A Forecast Analysis on Global Production of Staple Crops

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Abstract

This study aimed to make a long-term forecast analysis on global crops production and thus provide the publics, researchers, and decision-makers with basal data on global crops production in the future. Historical data on production and yield of cereals, paddy rice, wheat, vegetables & melons, and fruits for the world, developed countries, developing countries, Africa, Asia, Caribbean, Oceania, South America, North & Central America, and Europe were used to fit trajectories and make forecasts. The results showed that GLM could generally fit trajectories of crops production. Forecasts of crops production and yield, per capita production, and crops composition for the world and various regions until 2030 were given and discussed in detail.

It is concluded that paddy rice and wheat could have an equivalent share in global cereals production till 2030. Paddy rice and wheat is estimated to account for 2/3 of the cereals production. Both paddy rice and wheat should be the dominant cereal food in the world before 2030. In per capita cereals production for developed countries, wheat would amount to 1/3 of cereals and paddy rice has a very low proportion, which demonstrates that wheat should be the dominant cereal crop in these countries. Unlike developed countries, paddy rice is expected to be the dominant cereal crop (1/2) and wheat is just 1/2 of paddy rice in developing countries' per capita production.

In African's cereals composition, paddy rice and wheat share the similar proportion, which reflects this region's equivalent dependency on rice and wheat. With two times of per capita wheat production, paddy rice should be the dominant cereal crop for Asia by 2030. Vegetables & melons are also the dominant crops in Asia. The dominant cereal crop in Caribbean is paddy rice, but the per capita production of fruits, and vegetables & melons are expected to be three and two times of cereals in this region, which means the fruits and vegetables & melons are the staple crop food in Caribbean. In Europe, wheat should be the dominant cereal crop (1/2) and paddy rice would still occupy a little proportion. The situation in North & Central America is much different. Wheat is expected to make up just 1/5 of per capita cereals production, and paddy rice may occupy a trivial proportion. Vegetables & melons, and fruits share the similar proportion. Oceania's dominant cereal is expected to be wheat, which accounts for 1/2 of per capita cereals production and paddy rice would hold just a little proportion. For South America, paddy rice and wheat should in total account for 1/3 of per capita cereals production within which paddy rice and wheat has the similar proportion. Equivalent to the sum of paddy rice and wheat, fruits are expected to be the staple crop food in South America till 2030.

Key Words: Cereals; Vegetables; Fruits; Production; Forecast; World

1 Introduction

Worldwide production and yield of crops have been increasing since 1960 due to the adoption of modern varieties, the expansion of agricultural lands, and the use of intensification measures (Abelson, 1995; Grigg, 1993; Matson et al., 1997). Yield growth accounted for almost all of the increases in food production in developing countries. Modern varieties accounted for 21% of the growth in yields and about 17% of production growth in the early Green Revolution period, and accounting for almost 50% of yield growth and 40% of production growth in the late stage for all developing countries. Land expansion accounted for about 20% of the increases in production and the rest came from intensification of input use (Evenson and Gollin, 2003). Major researches on forecasts of crops yield and production have been conducting around the world since the mid-20th century. Most of these researches focus on the forecasts of seasonal yield and production of crops. For example, the maize yield forecasts using leaf area index based model (Baez-Gonzalez et al., 2005) and using NDVI data (Mkhabela et al., 2005), seasonal prediction of wheat yield using wheat model (Bannayan et al., 2003) and circulation model (Hanson et al., 2004), forecast of sorghum yield with a regional model (Potgieter et al., 2005), crop yield forecast based on weather forecast (Cantelaube and Terres, 2005), vegetation index and land cover data (Genovese et al., 2001), yield monitor data (Taylor et al., 2001), GIS-based crop model (Priya and Shibasaki, 2001), and other forecasts on seasonal crop performance (Stone and Meinke, 2005).

Seasonal forecasts have been conducted to make seasonal economic evaluations and decisions. They provided much less valuable information on global and strategic problems, such as long-term trends and sustainability, food supply and demand at continental level, regional distribution and variation, etc., which may be partially resolved through explaining the information from various long-term forecasts (Tilman et al., 2001; Zhang et al., 2004). On the other hand, food demand and production have usually been studied separately and therefore resulted in all-or-nothing results. These two aspects link primarily at the regional level. Regional problems in production and distribution can be difficult to counter even when global supplies are adequate (Daily et al., 1998). The studies on food production and demand for various regions are therefore needed. Further, translation of data into a workable set of social indicators, for example, forecasting production and yield for various crops, is so important, which enable policy debate to be conducted in an illuminating manner (Daily et al., 1998). Meanwhile, having these research data available to assess rapidly emerging problems and quickly respond to public outcries for a solution would offer significant benefits to publics (Rasmussen et al., 1998). A number of agricultural businesses should also benefit from an ability to forecast production likelihood at regional scale (Potgieter et al. 2005).

In this paper we try to make a long-term forecast analysis on crops production worldwide and provide the researchers, decision-makers, and publics with systematic data on crops production in the future. The results will help people understand possible changes in crops production, make decisions for agricultural management and food commerce, etc. Detailed forecasts of crops production and yield, per capita production, and crops composition for the world and various regions over the period of 2010 to 2030 were given and discussed.

2 Materials and Methods

Production and yield of cereals, paddy rice, wheat, vegetables & melons, and fruits for the world, developed countries, developing countries, Africa, Asia, Caribbean, South America, North & Central America, Europe, and Oceania were collected from FAOSTAT (FAO, 2005).

We had used both time and total population as independent variables to simulate trajectories of crops production. It was found that dynamics of crops production for various regions is overall a linear function of time, as illustrated in Fig. 1. The model with total population as independent variable has not better fitness than the model with time as independent variable. We thus used the GLM (SPSS for Windows 11.0.0, 2001; Matlab 6.5, 2002), with time as independent variable, to fit the dynamics of crops production: $x(t)$=a+r t, where t is year, $x(t)$ is crops production at the year t, and r is the annual rate of crops production. GLM was statistically tested with F-test, based on adjusted R^2 for the GLM.

Forecasts of crops production and their confidence intervals were derived from GLM. Total population is a stable and easy forecast variable. Our forecasts on per capita crops production were therefore based on the forecasts of crops production and total population. Confidence intervals for forecasts of per capita production were not given because total population is not a complete deterministic variable. Dynamic trends and forecasts of total population for various regions were gained from a recent study (Zhang, 2007).

All forecasts were made over the period 2010-2030, which is a long-term analysis (Rasmussen et al., 1998). They were estimates of crops production from past trajectories. These forecasts thus assumed similar technological, social and environmental patterns in the forecast period. Further, the forecasts based on mechanistic models with various variables could supplement our forecasts and therefore are needed if they are available.

3 Results

GLM has yielded good fitness on the trajectories of crops production in most cases. It may describe the overall trends of global crops production.

Forecast details on global crops production and per capita production over the period 2010-2030, at 5-year interval, are omitted due to page limitation. In the following we compare the forecasts of the year 2030 against the current values in order to explain variability and similarity across regions and periods. Current production was temporally extrapolated from the data available (Tilman et al., 2001).

3.1 Crops Production

3.1.1 Cereals

If the past pattern continues, cereals production and yield around the world are forecasted to grow at annual rates of 30,364,301±1,716,013 Mt and 43.9±1.4 kg/ha over the following years. By the year 2030, global cereals production is expected to reach $3.0532\pm0.1674*10^9$ Mt, an increase of 24.2-38.6% against the current production. Cereals yield should by 2030 increase 27.3-35.6% and reach 4.27-4.55 Mt/ha. Cereals production and yield in both developed (Production: 6.5-37.6%, yield: 21.6-38.2%) and developing (Production: 32.9-43.1%, yield: 30.1-38.7%) countries may also increase till 2030. The production in developing countries is estimated to grow much faster than developed countries.

Cereals production in all of the regions, in exception of Europe, would continually increase by the year 2030. Europe's cereals production (-32.8-53.9%) is estimated to increase probably but there is an uncertainty. In comparison to Africa (21.6-48.5%), South America (25.6-47.9%), Oceania (6.2-69.9%), Caribbean (10-50%), and North & Central America (8.6-47.2%), Asia's cereals production increase (3.5-31.3%) is estimated to be lower but its production should still be the greatest (1.0803 -$1.3705*10^9$ Mt) by 2030.

Cereals yield in Europe is projected to reach 4.21-6.04 Mt/ha by the year 2030, and achieve a greatest growth (14.6-64.5%) in the world. Europe (34.3-86.7 kg/ha) and North & Central America

(54.8-67.8 kg/ha) are expected to hold fastest annual rates in cereals yield growth. At an annual rate of 8.8-12.0 kg/ha, the lowest growth in cereals yield would occur in Africa (7.3-30.3%) and it could just reach 1.42-1.73 Mt/ha by 2030.

Paddy Rice

World's paddy rice production is forecasted to grow at annual rate of 9,550,912±351,843 Mt over the coming years and would reach 8.4647-9.1511*10^8 Mt by 2030, equivalent to an increase of 29.9-40.5% based on the current value. Paddy rice yield should by 2030 increase 24.7-35.5% and reach 5.28-5.73 Mt/ha. Paddy rice production in developing countries is estimated to grow at annual rate of 9,476,885 Mt, much higher than developed countries (74,027 Mt/yr). Till 2030 the production in developing countries is expected to significantly rise 30.9-41.8% against the probable increase of –7.6-21.0% in developed countries. Yield increase in developing countries (25.6-36.9%) may also be higher than developed countries (4.0-23.1%).

With a projected production of 5.9996-7.7366*10^8 Mt, Asia is forecasted to be still the major region for paddy rice production in the world. By 2030 Asia's paddy rice yield is estimated to increase 11.7-23.4% and reach 4.59-5.08 Mt/ha. On the other hand, Europe (79.0-139.2 kg/ha/yr), Oceania (69.3-106.7 kg/ha/yr), and North & Central America (65.8-74.0 kg/ha/yr) are estimated to have higher annual rates in paddy rice yield, and the production in these regions is expected to reach 7.66-9.75 Mt, 8.82-12.47 Mt/ha, and 7.49-8.29 Mt respectively by 2030.

Wheat

Wheat production around the world is estimated to annually grow 9,189,341±716,977 Mt in the forecast period and would reach 8.1692-9.5678 *10^8 Mt by 2030, an increase of 22.6-43.6% compared to the current production. Global production of wheat and paddy rice is similar for each other. However the wheat yield (3.81-4.22 Mt/ha) of the world may still be lower than paddy rice by 2030. Unlike paddy rice, wheat production in developing countries (4.235-4.8658*10^8 Mt) and developed countries (3.7737-4.8625*10^8 Mt) could be similar till 2030. Wheat yield in developing and developed countries is expected to have similar levels till 2030.

By 2030, Asia (2.3882-3.4500*10^8 Mt), Europe (1.4049-3.3667*10^8 Mt), and North & Central America (0.9768-1.5700*10^8 Mt) are expected still to be the major regions for wheat production in the world. Africa (15.8-63.2%), South America (10.2-57.0%), and probably Oceania (-7.2-75.2%) should by 2030 achieve larger increases in wheat production. The growth of wheat yield in Africa (28.7-36.5 kg/ha/yr) and Europe (9.4-57.6 kg/ha/yr) is expected to be the greatest in the world.

3.1.2 Vegetables & Melons

Global production of vegetables & melons is projected to annually grow 13,835,207± 1,497,758 Mt during the following years. The production of vegetables & melons would increase 24.9-64.2% and reach 0.9313-1.2235*10^9 Mt by 2030. The yield would by 2030 reach 21.46-22.24 Mt/ha and increasing 22.4-26.8% against the present value. Developing countries (24.9-78.9%) are forecasted to achieve a much higher production than developed countries (12.7-28.1%) in 2030. The production in developing countries (0.7139-1.0221*10^9 Mt) is expected to be four times of that for developed countries' production (0.1960-0.2228*10^9 Mt), but the later (25.59-29.29 Mt/ha) is expected to have a higher yield than the former (2.05-2.22 Mt/ha) by 2030.

With 0.6544-0.9114*10^9 Mt of production in vegetables & melons, Asia would by 2030 continue to be the largest production region. The production in Asia only is projected to be four times of that in developed countries. Excepting for Africa (11.46-12.27 Mt/ha) and Caribbean (8.94-16.16 Mt/ha), the yield of vegetables & melons for other regions (21-29 Mt/ha) may not have significant differences by 2030. In consideration of the relative increase by 2030, Asia (25.4-74.6%) and Caribbean (0-106.7%) are expected to be the fastest growing regions in the production of vegetables

& melons.

3.1.3 Fruits

Fruits production around the world is forecasted to grow at annual rate of 7,237,618±316,971 Mt over the coming years, and would reach 6.3503-6.9685*10^8 Mt by 2030, equivalent to an increase of 29.0-41.6% against the current level. Global fruits yield is estimated to slowly grow and reach 9.84-11.63 Mt/ha by 2030. In 2030 the fruits production in developing countries (4.7354-5.6162*10^8 Mt) is expected to be nearly four times of developed countries' production (1.2527-1.7145*10^8 Mt). Fruits yield in developed (10.39-13.43 Mt/ha) and developing (9.81-11.12 Mt/ha) countries may not have significant differences till 2030.

Europe's fruits production is estimated to fall at annual rate of 213,108 Mt, and probably have a decrease of 6.9% (-40.7-26.9%) by 2030. Asia may be the largest fruits production region till 2030. Asia's fruits production in 2030 (3.9108-4.3052*10^8 Mt) is expected to be three times of production in developed countries. With the expected production of 0.9974-1.1230*10^8 Mt in 2030, South America is forecasted to be the second largest region for fruits production. Africa is the third largest but its fruits yield would be the lowest (6.81-7.82 Mt/ha) compared with the other regions (10-18 Mt/ha).

3.2 Per Capita Crops Production

3.2.1 Cereals

Per capita cereals production of the world is estimated to probably increase 4.5% (-1.3-10.2%), and reach 375.3 kg/yr by 2030 (Table 1). Per capita production in developed countries (7.9-39.5%) may have a much higher level than developing countries (0.2-7.7%), and is projected to be three times of the later (899.1 kg/yr *vs.* 273.8 kg/yr) till 2030. Oceania (955.2 kg/yr) and North & Central America (833.6 kg/yr) may have the greatest per capita cereals production, while per capita production in Caribbean (62.1 kg/yr) and Africa (122.2 kg/yr) should be lower by 2030. Asia is forecasted to be the largest region in cereals production but per capita production in this region (233.3 kg/yr) may still be lower.

3.2.2 Vegetables & Melons

World's per capita production of vegetables & melons is projected to grow and reach 132.4 kg/yr by 2030, an increase of 14.9% (-0.7-30.6%) against current value. Per capita production in developed (158.5 kg/yr) and developing (127.4 kg/yr) countries could be similar from each other. Europe (190.4 kg/yr), Asia (149.0 kg/yr) and North & Central America (107.3 kg/yr) are expected to reach a higher per capita production by 2030. Per capita production in Africa (-15.4- -0.5%), Europe (-36.1- -23.9%), and Oceania (-16.6-1.5%) is expected to fall in the forecast period. Among these, Africa's per capita production would fall to 50.8 kg/yr by 2030.

3.2.3 Fruits

Per capita fruits production for the world is forecasted to slowly grow and reach 81.9 kg/yr by 2030, just increasing 2.6-12.6%. Per capita fruits production in developed countries (112.3 kg/yr) is estimated to be much higher than developing countries (76.0 kg/yr). In contrast to Asia (23.8-36.4%), South America (10.7-24.7%), and Caribbean (7.3-27.7%), per capita fruits production in Africa (-17.6- -9.3%), Oceania (-19.5- -5.3%), and North & Central America (-10.4-0.2%) are estimated to fall till 2030. Africa's per capita fruits production (62.4 kg/yr) is projected to be the lowest in the world by 2030. South America (238.2 kg/yr), Caribbean (187.4 kg/yr), and Oceania (162.2 kg/yr) may continue to keep higher per capita production by that year.

Table 1 Forecasts of per capita crops production over the period 2010-2030.

		World	Developed Countries	Developing Countries	Africa	Asia	Caribbean	Europe	N & C America	Oceania	South America
	2010	356.9	745.6	261.3	133.9	253.4	51.7	593.1	878.3	1041.3	305
Cereals	2015	359.9	775.1	263.6	130.2	246.6	52.9	615.4	870.5	1030.5	312.3
(kg/yr)	2020	363.9	809.6	266.4	127	241.1	54.5	642	860.1	1011.7	321.2
	2025	369	850.4	269.7	124.3	236.6	59.1	673.3	848	985.1	332.7
	2030	375.3	899.1	273.8	122.2	233.3	62.1	707.9	833.6	955.2	346.9
	2010	100.6	19.8	120.5	19.8	137.7	38.7	4.9	24.2	38.8	58.1
Paddy Rice	2015	102.2	19.9	121.3	19.4	135.2	40.6	5.2	24.4	39.1	59.3
(kg/yr)	2020	103.9	20.2	122.3	19.2	133.2	42.9	5.7	24.4	39.2	61
	2025	105.9	20.7	123.5	19	131.7	45.6	6.1	24.4	38.6	63.1
	2030	108.3	21.4	125.1	18.8	130.8	48.9	6.6	24.2	37.8	65.7
	2010	102.6	269.6	61.5	20.3	62.4	–	286.1	192.7	634.7	58.5
Wheat	2015	103.8	280.7	62.7	19.9	60.2	–	302.3	189.6	624.1	59.5
(kg/yr)	2020	105.2	293.7	64	19.5	58.3	–	321	186.1	609.3	60.9
	2025	106.9	308.9	65.3	19.2	56.8	–	342.2	182.4	590.4	62.8
	2030	109	326.9	66.8	19	55.6	–	365.3	178.3	569.8	65.3
	2010	116.8	132.9	112.9	53.3	133.4	81.3	144.9	107.8	104.7	55
Vegetebles	2015	120.5	137.7	116.5	52.4	137.4	86.5	154.5	108.3	106.6	56.6
& Melons	2020	124.3	143.5	120.1	51.8	141.3	92.4	165.3	108.4	104.9	58.3
(kg/yr)	2025	128.2	150.3	123.7	51.2	145.1	101.7	177.3	108	102.3	60.5
	2030	132.4	158.5	127.4	50.8	149	109.8	190.4	107.3	99.4	63.1
	2010	76	100.5	70	68.7	63	160.8	102.2	119	180.7	204.4
Fruits	2015	77.2	102.4	71.4	66.7	67.2	164.9	102.3	118.4	177.7	210.7
(kg/yr)	2020	78.6	104.8	72.8	64.9	71	170.4	102.9	117.5	173.4	218.2
	2025	80.1	108.1	74.3	63.5	74.7	177.8	104.1	116.2	168	227.3
	2030	81.9	112.3	76	62.4	78.2	187.4	105.7	114.5	162.2	238.2

Note: Wheat data are not available for Caribbean.

4 Conclusions and Discussion

If the past pattern continues, global cereals production is forecasted to grow at annual rate of 30,364,301±1,716,013 Mt. By the year 2030, global cereals production would increase 24.2-38.6% and reach 2.8858-3.2206*10^9 Mt. Per capita cereals production of the world is estimated to probably increase 4.5% and reach 375.3kg/yr by 2030.Cereals yield is projected to grow at annual rate of 43.9±1.4 kg/ha and increase 27.3-35.6%, reaching 4.27-4.55 Mt/ha by 2030. Cereals production and yield in both developed (Production: 6.5-37.6%, yield: 21.6-38.2%) and developing (Production: 32.9-43.1%, yield: 30.1-38.7%) countries are estimated to increase to the end of the forecast period. Per capita production in developed countries (899.1 kg/yr) could have a much higher level than developing countries (273.8 kg/yr) by 2030.

World production of vegetables & melons is expected to grow at annual rate of 13,835,207± 1,497,758 Mt and reach 0.9313-1.2235*10^9 Mt by 2030. Global per capita production of vegetables & melons would grow and reach 132.4 kg/yr, a probable increase of 14.9%. The yield is forecasted to reach 21.46-22.24 Mt/ha and increase 22.4-26.8% by 2030. The production in developing countries (0.7139-1.0221*10^9 Mt) would be four times of developed countries' production (0.1960-0.2228*10^9 Mt). However, the yield for developed countries in 2030 (25.59-29.29 Mt/ha) is expected to be higher than developing countries (2.05-2.22 Mt/ha). Per capita production in developed (158.5 kg/yr) and developing (127.4 kg/yr) countries could be similar from each other at the end of the forecast period.

Global fruits production is forecasted to grow at annual rate of 7,237,618±316,971 Mt over the following years, and would by 2030 reach 6.3503-6.9685*10^8 Mt, increasing of 29.0-41.6%. Per capita fruits production for the world is projected to slowly grow and reach 81.9 kg/yr by 2030. Fruits yield around the world would grow slowly and reach 9.84-11.63 Mt/ha by that time. In 2030 the fruits production in developing countries (4.7354-5.6162*10^8 Mt) is expected to be nearly four times of developed countries' production (1.2527-1.7145*10^8 Mt). Per capita fruits production in developed countries (112.3 kg/yr) is estimated to reach a much higher level than developing countries (76.0 kg/yr). However, fruits yield in developed (10.39-13.43 Mt/ha) and developing (9.81-11.12 Mt/ha) countries may not have significant differences until 2030.

From the forecasts, we may find that paddy rice and wheat could have an equivalent share in global cereals production till 2030. Paddy rice and wheat is estimated to account for 2/3 of the cereals production. Both paddy rice and wheat should still be the dominant cereal food in the world before 2030. In per capita cereals production for developed countries wheat would amount to 1/3 of cereals and paddy rice has a very low portion, which demonstrates that wheat should be the dominant cereal crop in these countries. Unlike developed countries, paddy rice is expected to be the dominant cereal crop (1/2) and wheat is just 1/2 of paddy rice in developing countries' per capita production.

In African's cereals composition, paddy rice and wheat share the similar portion, which reflects this region's equivalent dependency on rice and wheat. With two times of per capita wheat production, paddy rice should be the dominant cereal crop for Asia by 2030. Vegetables & melons are also the dominant crops in Asia. The dominant cereal crop in Caribbean is paddy rice, but the per capita production of fruits, and vegetables & melons are expected to be three and two times of cereals in this region, which means the fruits and vegetables & melons are the staple crop food in Caribbean.

In Europe, wheat should be the dominant cereal crop (1/2) and paddy rice would still occupy a little portion. The situation in North & Central America is much different. Wheat is expected to make up just 1/5 of per capita cereals production, paddy rice may have a trivial portion. Vegetables & melons, and fruits share the similar portion. Oceania's dominant cereal is expected to be wheat, which accounts for 1/2 of per capita cereals production and paddy rice would hold just a little portion. For South America, paddy rice and wheat should in total account for 1/3 of per capita cereals production within which paddy rice and wheat has the similar portion. Equivalent to the sum of paddy rice and wheat, fruits are expected to be the staple crop food in South America till 2030.

According to the theoretical expectations and experimental studies (Holden,1998; Hoching and Stapper, 2001; Pandey et al., 2001; Bish et al., 2002; Dobermann et al., 2003; Duppong et al., 2005; Kallsen, 2005), our forecasts on crops yield should not be unreasonable.

Major factors to impact our forecasts include extreme climate change and widespread use of new over-yield-barrier crop varieties (Holden, 1998) in the forecast period. Global climate change generally proceeds in a graduate manner. We thus expect that the extreme climate change should not occur in the near future, and thus crops production and yield are predictable (Lobell and Asner, 2003). So it would not be our focus in the forecast period. Continuous adoption of high-yielding varieties that bred mainly by traditional breeding methods, has contributed to steady growth of crops yield and production since the 1960's (Evenson and Gollin, 2003). However, as the rapid development of modern biotechnologies particularly the genetic and transgenic approaches, we should closely follow the advances in use of new over-yield-barrier crop varieties and update these forecasts at proper time.

Nearly 1.5 billion of the world population of 6 billion live in severe poverty at the dawn of the new millennium (Swaminathan, 2000). As indicated in this paper, the dominant food crop production per capita in developing countries would just reach 1/3 of the developed countries by 2030. Major increases in crops production and yield will be required to meet the future demand for food worldwide (Lobell and Asner, 2003), especially in Africa and Asia (Daily et al., 1998). On the other hand, the development issues such as the growing division between rich and poor, the feminization of poverty, the loss of lands and biodiversity, the depletion of water resources, and the environmental and human health consequences of fertilizer and pesticide application in intensive production systems, are of growing concern (Matson et al. 1997; Daily et al., 1998; Swaminathan, 2000; Tilman et al., 2001; Green et al., 2005; Zhang et al., 2006). Among these the expansion of agricultural lands, driven by increasing requirement for crops production, exacerbates the climate changes, the degradation of environment, and the loss of biodiversity (IRRI, 2005).

Studies are being conducted to find solutions (Green et al., 2005). Besides continuous use of high-yielding crop varieties (Evenson and Gollin, 2003), sustainable agriculture has been applying in many countries, which may meet current production goals without compromising the future in terms of resource degradation or depletion and therefore can stabilize the agricultural land area without food deficiency (Matson et al., 1997), for example, the effective fertilizing techniques such as site-specific nutrient management (Witt and Dobermann, 2002), the uses of manure and organic fertilizers and manure crops (Ingram and Swift, 1989), and sustainable pest management for reducing pesticide uses (Zhang and Qi, 2004), etc.

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