya	138	169	266
Kigali, Rwanda	184	270	284
Ruhengeri, Rwanda	191	240	260
Dar es Salaam, Tanzania	165	188	307

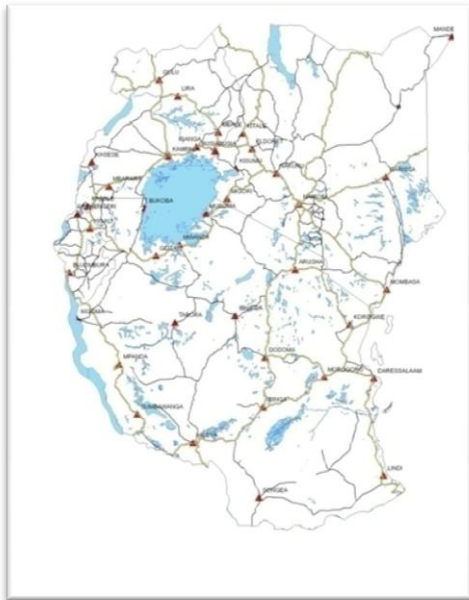
Arusha, Tanzania	188	157	277
Mbeya, Tanzania	114	147	232
Mwanza, Tanzania	187	205	260
Songea, Tanzania	109	154	225
Sumbawanga, Tanzania	118	134	212
Tanga, Tanzania	176	196	246
Bukoba, Tanzania	206	219	278
Iganga, Uganda	133	155	252
Kabale, Uganda	168	176	238
Kampala, Uganda	172	182	245
Kasese, Uganda	153	181	201
masindi, Uganda	150	152	205
Mbale, Uganda	165	160	303
Lira, Uganda	151	171	254



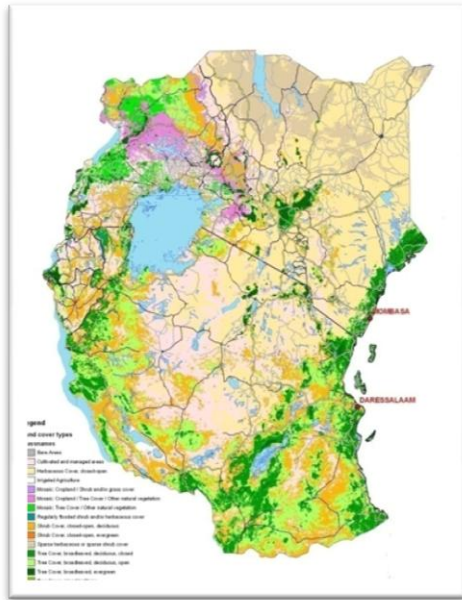
It is reasonable to believe that maize tends to transport to market with the highest trading price and at the same time has lowest transport costs. Using ArcGIS spatial analysis extension, market sheds is developed. Within each market shed, maximum economic margins can be obtained when transporting maize from farm-gate to the corresponding marked city. In each market shed, similarly to urea price disaggregation, pixel level maize price has been developed. There are two points need to be pointed out here. First, unlike urea transport only from Mombasa or Dar Es Salaam to farm-gates , the destination of the maize transportation is 40 cities. Maize at farm-gate is transport to one of the 40 cities listed above. Second, because maize is transported from the farm-gate to the local market cities, the following equation is applied to calculated pixel level maize price at farm-gate.

$$P_{ai} = P_{ac} - C_{ait}$$

Where P_{ai} is maize price of pixel i in market a ; P_{ac} is the maize price of the city a ; C_{ait} is the total transport costs from the pixel i to city a



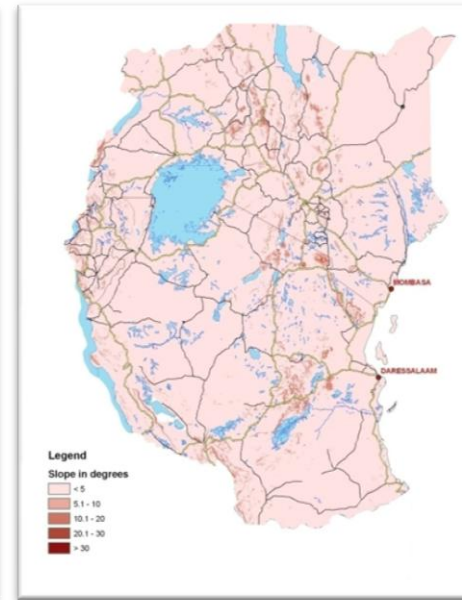
40 markets and road networks



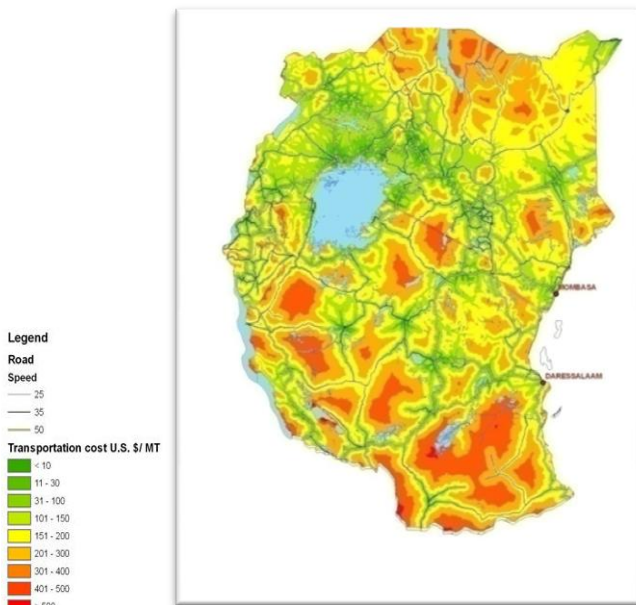
Land cover types



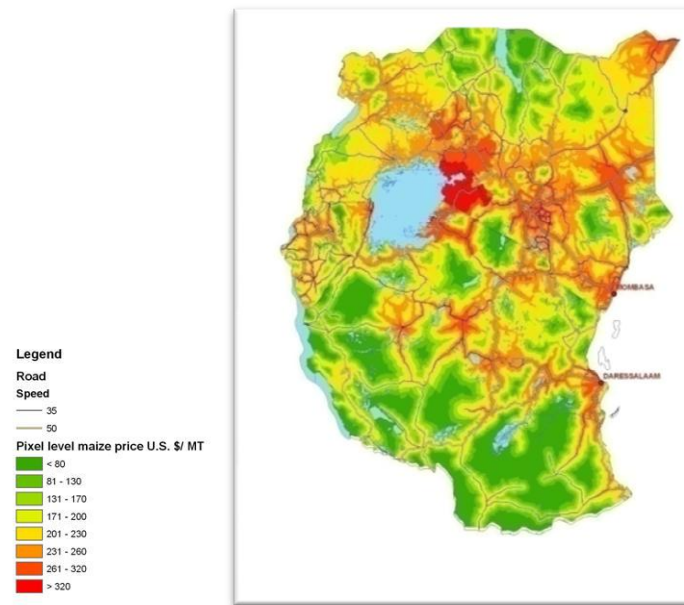
40 market sheds



Slopes



Maize transport cost from farm-gate to target market



Net maize farm-gate price

5. Value cost ratio at pixel level

Since unit urea price and unit maize price at pixel level has been calculated. It is quite straight forward to calculation value cost ratio (VCR). VCR is commonly used when detail information are not available to the economists. IFDC suggests VCR >4 to accommodate price and climatic risks and still provide an incentive to farmers. The VCR is calculated as below:

$$VCR_{x,y} = \frac{\Delta Y(N)_{x,y} * MPrice_{x,y}}{N * Fprice_{x,y}}$$

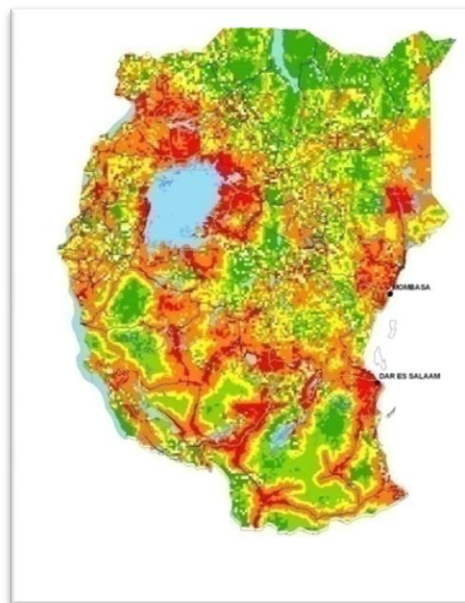
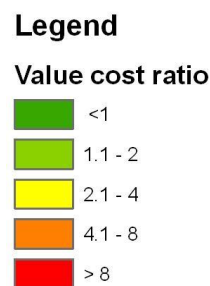
Where N= N application rate (kg/ha) (0, 5,10 ... 45, 50 kg/ha)

Y(N) = maize yield response with fertilizer at N rate (kg/ha)

Mprice = maize price at pixel x,y

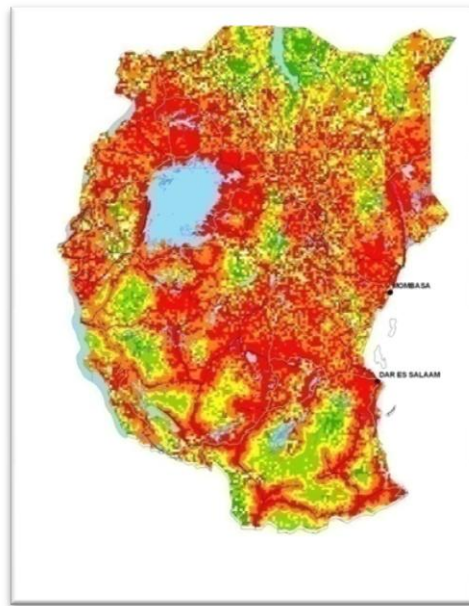
F price = Urea price at pixel x, y

One of VCR map is displayed as below:



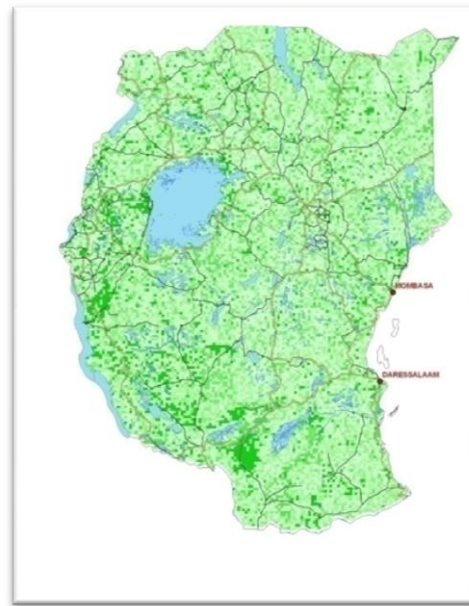
VCR value with 35kg N application

Correspondingly, maximum VCR is defined as Max of VCR of different level urea application and optimal urea amount is equal to the urea application levels that achieving maximum VCR in each pixel. The results is display in the below maps.



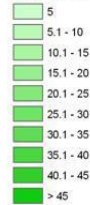
Legend

Value cost ratio



Legend

Optimal N amount kg/ha



Max VCR among N use of 5-50 kg/ha

Optimal N amount kg/ha

Conclusion

This paper is set out to examine disaggregated transport costs using GIS tools with limited resources. With the help of spatial analysis programs, transport costs could be simulated and disaggregated into pixels. Based on constructed transport costs surface, urea price at pixel level is calculated with the consideration of port regulation fee, handling fees et.al. Similar ideas are applied to disaggregate maize price into pixel level. The transport cost simulation program provide not only a chance to examine the spatial distribution of commodity prices but also an possible tool to develop further strategy, policy and economic analysis which use to be investigated at administration level such as sub-national or district level without considering spatial variations. By simulated differently policy and strategy application, it could be used to help us understand the possible impacts to a feasible policy application. More importantly, because the simulation is based on limited input resources, it would be possible to extend the research scales to a larger area at less cost.

Based on the transport cost surface, five strategy scenarios of farm-gate urea price surfaces are established. The impacts among scenarios are examined. Scenario 1 which is reducing landed urea price by 20% and 50% reduces urea price in every single pixels across all five countries.

Scenario 2 that reducing road transport cost by 20% and 50% has stronger impacts on high accessible regions compared to the region with less accessibility. Scenario 3 which is reducing border crossing cost will lower the urea price in Uganda, Burundi and Rwanda but has no impacts to Tanzania and Kenya. Scenario 4 which is the combination of the three have the strongest impact on reducing farm-gate urea price even though some remote area such as north-west Kenya or western Tanzania still keep high urea prices. Table below demonstrates the different urea prices by the categories of market accessibility. It demonstrates that landlocked countries have higher fertilizer prices. Higher accessibility, lower urea price is also clearly shown in the table.

Average farm-gate urea prices (2005 US\$/Ton)

Country	Market Access			
	High	Med	Low	Total
Burundi	659	684	693	679
Kenya	458	486	522	490
Rwanda	647	675	699	677
Tanzania	526	552	622	569
Uganda	553	577	613	585
Total	542	566	610	575

Farm-gate maize price is also estimated using similar strategy. Farm-gate maize price is simulated with the knowledge of monthly maize trading price in 40 cities together with transport costs in the market sheds. The country aggregation maize price is demonstrated below.

Average farm-gate maize prices (2008 US\$/Ton)

Country	Market Access			
	High	Med	Low	Total
Burundi	234	200	185	206
Kenya	288	238	182	233
Rwanda	236	209	178	204

Tanzania	245	214	128	193
Uganda	244	202	168	200
Total	255	216	164	209

Unlike urea price, maize prices are lower in landlocked countries. The higher accessibility, higher farm-gate maize prices because it cost less to transport farm-gate maize to local market.

With unit urea price (cost) and unit maize price (value) established, it is possible to involve fertilizer profitability analysis if we could estimate yield response to unit fertilizer. Crop growth model provides support to estimate yield response to different fertilizer applications. DSSAT crop growth simulation model which is a biophysical crop growth model can simulate crop growth as well as crop response to certain variable(s). Disaggregated urea and maize price along with yield response is used to generate disaggregated VCRs. Below are the VCRs when 35 kg N/ha fertilizer is applied.

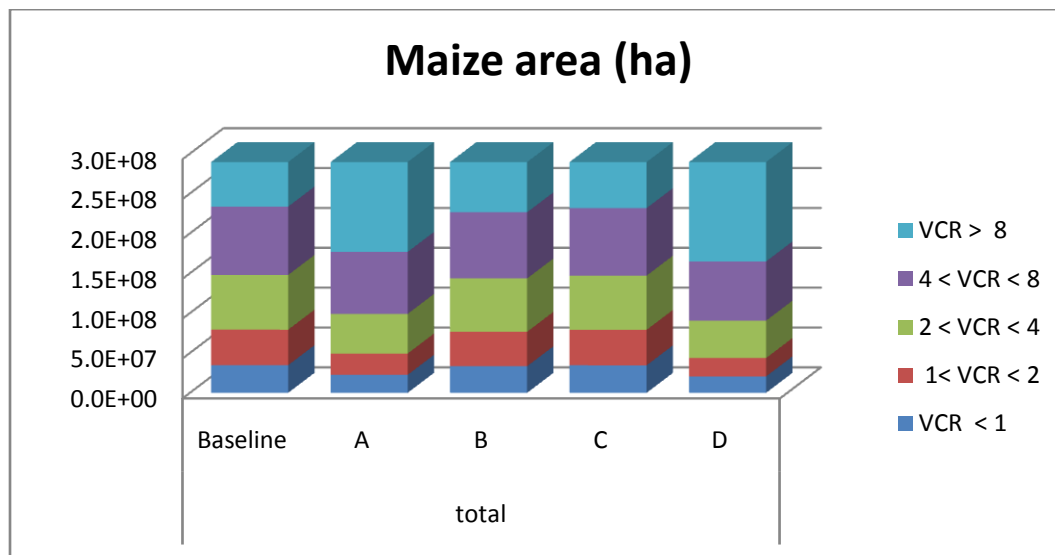
Value-cost ratio with 35 kg N/Ha application)

Country	Market Access			
	High	Med	Low	Total
Burundi	2.5	2	2	2.25
Kenya	2.75	2.25	1.5	2.25
Rwanda	2	1.5	1.5	1.75
Tanzania	3.25	2.75	1.25	2.5
Uganda	3	2	1.75	2
Total	2.75	2.25	1.5	2.25

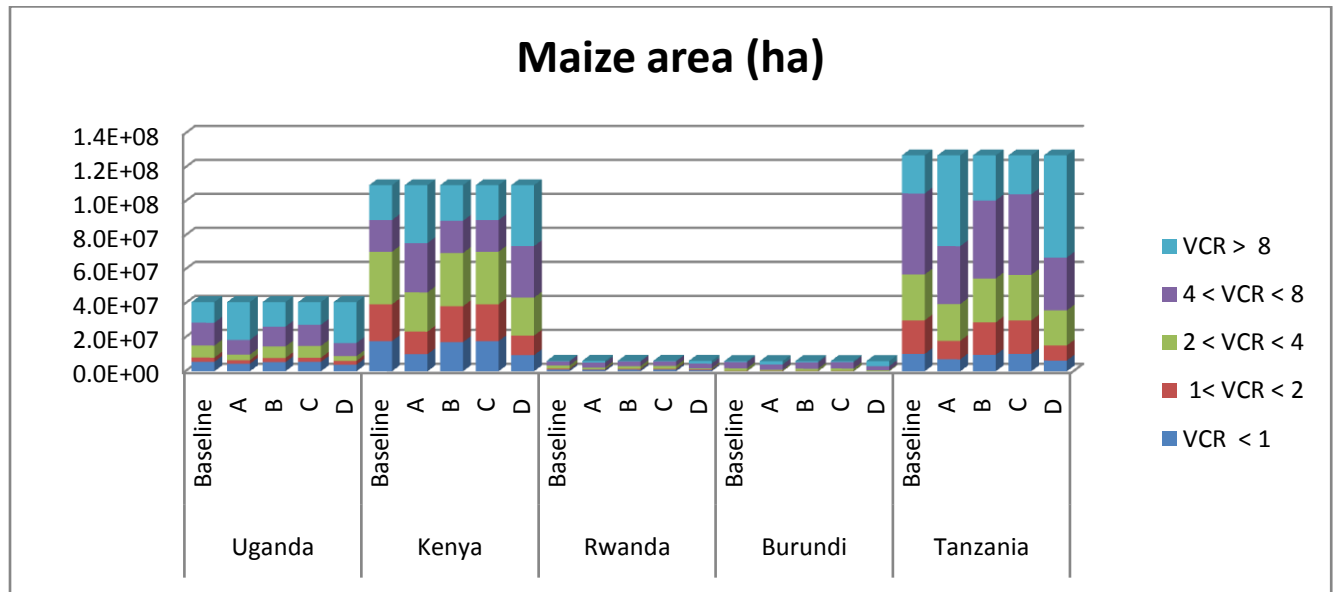
Low accessibility has lower VCRs which is make sense since the costs to apply fertilizer is higher in remote area. Also landlocked countries are less attractive to increase fertilizer use if there are no effective strategies to encourage farmers. Farmers in high accessible regions have high incentives to apply fertilizers because the profits are higher compared to these of low accessible area.

To examine the impacts of different strategies on fertilizer profitability, the changes of VCRs in area calculated through five scenarios (baseline, A: decreasing port urea price by 20%, B: decreasing road transport cost by 20%, C: decreasing boarding crossing cost by 50%, D: combination of all three) and compared among countries. With policies that could lower transport costs or fertilizer price, the area with High VCRs values would increase which means that farmers would have higher incentives to apply fertilizer because of higher profit. Five scenarios have been investigated including one baseline scenario.

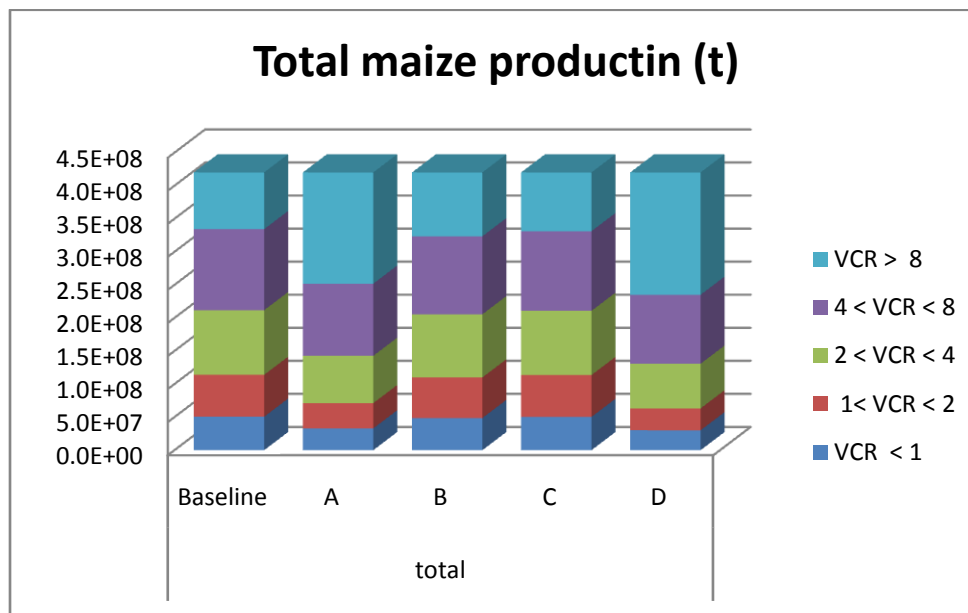
Disaggregated VCRs also provide an opportunity to investigate the impacts of different strategies scenarios in each of the country. With fertilizer/N application (the N =35kg/Ha in this case) unchanged, A, B, C, and D scenarios are generally pro-fertilizer application comparing to Baseline because all the four strategies changes make the farm-gate fertilizer price drop and VCRs values increase. The impacts of the strategies behave variously through countries. Suggested by IFDC, VCR value above 4 is considered as favorable land for fertilizer application. Take harvest area for example, in Uganda, if landed urea price drop by 50%, the area with VCR value < 4 will be decreased by 35.4% and area with VCR > 4 will increase by 20.7% compared to the baseline scenarios. In scenario B, area with VCR > 4 only increase 2.15% but it does not mean that the impact of the road network is low because if we look closely, the area with VCR > 8 increases by 19%. It explained that the area with VCRs > 4 has a large proportion (40%) in the baseline scenario. The road networks with increasing only 20%, has a relatively strong impacts on VCRs. The border crossing has 3% impacts in area when we assume that the processing time is only one day. If we take delays into account (usually, it took 15-30 days to cross country borders), the border crossing cost would increase dramatically. In Rwanda, scenario B almost doubles the area with VCR > 4. Scenario C also has 15.8% increase in area with VCR > 4. It demonstrates that improvement of road network would encourage farmer to purchase fertilizers. The border crossing has stronger impacts of 10% increase in area with VCR > 4 because in order to transport fertilizer to Rwanda, two countries need to be passed. The changes of the total VCRs area through 5 countries are displayed in the figure below.

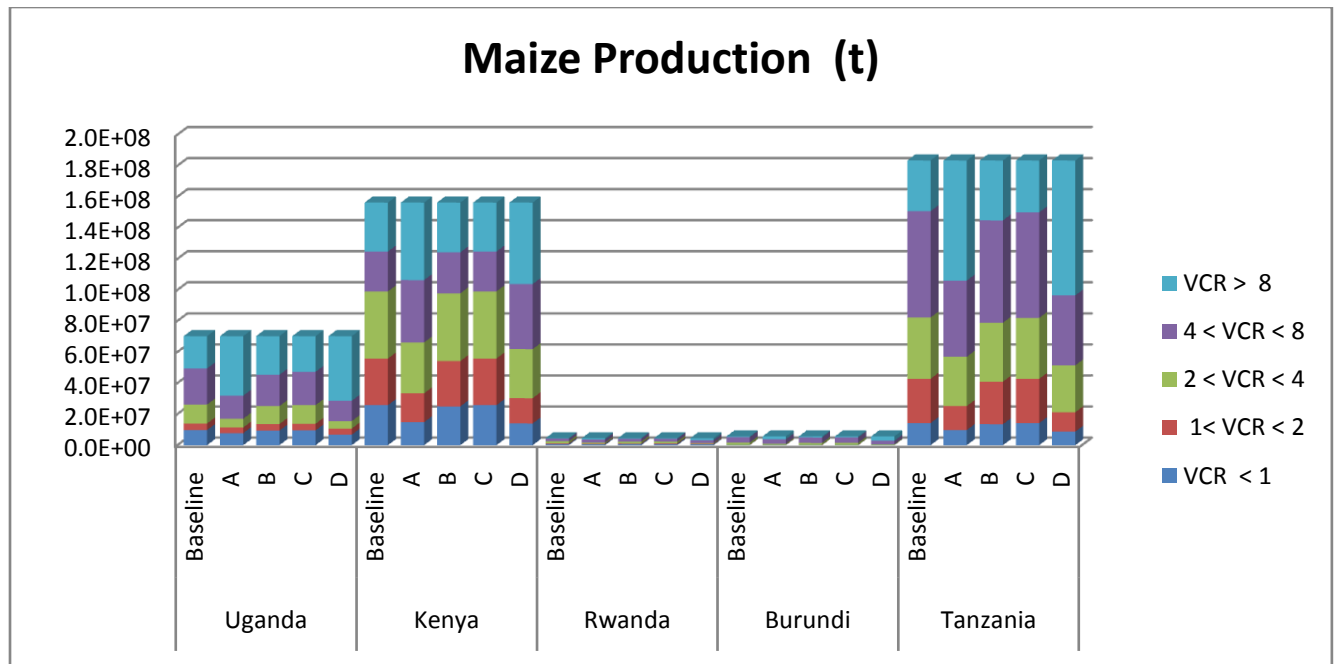


The impacts of the scenarios in each individual country are also displayed in the chart below. As explained above, even though all the 4 scenarios are pro-fertilizer application, scenarios behave differently from country to country. Even with in the country, the fertilizer profitability has various spatial distributions.



Impacts in different scenarios also investigated. The patterns are similar to area. In general, scenario A has the strong impacts on VCRs in maize production. Scenario B varies in countries. To countries have high road density, the impacts is bigger. Scenario C has no impacts on Kenya and Tanzania but relative strong impact on Rwanda, Burundi and Uganda. Of course, Scenarios D which is the combination of the all four has the strongest influence. The overall impacts of the scenarios are displayed as below with the impacts to individual country followed.





To summarize, this research provides a prototype to disaggregate and simulate transport costs, farm-gate fertilizer price, maize price and VCRs in pixel level units with the help of GIS spatial analysis model. The method can be used to capture the spatial variations among economic variables such as prices and profitability. The method also can be applied to simulate strategies impacts to local farmers. It can be used to examine the potential impacts of the policies and strategies applications. Eventually it could be used to help policy makers to evaluate policies before enforce them and help them to design efficient policy to encourage farmers to use fertilizers and hence increase crop productions. Similar to other models, data quality and availability is critical to the outputs but at least there is a possibility to apply this method in a relative large scale in the future. The model also has high potential to be expanded with detail local information and data. With the data quality and quantity improved, it is more likely that the method would have a broader application in both spatially and temporally.

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