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MDG Hunger Target: Analysis of Cereal Production System and the Evaluation of Cereal Production Potential in Africa

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Abstract

The contradiction between Africa's GDP growth and poverty has raised much debate in the scientific community, which casts much doubt on Africa's prospect in achieving MDG (Millenium Development Goals) hunger target. To better tackle this issue, we resort to grey system theory for solution. Firstly, by grey relational analysis (GRA), we aim to find out the relationship between the population undernourished (PU, the major index of MDG hunger target), and cereal production (CP). Then we establish a grey system composed of 8 factors, to identify the major ones in affecting cereal production. Through GRA and grey prediction model GM(1,1), the grey relations between each set of 2 factors out of the 8, as mentioned above, are analyzed and predicted. Next, we evaluate the short-term performance of Africa in reaching MDG hunger target by utilizing GM(1,1) as well. Finally, long-term continental and national cereal productions are forecasted by GM(1,1) from 2021 to 2051, based on data 1961-2011, which can serve as a signifier for Africa's CPP (cereal production prediction) and the corresponding potential in cutting down PU in the long run. The results from this study suggest that PU and CP are related so that we could cut down PU by promoting CPP, that different factors is likely to show different extents of projected relativeness with cereal production in the future, and that the national disparities of cereal production in Africa are inclined to rise, although the majority of African countries may be able to enjoy a remarkable boost in cereal production prediction. Most importantly, 38% of Africa countries show encouraging signs in achieving MDG hunger target on the national level, indicating that we need to be very cautious in believing in Africa's ability of achieving it on the whole continent. Finally, several methods and suggestions in eradicating hunger and promoting cereal production are come up with.

Keywords: cereal production, population undernourished, MDG hunger target, grey system theory, Africa

1. Introduction

The Millenium Development Goals were mapped out in September 2000, aiming at solving wide-ranging global social, economic, and environmental issues, among which agriculture and hunger eradication have taken their rightful places as one of the top priorities on this international agenda (FAO, 2012). Factually, several authors either opine their concerns about the accuracy and reliability of the MDGs' design, or harbor quite pessimistic opinions about achieving these seemingly out-of-reach targets (Gunter et al., 2008; Konotey-Ahulu, 2008; Liu et al., 2008; Easterly, 2009; Wakabi, 2010; Ogujiuba & Jumare, 2012; Fukuda-Parr et al., 2013). Despite all of these different voices, researchers from FAO still remain optimistic and reassure us that the new estimates show that progress in reducing hunger during the past 20 years has been better than previously believed, and that, given renewed efforts, it may be possible to reach the MDG hunger target at the global level by 2015 (FAO et al., 2012).

However, FAO researchers' encouraging assertion cannot keep us from wondering how well this claim applies to Africa, since it has earned a world-renowned reputation as a starving continent for quite a while, and is just underway in trying to promote crop production, feed the poor, and alleviate the rampant hunger (Lana, 1992; Lamb, 2000; Maredia et al., 2000; Buerkert et al., 2001; Scanlan, 2004; Misselhorn, 2005; Love et al., 2006; del Ninno et al., 2007; Valente, 2009; Misselhorn et al., 2012). One lesson that we have learned from prior legends in alleviating poverty like China is that investment in agriculture, more so than that in other sectors, can bear economic growth fruits that channels more benefits to the poor, hungry and malnourished (FAO, 2012).

As to food security, it seems to have something in common with MDG hunger target in a sense, since both of them prioritize feeding the world and caring for the poor (see Figure 1, which is plotted with reference to the information on the webpage http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/). Undoubtedly, crop production, especially cereal production, matters a lot more than transnational crop trade or domestic crop stock in the chain of food supply, and is the very cornerstone for domestic food security to any country. Therefore, promoting crop production is one of the most effective ways of improving agricultural productivity, reducing poverty and especially eradicating hunger (Misselhorn, 2005; Misselhorn et al., 2012).

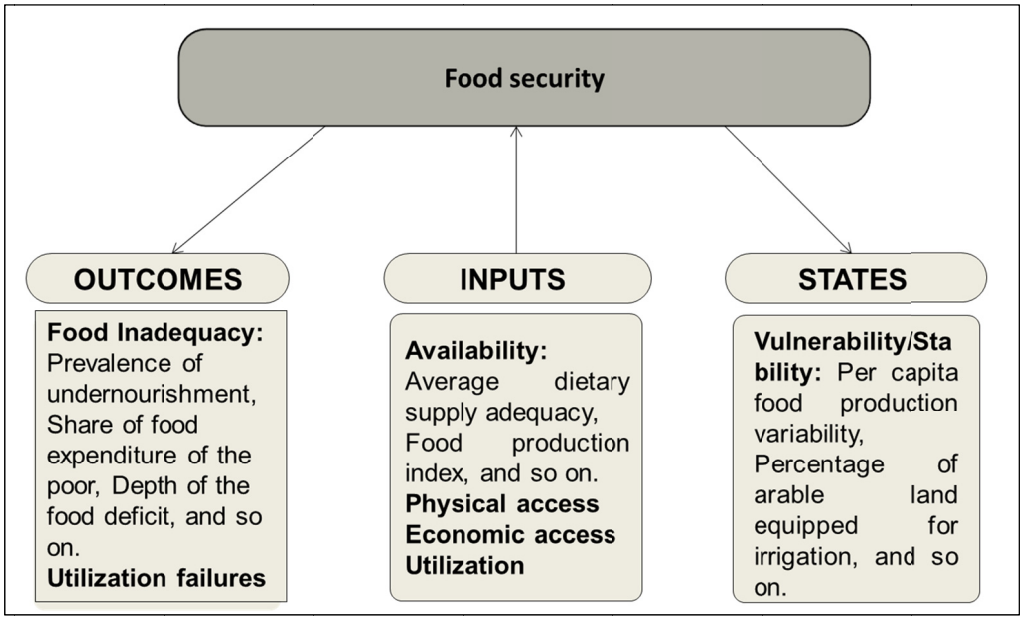

Figure 1. Food production and food security

In simple words, crop production is the process of growing and cultivating the crop, with its product harvested by humans at some point of its growth stage. Recently, a multitude of literatures have focused on exploring the role of water (Pachpute, 2010; Antwi-Agyei et al., 2012), land (Smaling & Dixon, 2006; Place, 2009; Petrick et al., 2012; Teka et al., 2013), fertilizer (Buerkert et al., 2001; Ladha et al., 2005), machinery (Akinola, 1987; Pingali, 2007) and labor (Chinedu, 1991; Frisvold & Ingram, 1995; Dorward, 2013) in African crop production. Besides, crop production models based on monitoring factors such as temperature change, rainfall variation and so on (Wright et al., 2002; Thitisaksakul et al., 2012; Worou et al., 2012) , have shown how vulnerable crop production is, and how important it is to improve the models (Wei et al., 2009; Xiong et al., 2010). That is to say, crop production is a system way too complex, where socio-economic, political, ecological as well as climatic elements each should take its fair share in the whole process. In other words, it is incredibly difficult to simulate and predict the behavior of this complex system, as what we have known seems to be quite minor, compared to what we do not know or know for sure.

Given that, we resort to grey system theory for solution, which is designed to describe this kind of complex systems (Deng, 1982; Yin, 2013). According to Deng (1982), color symbolizes the extent of knowledge and understanding of a system. It is defined that situations with no information at all are black, those with perfect information are white, and situations between these 2 extremes are described as being grey. Therefore, the grey system is a system whose information is partly known or known with uncertainty (Hao et al., 2006). More specifically, GRA (grey relational analysis) is proved to be very useful in identifying predominant factors in

complex social systems, and could act as the preliminary procedure towards other complicated decision-making process (Wu et al., 2012; Yin & Tang, 2013). In addition, grey prediction model GM(1,1) has gained worldwide reputation in many fields, due to its comparative simplicity and accuracy in modeling (Tien, 2005; Hao et al., 2006; Truong & Ahn, 2012; Yin & Tang, 2013). Grey prediction model can make predictions about future behaviors of systems with or without perfectly knowing their mathematical models. In grey system theory, GM(n,m) denotes a Grey model, where n, m are the order of the distance equation and the number of variables, among which the best-known one is GM(1,1), that is, first order, one variable (Truong & Ahn, 2012). Besides, it is assumed that all the data used in grey models are positive, and the sampling frequency of the time series is fixed, when doing with time series (Kayacan et al., 2010).

Therefore, to shed some light upon the prospect of Africa and the MDG hunger target, we establish a grey system composed of 8 factors including cereal production, cereal harvested area, cereal yield, arable land area, fertilizer consumption, agricultural tractors in use, irrigation coverage rate (the share of total area equipped for irrigation in arable land area), and total economically active population in agriculture. As with other important factors like herbicides and pesticides, we do not investigate in detail in this study due to the lack of data. Besides, we choose the population undernourished (percentage), as the main index for MDG hunger target, also for the sake of data availability and completeness. Simply put, our research primarily focuses on physical inputs in cereal production, with other significant climatic, technological, political, and ecological impacts being the background information and hopefully remaining to be further explored in the future.

In our grey system, major issues calling for this study are listed below. For instance, how significant is cereal production for MDG hunger target? What are the implications for any pair of these 8 factors? Especially, which one plays a relatively bigger part than others in affecting cereal production? By when and by how much do those impacts change? Where does it matter most? How will cereal production change in the future? What can we do to improve cereal production in Africa? Is the MDG hunger target reachable for Africa after all? And what's Africa's potential in producing cereals and wiping out hunger in the long run? The fact that much remains to be studied about the implications and prediction of those agricultural elements, and little is known by now, makes our study quite necessary in this respect, from our point of view. The next section explained the data and methods used in detail, followed by the corresponding results in section 3. And then, some essential discussion is presented in section 4, which mainly focuses on elaborating upon the conclusion of results.

2. Methodology

First, we try to find out the implications between the population undernourished (percentage), and cereal production. Then, the grey system of cereal production was analyzed, where hierarchies between the 8 factors are shown by Figure 2. Furthermore, with GRA and GM(1,1), implications between the 8 factors of the grey system are calculated, both continentally and nationally. Finally, forecast about the population undernourished (percentage) and cereal production prediction in 2015 is made. In the following, we will further specify those methodologies employed in this study one by one.

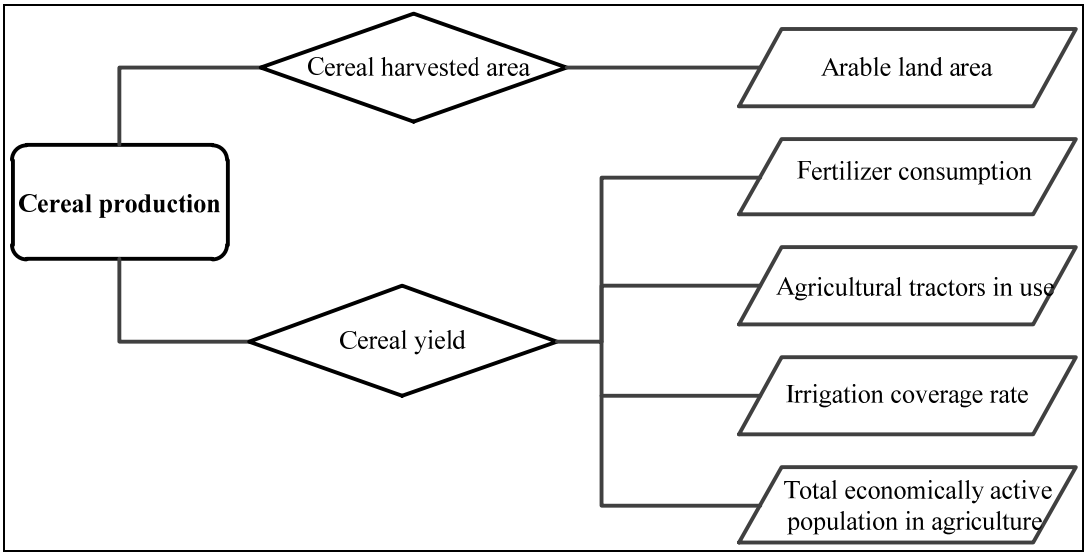

Figure 2. The grey system of cereal production

2.1 The Data

All the data used is from FAO's (http://faostat3.fao.org/) and UN's (http://mdgs.un.org/) online databases, and some necessary correction and replenishment is carried out when data appears to be inconsistent or missing, with reference to FAO's published yearbooks, that is, Statistical Yearbooks 2004-2013. To emphasize, we set different prediction steps when making long-term forecasts. For instance, prediction step of GRG (grey relational grade) between the 8 factors in the grey system is set at 7 since the available date set is between1980 and 2007, while that of cereal production is 10 as its data spans from 1961 to 2013. All these prediction steps are chosen after many an experiment, in order to make the most of available data and obtain the best prediction precision. Consequently, we get predictions at 2049 and 2051 accordingly, which can be rated as consistent in long-term predictions. However, our prediction step is set to be 1 when making short-term predictions, namely the population undernourished (percentage) and cereal production in 2015, with the available dataset extends from 1990 to 2012, also to get the most precise results.

Additionally, we rate cereal crops as the assemblage of barley, buckwheat, canary seed, fonio, maize, millet, oats, rice (paddy), rye, sorghum, triticale, wheat, and other cereals (nes.), in reference to the definition of FAO online database. Also, 53 African countries studied in this paper are listed alphabetically, namely, Algeria, Angola, Benin, Botswana, Burkina, Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Côte d Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea-Bissau, Guinea, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Réunion, Sao Tome and Principe, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Togo, Tunisia, Uganda, United Republic of Tanzania, Western, Sahara, Zambia, and Zimbabwe.

As with computing the grey relational grade (GRG) between the population undernourished (percentage) and cereal production, we mainly use the yearly data from 1990 to 2012 for African countries, and some exceptions include: (1) Democratic Republic of the Congo, Réunion, Somalia, and Western Sahara are not calculated for lack of data; (2) Eritrea's and Ethiopia's data are from 1993 to 2012.

When doing GRA for the grey system, the data of 8 factors in the whole African continent from 1980 to 2007 are used, including: (1) production of cereals, total, in tonnes; (2) area harvested of cereals, total, in ha; (3) yield of cereals, total, in hg/ha; (4) arable land area, in 1000 ha; (5) consumption of fertilizers from 1980 to 2002, total, in tonnes, and consumption in nutrients of fertilizers from 2002 to 2007, in tonnes of nutrients; (6) agricultural tractors, total, in use, in number; (7) total area equipped for irrigation, in 1000 ha; and (8) total economically active population in agriculture, in thousands.

As to predictions of GRGs by GM(1,1) between 2008 and 2049, GRGs of cereal production and other 7 factors in the whole African continent from 1980 to 2007 obtained through GRA are used.

Meanwhile, the long-term continental and national cereal productions in Africa by 2051 are forecasted by GM(1,1), based on annual cereal production data from 1961 to 2011, with some exceptions, including: (1) Djibouti's data dates from 1981 to 2011; (2) Eritrea's date is between 1993 and 2011; and (3) Ethiopia PDR's, and Ethiopia's data each spans from 1961-1992 to 1993-2011 respectively, owing to the changing hands of power mostly within the same sovereignty borders in 1990s. Accordingly, no prediction can be made if no data is available at all in the case of South Sudan, Saint Helena, Seychelles, and other territories alike. Furthermore, we choose the data in 1961, 1971, 1981, 1991, 2001, and 2011 as the standard input dataset in most cases, which enables us to make only 4-step predictions to obtain forecasts in 2051 and thus greatly improves the prediction precision. Other corresponding readjustments dealing with these exceptions are: (1) Djibouti's input data are annual cereal productions of 1981, 1991, 2001, and 2011; (2) Ethiopia's and Ethiopia PDR's data are combined together to create the standard input dataset; (3) Eritrea's data are from 1993 to 2011; and (4) Western Sahara's input dataset contains annual cereal productions of 1971, 1981, 1991, 2001 and 2011.

In addition, GM(1,1) is utilized as well when we try to evaluate the implications between Africa and the MDG hunger target in 2015, namely halving the proportion of people suffering from hunger by the standard of 1990. Here in this study, we try to approach this problem by making forecasts about the population undernourished (percentage) and cereal production in 2015 both continentally and nationally, with these of 1990 being the benchmark. More specifically, country data are chosen yearly from 1990 to 2012 in most cases, with 2 exceptions as both Eritrea's and Ethiopia's data are from 1993 to 2012.

2.2 GRA Modeling Methodology: Testing Relativeness and Identifying Key Implications

In this paper, we will use the methodology of GRA twice: one is to find out the relativeness of the population undernourished (percentage) and cereal production, and another is to identify the implications for any pair of 8 factors in the grey system. More specifically, the former is done by analyzing yearly data from 1990 to 2012, while the 8 factors' time series data is between 1980 and 2007, and split into 4 periods of the same length, that is, 1980-1986, 1987-1993, 1993-2000, and 2001-2007.

As the step-by-step algorithm of grey relational analysis has been comprehensively summarized in other relevant literatures (Lin et al., 2009), here we just elaborate a bit on the test of GRG (see Table 1).

Table 1. The test of GRG (grey relational grade)

Relational Level	1	2	3	4	5
GRG	0.90	0.80	0.70	0.60	less than 0.60
Implication	closest	closer	close	less close	least close

In addition, when and only when GRG is more than 0.6 do we rate the 2 objects studied as relevant and their GRG is significant in terms of GRA (Liu et al., 2010).

2.3 Grey Prediction Model-GM(1,1): Predicting Future Behaviors

Here in this paper, GM(1,1) will be utilized in 3 ways: the first one is the forecast of GRGs in the grey system, the second one is the short-term prediction of the population undernourished (percentage) and cereal production in order to make judgments about Africa's ability in achieving MDG hunger target, and the last one is the long-term project of cereal production, which highlights the analysis of Africa's potential in producing cereals and ultimately the possibility in alleviating hunger in the long run.

Table 2. The test of GM(1,1) based on -a and ARE

Criteria 1								
		-a≤-2	-2<-a≤0.3	0.3<-a≤0.5	0.5<-a≤0.8	0.8<-a≤1	1<-a<2	-a≥2
	Precision level	6	1	2	3	4	5	6
	Model precision	nonsensical	more than 90%	more than 80%	between 70% and 80%	less than 70%	less than 40%	nonsensical
	Advisable prediction steps	nonsensical	10	10	5	1	0	nonsensical
	Suggestion	quit	applicable to middle and long-term prediction	applicable to short-term prediction	be cautious	residual modification model	not recommended	quit

Criteria 2					
	Precision level	1	2	3	4
	ARE	0.01	0.06	0.10	0.20

The detailed procedure of GM(1,1) has been detailed in other relevant research (Tien, 2005; Wu & Chen, 2005; Kayacan et al., 2010; Truong & Ahn, 2012; Yin & Tang, 2013). So here we only present 2 criteria for testing the model precision of GM(1,1): one is -a (the development coefficient in the model), and the other is the average relative error (ARE) (see Table 2), citing Liu et al. (2010).

In general, ARE is more frequently-used than -a in identifying the precision level due to its simplicity, whereas the latter appears to be more explicit. For instance, all seems to boil down into "the less the value the better" for ARE. But it still remains a little ambiguous when ARE > 0.20, for we cannot decide for sure whether the

prediction model is reliable or not. Therefore, we will combine the 2 criteria when making the judgment in this paper, in order to avoid any fogginess and uncertainty.

3. Results

3.1 The Test of Relativeness Between PU and CP

First, we need to dig out the relativeness of the population undernourished, percentage (PU) and cereal production (CP), so that we can be certain that promoting CP is the sure way to achieve the MDG hunger target. When we set the distinguishing coefficient as 0.5, we get the GRGs of 49 African countries, as shown in Table 3.

Table 3. The GRGs of 49 African countries from 1990 to 2012

Country	PU& CP	Country	PU& CP	Country	PU& CP	Country	PU& CP	Country	PU& CP
Algeria	0.60	Comoros	0.67	Guinea	0.67	Mauritius	0.52	South Africa	0.64
Angola	0.63	Congo	0.58	Guinea-Bissau	0.70	Morocco	0.59	Sudan (former)	0.49
Benin	0.57	Cote d'Ivoire	0.57	Kenya	0.69	Mozambique	0.60	Swaziland	0.60
Botswana	0.59	Djibouti	0.57	Lesotho	0.55	Namibia	0.63	Togo	0.58
Burkina Faso	0.53	Egypt	0.52	Liberia	0.60	Niger	0.65	Tunisia	0.57
Burundi	0.50	Eritrea	0.71	Libya	0.54	Nigeria	0.48	Uganda	0.68
Cameroon	0.62	Ethiopia	0.64	Madagascar	0.55	Rwanda	0.72	United Republic of Tanzania	0.57
Cape Verde	0.75	Gabon	0.52	Malawi	0.59	Sao Tome and Principe	0.53	Zambia	0.64
Central African Republic	0.60	Gambia	0.71	Mali	0.68	Senegal	0.68	Zimbabwe	0.66
Chad	0.64	Ghana	0.49	Mauritania	0.57	Sierra Leone	0.73	Country Average	0.61

Obviously, PU and CP are related on average in terms of GRGs from 1990 to 2012 in Africa on the whole, with the country average being 0.61. Therefore, what we need now is to further investigate on cereal production and its grey system.

3.2 The Identification of Key Factors and the Projection of the Cereal Production System

To better understand the changing pattern of the implications between factors in the cereal production system, we divide the 1980-2007 data into 4 interims of 7-year steps, namely, 1980-1986, 1987-1993, 1993-2000, and 2001-2007, and denote their grey relational grade matrixes each as R^1, R^2, R^3, and R^4 respectively.

Following the above GRA (grey relational analysis) procedures, we get the matrixes as shown below, when we set the distinguishing coefficient as 0.5.

$$R^1 = \begin{bmatrix} 1 & 0.71 & 0.72 & 0.61 & 0.64 & 0.67 & 0.60 & 0.61 \\ 0.68 & 1 & 0.52 & 0.71 & 0.70 & 0.69 & 0.68 & 0.66 \\ 0.73 & 0.57 & 1 & 0.73 & 0.69 & 0.58 & 0.69 & 0.61 \\ 0.60 & 0.72 & 0.71 & 1 & 0.69 & 0.61 & 0.82 & 0.67 \\ 0.62 & 0.70 & 0.64 & 0.68 & 1 & 0.71 & 0.74 & 0.81 \\ 0.69 & 0.74 & 0.58 & 0.65 & 0.76 & 1 & 0.72 & 0.86 \\ 0.56 & 0.67 & 0.63 & 0.80 & 0.73 & 0.66 & 1 & 0.75 \\ 0.62 & 0.70 & 0.60 & 0.69 & 0.83 & 0.85 & 0.79 & 1 \end{bmatrix} \quad (1)$$

$$R^2 = \begin{bmatrix} 1 & 0.65 & 0.63 & 0.60 & 0.58 & 0.58 & 0.64 & 0.65 \\ 0.61 & 1 & 0.74 & 0.69 & 0.70 & 0.67 & 0.73 & 0.84 \\ 0.59 & 0.74 & 1 & 0.67 & 0.69 & 0.68 & 0.66 & 0.70 \\ 0.58 & 0.70 & 0.68 & 1 & 0.84 & 0.92 & 0.93 & 0.77 \\ 0.58 & 0.74 & 0.73 & 0.85 & 1 & 0.84 & 0.85 & 0.74 \\ 0.54 & 0.67 & 0.69 & 0.92 & 0.82 & 1 & 0.86 & 0.73 \\ 0.61 & 0.74 & 0.67 & 0.93 & 0.83 & 0.87 & 1 & 0.81 \\ 0.58 & 0.82 & 0.67 & 0.73 & 0.68 & 0.70 & 0.77 & 1 \end{bmatrix} \quad (2)$$

$$R^3 = \begin{bmatrix} 1 & 0.70 & 0.79 & 0.71 & 0.55 & 0.64 & 0.70 & 0.56 \\ 0.72 & 1 & 0.73 & 0.77 & 0.54 & 0.83 & 0.78 & 0.64 \\ 0.75 & 0.66 & 1 & 0.70 & 0.54 & 0.59 & 0.70 & 0.54 \\ 0.69 & 0.72 & 0.71 & 1 & 0.57 & 0.70 & 0.83 & 0.68 \\ 0.59 & 0.55 & 0.63 & 0.64 & 1 & 0.57 & 0.59 & 0.81 \\ 0.67 & 0.83 & 0.67 & 0.76 & 0.57 & 1 & 0.78 & 0.64 \\ 0.69 & 0.74 & 0.72 & 0.84 & 0.53 & 0.73 & 1 & 0.61 \\ 0.57 & 0.62 & 0.61 & 0.72 & 0.79 & 0.61 & 0.65 & 1 \end{bmatrix} \quad (3)$$

$$R^4 = \begin{bmatrix} 1 & 0.80 & 0.70 & 0.70 & 0.78 & 0.58 & 0.58 & 0.73 \\ 0.73 & 1 & 0.75 & 0.75 & 0.80 & 0.57 & 0.57 & 0.79 \\ 0.59 & 0.73 & 1 & 0.81 & 0.64 & 0.62 & 0.61 & 0.83 \\ 0.60 & 0.73 & 0.81 & 1 & 0.65 & 0.60 & 0.61 & 0.91 \\ 0.74 & 0.82 & 0.70 & 0.70 & 1 & 0.52 & 0.52 & 0.75 \\ 0.58 & 0.65 & 0.72 & 0.71 & 0.58 & 1 & 0.93 & 0.69 \\ 0.57 & 0.64 & 0.72 & 0.71 & 0.57 & 0.93 & 1 & 0.69 \\ 0.61 & 0.77 & 0.83 & 0.90 & 0.69 & 0.57 & 0.57 & 1 \end{bmatrix} \quad (4)$$

As we try to explore the grey relational grades of cereal production in the future, the grey prediction model GM(1,1) comes into use for this purpose, and the results are shown in Table 4.

Here in the table, for instance, 0.01 means the grey prediction model of the GRG (grey relational grade) between CP (cereal production) and CHA (cereal harvested area) has a 0.01 ARE, falling into the category of the 1st precision level. The same also goes for the criterion of -a. Besides, it is self-evident that the grey relational grade of CP&CP will always be 1, so it is meaningless to evaluate the precision level of the prediction model. The GRGs of CP&CHA and CP&FC (fertilizer consumption) will gain the most momentum in the leap-up to 1, and this is especially true for CP&FC, which remains rather low-key before 2000. As for CP&ALA (arable land area) and CP&TEAPA (total economically active population in agriculture), they will experience a relatively similar and slow growth to 1, with CP&CY (cereal yield) lagging not too far behind. However, CP&ATU (agricultural tractors in use) and CP&ICR (irrigation coverage rate) are likely to decrease after 2007, ending up in rather inferior positions.

Table 4. The GRGs of cereal production from 1980 to 2049

Serial number	Period	CP&CP	CP&CHA	CP&CY	CP&ALA	CP&FC	CP&ATU	CP&ICR	CP&TEAPA
1	1980-1986	1	0.71	0.72	0.61	0.64	0.67	0.60	0.61
2	1987-1993	1	0.65	0.63	0.60	0.58	0.58	0.64	0.65
3	1994-2000	1	0.70	0.79	0.71	0.55	0.64	0.70	0.56
4	2001-2007	1	0.80	0.70	0.70	0.78	0.58	0.58	0.73
5	2008-2014	1	0.87	0.77	0.77	0.89	0.59	0.59	0.73
6	2015-2021	1	0.96	0.80	0.83	1	0.59	0.56	0.78
7	2022-2028	1	1	0.83	0.89		0.58	0.54	0.83
8	2029-2035	1		0.87	0.95		0.58	0.51	0.88
9	2036-2042	1		0.90	1		0.58	0.49	0.93
10	2043-2049	1		0.94			0.57	0.47	0.99
ARE			0.01	0.08	0.04	0.09	0.04	0.07	0.09
Precision level			1	3	2	3	2	3	3
-a			0.10	0.04	0.07	0.17	-0.01	-0.04	0.06
Precision level			1	1	1	1	1	1	1

3.3 The Short-Term Prediction of Africa in Achieving MDG Hunger Target

In appraising the implication of Africa and MDG hunger target in 2015, we set PU (the population undernourished, percentage) and CP (cereal production) of 1990 as the benchmark, and then readjust the GM(1,1) estimates accordingly. Figure 3 shows each country's performance in accomplishing MDG hunger target.

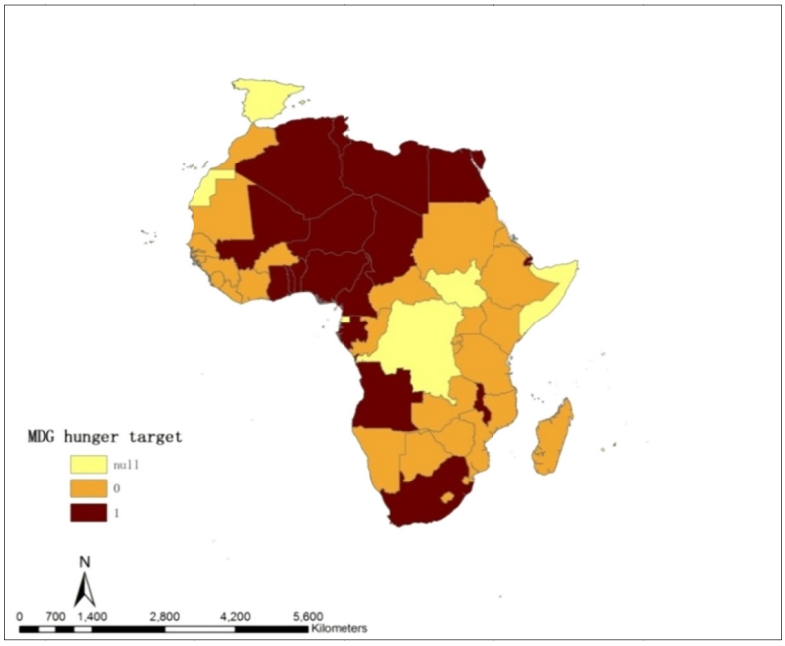

Figure 3. The prospect of Africa in achieving MDG hunger target in 2015

Given MDG hunger target of halving the proportion of people suffering from hunger by the standard of 1990, we make the criterion for the hunger target as a 50% decrease for PU, or a PU less than 5% (indicating the number of undernourished people is not statistically significant) by 2015. Consequently, we assign the value of 1 to a

particular country or region if it does meet the criterion, or else 0 is given if the opposite happens. But if there is no data for a particular country or region, "null" is given in that case.

Furthermore, we only need to make a 3-step prediction to get data of 2015, which can greatly improve the model precision (See Table 5). As with the short-term CPP in 2015 for African countries, the results are shown in Figure 4.

Table 5. Model summary of Africa MDG hunger target in 2015 by GM(1,1)

Country Level			Africa as a Whole				
	count	share (%)		2015	ratio of 1990	-a	ARE
0	31	62	PU (percentage)	21.5	0.77	-0.01	0.02
1	19	38	Precision level			1	2
-a of country average	-0.02	precision level 1	CP (tonnes)	1.82E+08	1.95	0.03	0.05
ARE of country average	0.07	precision level 3	Precision level			1	2

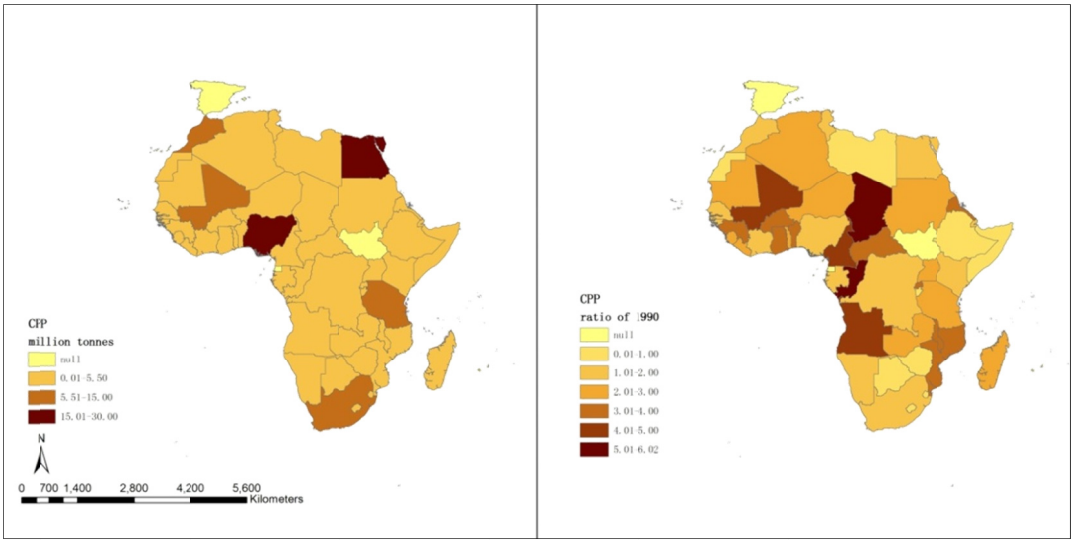

Figure 4. CPP in 2015 and its ratio of 1990 for African countries

3.4 The Long-Term Cereal Production Prediction on Both Continental and National Levels

Table 6. Observations and predictions of Africa's cereal production on the whole continent

Observations			Forecasts		
Year	CP (tonnes)	ratio of 2011	Year	CPP (tonnes)	ratio of 2011
1961	4.63E+07	0.29	2021	1.90E+08	1.21
1971	6.56E+07	0.42	2031	2.36E+08	1.50
1981	7.76E+07	0.49	2041	2.94E+08	1.87
1991	1.05E+08	0.67	2051	3.65E+08	2.32
2001	1.16E+08	0.74	-a	0.22	precision level 1
2011	1.57E+08	1.00	AVE	0.04	precision level 2

First, African cereal production prediction (CPP) is calculated, to investigate on the overall trend on the whole continent (see Table 6). And then, more detailed forecasts on the country level are carried out.

Finally, we get the prediction results of 48 African countries, with the average values of -a and ARE of these countries each being 0.23 and 0.19, by discarding 5 outlier cases of Cape Verde, Eritrea, Libya, Mauritius, and Sao Tome and Principe. But then again, we just present all the 53 countries' prediction results in Figure 3, for fear of leaving out any useful information, as even the results of these 5 outlier cases can give a hint of the tendency in the future, regardless of their precision levels.

In order to compare the cereal production potential among countries in Africa, we set each nation's cereal production in 2011 as the benchmark value, and each country's cereal production forecasting in 2021, 2031, 2041, and 2051 is reassigned as the ratio of its own cereal production in 2011. Furthermore, we turn to ArcGIS for better description of the spatio-temperal patterns, with regard to CPP in each African country (see Figure 5).

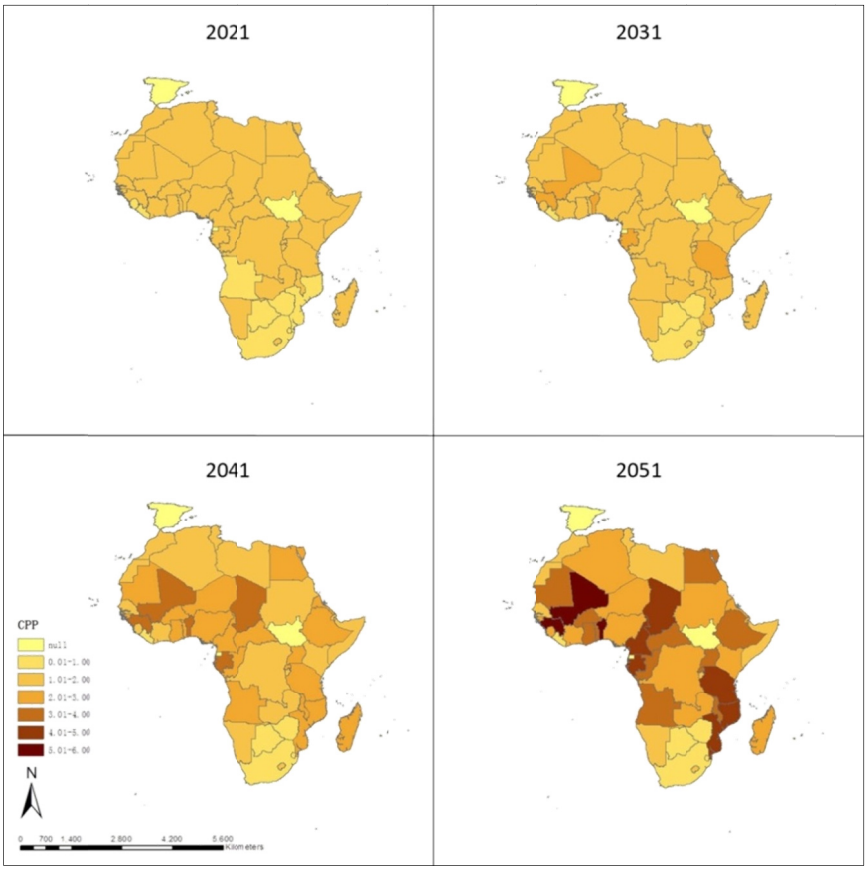

Figure 5. African countries' CPP

Particularly, Sudan will not be able to behave in accordance with its prediction, as it was split into Sudan and South Sudan in 2011. In other words, what the figure shows is the whole amount CPP of both Sudan and South Sudan after 2011, if both states could enjoy a favorable degree of regime stability in the future and suffer no dramatic social unrests that might drastically undermine agricultural production, especially cereal production.

4. Discussion

Above all, our investigation on the future trend of GRG (grey relational grade) based on time series GRA (grey relational analysis), and the evaluation of Africa performance in achieving MDG hunger target is creative work, based on all the efforts and innovations made by predecessors in this field, for which we deeply appreciate. Besides, our results show that most of the GRA and GM(1,1) processing is satisfactory and up to par, with just a few exceptions or outliers, admittedly. The following are some more specific analyses.

(1) In terms of GRA, the GRG of the population undernourished, percentage (PU) and cereal production (CP) is significant on the whole African continent. However, not all the countries' GRG between PU and CP are significant, for which we reckon that some disturbances like social unrest, economic slump, natural disaster and so on should take the blame.

(2) Based on the data analysis between 1980 and 2007, it seems to be an effective approach to promote fertilizer consumption and cereal harvested area in improving CP, as these 2 factors appear to matter the most in GRG and its prediction by GM(1,1), with arable land area, total economically active population in agriculture, and cereal yield closely following behind. However, agricultural tractors in use (ATU) and irrigation coverage rate (ICR) seemingly have less relationship with CP in comparison. To put it another way, Africa needs to pay more attention to ATU and ICR in the future, so as to fully explore its cereal production potential, although doing this may be less effective compared to promoting other factors (Table 4).

(3) Both short and long-term CPPs (cereal production prediction) remain generally encouraging, as Africa's CP (cereal production) is estimated to retain its previous growth rate, and climb to 182 and 365 million tonnes in 2015 and 2051 respectively, each standing at being 1.95 and 2.32 times of their benchmarks (Table 5 and 6).

Table 7. The top and the last 5 countries in terms of CP (tonnes), CPP (tonnes), and ratio of 2011

1961	CP	2011	CP	2051	CPP	2051	Ratio of 2011
The top 5							
Nigeria	7.89E+06	Nigeria	2.20E+07	Ethiopia	6.98E+07	Benin	5.93
South Africa	6.70E+06	Egypt	2.20E+07	Egypt	6.94E+07	Mali	5.54
Egypt	5.01E+06	Ethiopia	1.78E+07	Nigeria	6.25E+07	Guinea	5.07
Ethiopia	4.20E+06	South Africa	1.29E+07	Tanzania	3.36E+07	Gabon	4.78
Sudan (former)	1.68E+06	United Republic of Tanzania	7.78E+06	Mali	3.20E+07	Mozambique	4.72
The last 5							
Comoros	1.13E+04	Cape Verde	5.57E+03	Swaziland	2.93E+04	Liberia	0.88
Gabon	9.29E+03	Sao Tome and Principe	3.90E+03	Botswana	1.80E+04	South Africa	0.84
Congo	5.00E+03	Western Sahara	1.92E+03	Réunion	1.75E+04	Zimbabwe	0.68
Sao Tome and Principe	4.00E+02	Mauritius	3.20E+02	Western Sahara	2.79E+03	Swaziland	0.52
Mauritius	1.80E+02	Djibouti	1.40E+01	Djibouti	3.28E+01	Botswana	0.26

(4) However, national disparities of CP and CPP in Africa seem to be on the increase from 1961 to 2051 (Table 7). For instance, the gaps between the largest and smallest national CP and CPP, extend by 1.42E+07 from 1961 to 2011, and by 4.77E+07 from 2011 to 2051. More specifically, the largest CPP is predicted to be more than twice that of its smallest counterpart in 2051. However, 6 countries, including Liberia, South Africa, Mauritius (please note its prediction result is not so reliable like others), Zimbabwe, Swaziland, and Botswana, is possible to be faced with some slump in 2051's CPP, while the rest may be able to embrace various extent of ballooning by contrast (Figure 5). This rocketing regional disparity also indicates to pull the poorest of the poor out of the poverty trap might get increasingly difficult in the future.

(5) Seeing from the whole continent, Africa is estimated not to be able to achieve MDG hunger target, as its PU is projected to be 21.50% in 2015, larger than half of that in 1990. However, in the case of African countries, 38% are projected to be good performers by PU (see Figure 3 and Table 5).

Admittedly, there are some limitations that remain to be overcome in the future research, as shown below.

(1) Much fogginess might be alleviated, if we could find a way to improve the precision of grey prediction models. Besides, forecasting comparisons between different models or scenarios may also make a difference in refining prediction results (Fischer et al., 2007; Kang et al., 2009; van Vuuren et al., 2011; Tang & Yin, 2012; Truong & Ahn, 2012).

(2) Our cereal production system composed of 8 factors seems to be not so enough to fully reveal all the complex dynamics and mechanisms, regardless of the fact that grey system theory is well-suited to study complex systems even though a lot remains unknown. Therefore, further research, aiming at the incorporation of other socio-economic, technological, environmental, ecological, and political factors in the cereal production system, is well needed, and our commitment to the future work as well.

(3) Our study relies on the analysis of PU and CP for evaluating Africa's performance in achieving MDG hunger target, which might be not sufficient, even though some simplification in scientific research is necessary admittedly. Therefore, we plan to incorporate more factors like cereal stock, trade, processing and waste of the whole food supply chain in future studies.

If we look more closely at Africa's issues, the first thing comes into sight may be the contradiction between Africa's GDP growth and poverty occurrences, a subject of much debate in the global science circles. On the one hand, Africa has distinguished itself from other regions as one of the most fast-growing economy, especially after the World Financial Crisis in 2008. On the other hand, however, social development and poverty elimination are still dragged far behind. Poverty trap seems just too difficult to escape for some Africa countries, where high transport costs, tropical diseases such as malaria, adverse conditions for agriculture like dependency on rain fed agriculture in sub humid or arid regions, and poor records of pro-poor economic development have jeopardized food security for years (Sachs & Mcarthur, 2005). Unsurprisingly, the problem of underdevelopment is getting increasingly intractable in some regions. To put it another way, to benefit the poor by economic growth, countries in Africa must carry out development policies that may facilitate economic growth and poverty elimination simultaneously (FAO, 2012; FAO et al., 2012).

Social orders also matter a lot. Conflict ridden states are always confronted with governmental disruptions, social turmoil, and even devastating fiscal debts (Ikejiaku, 2009). For instance, hunger still lingers on countries like Egypt, Sudan and South Sudan, all of which are just like the hotchpotch for regional conflicts, worsening social order, and run-down infrastructures. In that sense, social expenditure may become inferior to other expenditures like military expenditure because of internal riots or regional confrontations (Stewart, 2003).

More importantly, climate change is playing an increasingly non-negligible role in cereal production (B. Chatterton & L. Chatterton, 1984; Kang et al., 2009; Thornton et al., 2009; Pachpute, 2010; Thornton et al., 2010; Antwi-Agyei et al., 2012). Similarly, it also holds true for other socio-economic, technological, and political factors (Brun & Bleiberg, 1980; Delgado & Miller, 1985; Adesina & Sanders, 1991; Boughton & Reardon, 1997; Scanlan, 2004; Misselhorn, 2005; Dorosh et al., 2009; Azadi & Ho, 2010; Bayala et al., 2012; Fraser et al., 2013). It is necessary to reveal the interrelationships and interactions of these cereal production actors, which may well contribute to the unusual intricacy and complexity of cereal production system technically, economically, socially, culturally and environmentally.

One solution is to increase the levels and the quality of investment in agriculture, which is central to achieving the MDGs, indicating we need to change our traditional investing ways. Clearly, increasing aid flows might make a difference in wiping out hunger and poverty in Africa, only on condition that corruption is well under control and funds are wisely managed. For instance, sustainable agriculture rests on good governance, stable macro-economic environments, efficient rural infrastructures, secure property rights and effective home and oversea markets so as to fully mobilize resources and cut down investment risks to the utmost extent, with a new emphasis on investment in protecting and enhancing the efficiency of natural resource use, and reducing waste at all stages of production, transportation, storage, processing, trade, and consumption (FAO, 2012; FAO et al., 2012).

Another approach is social safety network. It takes time for economic growth to reach the poor, and there is even a possibility that economic growth cannot find its way to the poorest of the poor. In this sense, social safety network or social protection is getting crucial in eliminating hunger. In addition, it can also facilitate economic growth by generating human capital and assisting farmers to cope with risks and even to adopt improved technologies, when designed appropriately (FAO, 2012).

Other ways like improving education, promoting science and technology, and population control can be quite effective as well. After all, rapid progress in reducing hunger requires sufficient food supply (for which cereal production is very important), easy access (indicating quick and efficient governmental actions to provide key

public goods and services within a governance system), and fair and proper utilization and distribution (calling for institutional transparency, public engagement, state accountability, good laws and regulations, and the respect for human rights). So to Africa, it still has a long way to go in achieving MDG hunger target, for which we should never get disheartened, as the promising future is well in store for us, according to our research.

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