Is Area Yield Crop Insurance Appropriate in Ghana?

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Abstract

Area yield crop insurance, a kind of index-based insurance product, might be helpful in aiding Ghana's farmers to reduce their yield loss. This product bases premiums and indemnities on aggregate yield, as opposed to individual yield. Due to the constraints of the data district yield has replaced individual yield. My objective for this project is to define the critical yield range in which indemnities are incurred.

Introduction

Previous study shows that there is the lack of correlation between rainfall and crop yield In the Northern region, Ghana. Perhaps the most promising potential is for research on an area index by district. Such an index may more accurately reflect the default risk for financial institutions making loans in a particular district. One potential product they may be considered is an area yield index. These have an advantage over farm yield insurance products in that they do not have the moral hazard or high administrative costs of a farm yield product, yet may have lower basis risk than a weather index product like drought insurance.

Area yield insurance products are some of the oldest forms of an index for agricultural loss, and may have hold promise if the yield for a district correlates well with losses for farmers, or possibly defaults on farm loans to financial institutions for that district. Perhaps (in part) because privately offered single peril contracts have been commercially feasible, index-based agricultural insurance has come to be viewed as a viable risk management tool for low income farmers in developing countries (in Ghana).

Area yield or production index programs for crops and, in Mongolia, for livestock have also been proposed and implemented either on a permanent basis (as in the United States and elsewhere) or on a pilot basis (as in Morocco, Malawi and Mongolia).In many developing countries, reliable current and historical data on average area yields are simply not available at the equivalent of the county level in developed countries like the United States. Fortunately Ghana has that data (1992-2008).

The primary attraction of area yield insurance schemes is that insurers do not have to contend with the informational problems of moral hazard and adverse selection (Halcrow). These problems can be dismissed because indemnities and premiums are based not on a producer's individual yield but rather on the aggregate yield of (a risk pool) a surrounding geographical area. Area yield insurance contracts (first proposed by Halcrow in 1949) provide the purchasing farmer with an indemnity only when average yields across all farms in the area fall below a critical yield. Typically, it is assumed, the individual farm's yield will have only a small impact on the area yield and therefore, area yield crop insurance contracts do not provide such large incentives for moral hazard.

Area yield insurance contracts must be based on an index of area yields. To reduce basis risk, the area or zone boundaries for an area yield contract should be selected so as to group together the largest possible number of farms with similar soils and climate. The climate of the Northern region, Ghana is relatively dry, with a single rainy season that begins in May and ends in October. The amount of rainfall recorded annually varies between 750 mm and 1050 mm. The dry season starts in November and ends in March/April with maximum temperatures occurring towards the end of the dry season (March-April) and minimum temperatures in December and January. The harmattan winds, which occur during the months of December to early February, have considerable effect on the temperatures in the region, which may vary between 14°C at night and 40°C during the day. Humidity, however, which is very low, mitigates the effect of the daytime heat. The main vegetation is classified as vast areas of grassland, interspersed with the guinea savannah woodland, characterized by drought-resistant trees such as the acacia, baobab, shea nut, dawadawa, mango, and neem.

The objective of this project is to develop accurate area yield and to choose trigger yield based on the Ghana's historical data along with theoretical model examined by Miranda et al. (1991). Also it seeks for establishing optimal premium rate of area yield crop insurance contracts on a pilot basis in Northern regions of Ghana.

Basics of Index Insurance

Index insurance differs from the traditional approaches to agricultural insurance in that loss estimates are based on an index, or proxy for loss rather than upon the individual loss of each policyholder. The index policy is designed to correlate the benefit with the actual value of the financial loss. Indexes can also be constructed from aggregate statistics such as area yields. Area-yield indexes are based upon aggregate crop output indicators such as county yields in the United States and district yields in India. Index insurance has a defined threshold and a limit that establish the range of values over which indemnity payments can be made. The threshold marks the point at which payments begin. Once the threshold is reached, the payment increases incrementally as the value of the index approaches the limit.

To the extent that it is not possible to tamper with the measuring devices, index insurance overcomes the problem of moral hazard because the policyholder's behavior cannot impact whatever the index is measuring, such as rainfall. If the sales closing is set in a proper fashion, index insurance also overcomes adverse selection because both buyer and seller should have equal knowledge regarding the likelihood of the weather event that will trigger payments. Most importantly there are no loss adjustment costs. The amount of loss can be calculated using the coverage value and the index level, and the benefit can be deposited directly in the policyholder's account.

Index insurance may not be an appropriate tool in all circumstances and there are trade-offs to be considered. While an index should be closely correlated to actual losses, there will always be some variance between the index and individual losses. This potential mismatch is known as *basis risk*. Basis risk occurs when an insured experiences a loss but does not receive a payment because the index threshold value is not met, or conversely, when an insured receives a payment but localized conditions may not have resulted in a loss or as severe a loss as the index value indicates. Both examples demonstrate how realized losses do not always correlate strongly with the index.

Literature Review

Several analyses have been devoted to the properties of area yield insurance. This risk-sharing mechanism between farmers and insurers, where the indemnity schedule is based on the aggregate yield of a surrounding area, was first promoted by Halcrow. (1949)

The problem of the efficient insurance purchasing strategy of a risk-averse individual in incomplete markets has been examined by Doherty and Schlesinger (1983). They have demonstrated that optimal insurance contracts are based on the stochastic dependence between insurable and uninsurable risks in the individual's portfolio.

Halcrow's proposal was resurrected by Miranda (1991) who examined the relative effects of area yields and individual yields on the variance of net farm yield, defined as the individual yield plus the indemnity payment minus the insurance premium. He concluded with recommendations on how area-yield crop insurance might be implemented.

Smith, Chouinard, and Baquet (1994) argued that ideal area yield insurance (from the perspective of the purchaser) would allow the purchaser to optimally select both coverage and scale. Recognizing that political considerations might not allow for unrestricted choice of coverage and scale, they propose an "almost ideal" area yield insurance contract where scale is set equal to 100% but coverage is bounded only by the condition that it must be greater than zero. Their empirical analysis was conducted using 1981-1990 farm yield data for 123 dry land wheat farms in Chouteau County, Montana.

The area yield insurance contract, known as the Group Risk Plan (GRP) was introduced in 1994 in the U.S. Gollier (1996) has shown that, when the uninsurable risk increases with the size of the loss of the insurable risk and when the premium is based upon the expected indemnity, the optimal insurance contract displays a disappearing deductible if the insured agent is prudent.

The design and the rate-making procedures used in implementing a workable area yield contract have been documented by Skees, Black, and Barnett. (1997)

Mahul (1999) has examined the optimal design of an area yield crop insurance contract in the expected utility model. His principal result is that the optimal coverage level equals the individual positive beta and depends neither on the degree of risk aversion of the insured producer nor on the insurance premium, unlike the optimal critical yield. Mahul considered the choice of an optimal contract I(y). If insurance is actuarially fair then the optimal contract is characterized by $I(y) = \beta_i (y_m - y)$, where y_m, the yield trigger, is the maximum possible value of y.

Relatively fewer studies have focused on determining its optimal form. This question was first addressed by Miranda, and by Smith, Chouinard, and Baquet, for the particular case of a farmer seeking to minimize the variance of net yield.

Vercammen (2000) considers the optimal design of an area-yield crop insurance contract when the yield trigger is constrained, for institutional reasons, to be below the maximum possible value of area yield.

The theoretical foundations of the linear additive model (LAM) investigated by Bharat Ramaswami (2004). On surface, the LAM bears a striking similarity to the capital asset pricing model (CAPM) of finance. The CAPM postulates returns on individual assets to be a linear stochastic function of the returns on the market portfolio. The CAPM beta-the slope coefficient in the model-measures the sensitivity of asset returns to the returns on the market portfolio. He concluded that the LAM of area-yield crop insurance is the consequence of aggregation of individual producer technologies and is not the outcome of optimization. He also derives $\beta_i = \mu_i / \mu$ in the general structural model.

Data Description

This research project is focused mainly on the northern part of Ghana where there is substantial farming activity. The northern region of Ghana is considered the major bread basket of the country, and is also the most susceptible to the vagaries of the weather, especially the lack of rainfall. This northern part of Ghana is made up of three main regions; Upper West Region, the Upper East Region and the Northern Region.

In this project I used primarily yield data on maize. Yield is calculated as follows: Estimation of yield was conducted using objective measurement techniques. Randomly located square plots were marked out in the field by an enumerator. The square is pegged and lined. Farmers were asked to work on these plots as in other fields on the farm. Produce from these plots were weighed at the time of harvesting by the field worker / enumerator and used as the basis for estimating the yield. The crops inside the plot were harvested by the enumerator at the time the holder harvests the rest of the field. The total production of food crops was determined by estimating the area under cultivation for each crop and the yield rate. The product of these two components was an estimate for the total production of the crop.

I researched a possibility of Area Yield Crop Insurance in Ghana, so I only considered yield data. Data collected by The Ministry of Food & Agriculture, which is the main government arm responsible for formulating and implementing agricultural policy in Ghana.

Changing districts and delays in obtaining supplementary information. This redistricting makes comparisons of districts difficult. For example, districts of Ghana were reorganized in 1988/1989 in an attempt to decentralize the government and to combat the rampant corruption amongst officials. The reform of the late 1980s subdivided the regions of Ghana into 110 districts, where local district assemblies should deal with the local administration. By 2006, an additional 28 districts were created by splitting some of the original 110, bringing their number up to 138. In February 2008, there were more districts created and some were upgraded to municipal status. This brought the final number to 170 districts in Ghana. There are still only 10 regions. Yield data are given by district based but 1985-1991 only region based .So yield data 1992-2008 completely given by District. All yield data measured production amount per hectare area (figure: Metric ton/Hectare=Mt/Ha, 1 hectare = 2.471 acres)

For Northern Region 1992-2004 data is given by 13 districts but some districts are named by differently (as a capital city) and 2005-2008 data is given by18 districts because the government broken down some districts in 2005. This downsizing happened in Upper East and Upper West regions in 2005. (5 to 8 districts)

Research Methodology

In order to conduct data analysis with same number of district every year I combined yield data from18 to 13 districts in Northern Region, from 8 to 5 districts in Upper East and Upper West Regions. See table 1,1a. 2 and 3.finally I prepared 23 district yield data for entire 3 regions. Then I assumed each district's yield data similar to individual producer's yield and entire 3 regions' yield to aggregated area yield. See table 4 and graph 1,2 and 6 for calculation of aggregate area yield data. Also I did 2 adjustments for prepared data because there are 2 unusual numbers in original data set. In 2002 Bawku East (Garu Tempane) district's yield is 6.04 and in 2003 Tonlon/Kumbugu district's yield is 7.3. I replaced those by the average one without that year with respect 1.22 and 1.15 as on the excel spreadsheet marked. Thus, we have 13 districts in Northern Region and 5 in Upper East and so on. These data are collected for 17 years from 1992-2008. See table 5 and graph3.

In this paper, we have consider a district (or a producer) i whose yield y_i is random due to the uncertain effects of weather and other natural phenomena. Suppose, the producer operates in an area where the aggregate yield across all 23 districts is y. By projecting district's individual yield y_i onto the area yield y, Miranda, 1991 has developed the following identity: the producer's individual yield y_i is projected onto the area yield y

$$y_i = \mu_i + \beta_i*(y - \mu) + \varepsilon_i. \quad (1)$$

where,

$$\beta_i = Cov(y_i, y)/Var(y) \quad (2)$$

$$E(\varepsilon_i) = 0 \quad Var(\varepsilon_i) = \sigma^2_{\varepsilon_i} \quad Cov(y, \varepsilon_i) = 0 \quad (3)$$

$$E(y_i) = \mu_i \quad Var(y_i) = \sigma^2_{y_i} \quad (4)$$

$$E(y) = \mu \quad Var(y) = \sigma^2_{y_i} \quad (5)$$

The coefficient β_i measures the sensitivity of the producer's individual yield to the systemic factors that affect the area yield. Equation (1) decomposes individual yield variation into a systemic component β_i $(y - \mu)$ that is perfectly correlated with the area yield and a nonsystemic component ε_i that is uncorrelated with the area yield. Suppose that the producer is offered area-yield crop insurance in which the indemnity and the premium are both denominated in production units, say, metric ton per hectare. The producer purchases coverage at a premium rate of P metric ton per hectare. If the area yield y subsequently falls below a critical yield level y_c, he receives an indemnity I(y), in metric ton per insured hectare, equal to the shortfall:

$$I(y) = \max(y_c - y, 0). \quad (6)$$

Assume that a premium P as in equation (7) below is actuarially fair; that is, it is equal to the expected indemnity EI(y). Then, with area-yield crop insurance, the producer's net yield equals

$$y_i^{net} = \pi = y_i + I(y) - P \quad (7)$$

and his yield risk, as measured by the variance of the net yield, is defined as (Miranda, 1991),

$$Var(y_i^{net}) = \sigma^2_{y_i} + \sigma^2_{I(y)} + 2*Cov(y_i, I(y)), \quad (8)$$

where $\sigma^2_{I(y)} = Var(I(y))$ is the variance of the indemnity. By acquiring area–yield insurance, the producer thus reduces his risk by the amount

$$\Delta_i = Var(y_i) - Var(y_i^{net}) = -\sigma^2_{I(y)} - 2*Cov(y_i, I(y)). \quad (9)$$

Assume now that the individual nonsystemic yield component ε_i and the area yield y are conditionally independent (a mild assumption given that they are uncorrelated by definition). Then the individual nonsystemic yield component ε_i and the indemnity I(y) are uncorrelated, and it follows from (1) that

$$Cov(y_i, I(y)) = \beta_i Cov(y, I(y)). \quad (10)$$

Defining

$$\beta_c = \frac{Var(I(y))}{2\,Cov(y, I(y))} \quad (11)$$

where $Var(I(y)) = \sigma^2_{I(y)}$, β_c called the critical beta. It shows that area yield insurance reduces the variance of net yield if the district's beta coefficient exceeds the critical beta. Miranda also proves that the farmer selects the optimal coverage level such that

$$\phi_i = \frac{\beta_i}{2\beta c} \quad (12)$$

The cumulative density function of the area yield is denoted F(y), and its support is contained in a compact interval [0, y_{max}] with $y_{max} > 0$. The cumulative distribution function of the nonsystemic risk is denoted G (ε_i) and its support is [$\mathcal{E}_{min}$, $\mathcal{E}_{max}$] with $\mathcal{E}_{min} \leq \mathcal{E}_{max}$. The insurance contract is described by a pair [I(y), P] where I(y) is the indemnity payment schedule when the realized area yield is y, and P is the insurance premium paid by the farmer regardless of realized area yield. A feasible indemnity function satisfies

I(y) for all $y \in [0, y_{max}]$. (13)

As is standard in the literature (Arrow, Borch), the insurance premium is assumed to be based upon the expected indemnity:

P=c [EI(y)] (14)

With c (0) =0 and c' (I) ≥ 0 for all I ≥ 0.

The risk-averse farmer's preferences are represented by the increasing and concave utility function u. Given equation (1) the purchase of an area yield insurance contract yields the following expected utility of net yield:

$$\int_0^{y\max} \int_{e\min}^{e\max} u\,(\mu_i + \beta_i\,(y - \mu) + I(y) - P + \varepsilon_i)\; dG(\varepsilon_i)\; dF(y)\;. \qquad (15)$$

The Pareto optimal insurance contract is obtained by finding the insurance premium P and the indemnity function I(y) that maximizes the insured farmer's expected utility of net yield under the constraints that the indemnity function is nonnegative and the premium is a function of the expected indemnity.

If the insurance premium is actuarially fair, the farmer purchases the area yield contract with full insurance and the optimal coverage level equals his or her beta coefficient. So $P = E[I(y)]$. It can be

$P=\beta_i\,(y_m-\mu)$, here $y_c = y_m$. (16)

Mahul considered that suppose a linear relationship between individual (district) yield and aggregate yield as characterized in (1) exists. If the producer's beta coefficient is positive; the optimal coverage level is lower than his beta coefficient $0 \leq \phi_i \leq \beta_i$. If his beta coefficient is negative; he does not purchase the area yield crop insurance policy, $\phi_i = 0$.

The optimal form of the insurance contract is based upon the district's coefficient β_i. When this coefficient is positive, the optimal insurance contract acts as a put option: the farmer who in that district receives an indemnity if the realized area yield is lower than a critical yield y_c. When it is negative, the optimal contract is like a call option: the farmer receives an indemnity if the area yield is higher than a critical yield $y_{c'}$. The optimal contract contains a coinsurance when β_i is less than 1. When β_i. is greater than 1, the "dis-appearing deductible" clause is the optimal risk-sharing contract. This clause means that an additional loss of one unit of area yield generates an additional indemnity payment greater than one unit: $I^{*\prime}(y) = \beta_i > 1$. Notice that, unlike the optimal design of insurance contract, the critical area yields depend on the degree of risk aversion of the insured farmer (district).

The key parameter of the model, beta coefficient is determined differently on previous papers. I examined better estimator of two models using MSE based on yield data.

$$MSE= (y_i-y_i')^2/n, \quad (17)$$

where y_i actual observation, y_i' estimated value by different β_i, n number of observation (17 years) in data.

$$\beta_i=\mu_i/\mu \quad (18)$$

in the second model.

Results and Implications.

Table 6 shows each district's basic statistical analysis. The expected aggregate area yield $\mu \approx 1.15$ Mt/Ha and the maximum aggregate area yield is equal to 140% of expected area yield, that $y_{max} \approx 1.4\,\mu$.

Table 7 shows that 11 of 23 districts had P value of regression analysis less than 0.05. Only these 11 districts had a significant linear relation with aggregate area yield. The same result is obtained from a correlation analysis between aggregate area yield and district yield, as seen in the last two columns of table 8.

Table 8 also shows a comparison of the MSE for two different estimates for the beta coefficient. The first estimate is preferred because its MSE is lower in all cases.

See table 9. About 44% of districts had beta lower that unity (average positive value of betas), 22% of district beta is between 0.8 and 1.2.According (16) the premium is then $P=0.74\,\beta_i$ per hectare, which is called as "ideal" area yield crop insurance. Consequently, the farmer is fully insured against the systemic risk and he bears only the non-systemic risk. The average premium paid by district's producers under this ideal contract is 0.38 Mt/Ha. Table 9 also shows that the first estimate for beta is greater than 1 it results in a higher premium than the second. If the first estimate is less than 1 the opposite is true.

Table 10 shows that the critical beta raises as the critical yield is increased, the critical beta achieves its theoretical minimum of zero and it's maximum of 0.53 and that the actuarially fair premium rises with critical yield level.

Table 11 shows that if critical yield is less than 130% of mean aggregate area yields ($\mu \approx 1.15$) then the optimal coverage level is lower than district beta and the condition $0 \le \phi_i \le \beta_i$ is not satisfied. So the critical yield should be y_c > 135% of mean aggregate area yield in Northern Ghana maize data set. The insured farmer can choose the critical area yield between 1.55 and 1.61 Mt/Ha, but there is no deductable in this contract.

Graph 6 is a Time Series of aggregate area yield in 3 regions, separately and combined.

Table 12. shows when the coverage level optional (1.35μ and 1.4μ the critical range) , then the maximum risk deduction that each dictrict producer can obtain from area yield insurance. Also comparisons of premiums for the both cases. From Table 12. 8 districts have β_i<0.51 which means 34.7% not optimally coverage, 6 of them have positive betas

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Appendix-A

Table A1: Sequence of modification/change of districts name.

(Renaming of districts over the years: 1992-2002, 2003-2004, 2005-2008)

	1992-2002	2003-2004	2005-2008	1992-2008 (Created for data analysis purpose)
1	Bimbilla	Nanumba	Nanumba North Nanumba South	Nanumba North-South
2	Bole	Bole	Bole Sawla-Tuna-kalba	Bole-Sawla-Tuna-kalba
3	Damango	West Gonja	Central Gonja West Gonja	West Gonja/Central Gonja
4	Gambaga	East Mamprusi	East Mamprusi Bunkpurugu-Yunyoo	East Mamprusi/ Bunkpurugu-Yunyoo
5	Gushiegu/Karaga	Gushiegu/Karaga	Gushiegu Karaga	Gushiegu/Karaga
6	Saboba/Chereponi	Saboba/Chereponi	Saboba/Chereponi	Saboba/Chereponi
7	Salaga	East Gonja	East Gonja	East Gonja
8	Savelugu/Nanton	Savelugu/Nanton	Savelugu/Nanton	Savelugu/Nanton
9	Tamale	West Dagomba	Tamale/Metropolitan	Tamale Metropolitan
10	Tonlon/Kumbugu	Tonlon/Kumbugu	Tonlon/Kumbugu	Tonlon/Kumbugu
11	Walewale	West Mamprusi	West Mamprusi	West Mamprusi
12	Yendi	East Dagomba	Yendi	Yendi
13	Zabzugu/Tatale	Zabzugu/Tatale	Zabzugu/Tatale	Zabzugu/Tatale
Total # Districts	13	13	18	13

	The Upper east region			
	1992	1993-2004	2005-2006	2007-2008
1	Builsa	Builsa	Builsa	BUILSA
2	Kasina/Nankana	Kasina/Nankani	Kasena/Nankana	KASSENA NANKANA
3	Bolgatanga (Bongo)	Bongo Bolgatanga	Bolgatanga Bongo Talensi Nabdab	BONGO BOLGA TALENSI NABDAM
4	Bawku East	Bawku East	Bawku Municipal Garu Tinpani	BAWKU MUNICIPAL GARU TEMPANE
5	Bawku West	Bawku West	Bawku West	BAWKU WEST

Table 2. The Upper East Region's district names comparison from original data set.Then I combined district data that:Bolgatanga+Bongo in 1993-2004,Bolgatanga+Bongo+Talensi Nabdab and Bawku Municipal+Garu Tempane =Bawku East in 2005-2008 because Bawku East district broken down to Bawku Municipal and Garu Tempane districts since 2005.

	The Upper West Region		
	1992-2002	2003-2004	2005-2008
1	Wa	Wa	Wa West Wa East Wa Municipal
2	Lawra	Lawra	Lawra
3	Tumu(Sisala east)	Sissala	Sisala East Sisala West
4	Jirapa	Jirapa-Lambussie	Jirapa-Lambussie
5	Nadowli	Nadowli	Nadowli

Table 3.The Upper West Region's district names comparison from original data set.Also I combined district data that: Wa West+Wa East+Wa Municipal=Wa and Sisala East+Sisala West=Sisala in 2005-2008 because broken down happened from Wa to the Wa West,Wa East and Wa Municipal, from Sisala to East and West Sisala since 2005. I assumed Sisala was named Tumu in 1992-2002 data sets.

District data combined method: First computed combining district's total production amount and total cropped area then calculated yield using a formula (Yield=total production/total cropped area) in each year.

region\production (metric ton)	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2,004	2005	2006	2007	2008
Northern	130560	166890	142464	154200	123440	109000	122000	107248	78800	69878	94560	79050	74566	96717	98157.28	88037.21	131856.6
Upper East	1710	6030	5755	8370	5800	1900	5532	6216	16280	15000	18390	20370	14650.2	14496	14711.84	8755.78	38256.4
Upper West	7957	47060	53020.8	54600	42950	42950	46207	42770	56725	50738	62560	60710	60801.48	47422	48127.85	40104.16	55233.23
total production (Mt)	140227	219980	201239.8	217170	172190	153850	173739	156234	151805	135616	175510	160130	150017.7	158635	160997	136897.1	225346.2
region\cropped area(hectare)																	
Northern	116500	127270	106540	114200	104500	109000	122000	112020	98500	104088	157020	89060	66255	79920	85644	72073.4	77351
Upper East	1670	6330	5790	8600	6500	3800	5698	8222	10466	9995	11410	11920	11040	13396	14355	17382	23763
Upper West	24113	36200	37600	38900	40500	42950	37578	35630	34979	36250	36730	37790	40260	34260	36714	35716.13	38438
total cropped area (Ha)	142283	169800	149930	161700	151500	155750	165276	155872	143945	150333	205160	138770	117555	127576	136713	125171.5	139552
Aggregation -AREA YIELD NORTI	0.99	1.30	1.34	1.34	1.14	0.99	1.05	1.00	1.05	0.90	0.86	1.15	1.28	1.24	1.18	1.09	1.61

Table 4. Aggregated area yield calculation for whole north 3 regions as maize crop. (Figure Mt/Ha)

	DISTRICT	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
The North	Bole/Saw	1.30	1.30	1.60	1.72	1.40	1.00	0.93	1.00	0.73	0.40	0.41	2.00	2.00	0.91	1.15	1.13	1.93
Region	East Gonja	1.00	1.20	1.30	1.40	1.30	0.84	0.90	0.90	0.70	0.51	0.80	1.30	1.30	1.00	0.97	1.35	2.00
	East Mam	0.50	1.20	1.30	1.40	1.10	0.87	0.89	0.90	0.80	0.70	0.39	0.80	1.00	1.18	1.05	1.08	1.69
	Gushiegu,	1.10	1.10	1.10	1.18	1.00	1.20	1.11	1.00	0.80	0.76	0.40	1.20	1.20	1.75	1.56	1.21	1.56
	Nanumba	1.30	1.30	1.30	1.40	1.20	1.12	1.18	1.23	1.00	1.20	1.80	1.10	1.10	1.51	1.40	1.48	1.74
	Saboba/C	1.30	1.60	1.80	1.94	1.68	1.29	1.28	1.20	0.90	1.00	0.59	1.00	1.00	0.96	0.86	0.81	1.20
	Savelugu/	0.90	1.20	1.20	1.29	1.20	1.18	1.20	1.10	0.90	0.90	0.78	0.80	1.00	1.03	0.98	1.17	1.40
	Tamale M	0.60	0.70	0.80	0.86	0.80	0.68	0.66	0.75	0.65	0.60	0.70	1.10	1.10	1.59	1.50	1.08	1.90
	Tonlon/Ku	1.70	1.60	1.30	1.40	1.20	1.17	1.00	1.00	0.90	0.60	0.44	1.15	2.00	0.71	0.68	1.26	1.50
	West Gon	1.30	1.30	1.30	1.40	1.08	0.67	0.70	0.80	0.70	0.60	0.90	0.12	1.20	1.17	1.12	1.19	2.29
	West Mar	1.30	1.30	1.30	1.40	1.20	1.09	1.10	1.00	0.90	0.70	1.00	1.35	1.35	1.72	1.64	1.35	1.90
	Yendi	1.00	1.60	1.60	0.99	0.96	0.89	0.90	0.95	0.60	0.60	1.00	0.10	1.00	1.58	1.50	1.35	1.04
	Zabzugu/T	0.70	0.90	0.90	0.97	0.90	0.64	0.67	0.08	0.80	0.60	0.60	0.76	1.00	0.83	0.80	0.99	2.00
The Uppe	Wa	0.33	1.30	1.48	1.21	1.10	1.21	1.00	1.27	1.80	1.50	1.60	1.40	1.44	1.48	0.97	1.52	0.64
East	Lawra	0.33	1.30	1.41	1.06	1.10	1.16	0.70	0.81	0.70	0.50	0.60	0.50	0.53	0.66	0.62	0.43	0.63
Region	Sisara(Tur	0.33	1.30	1.21	1.30	1.20	1.28	1.70	1.45	1.70	1.60	2.10	2.10	2.04	1.56	1.31	1.20	1.09
	Jirapa	0.33	1.30	1.28	1.02	1.10	1.16	0.80	0.91	1.79	1.40	1.50	1.40	1.20	1.34	1.22	1.20	1.56
	Nadowli	0.33	1.30	1.50	1.89	0.90	0.98	1.50	1.18	1.50	1.30	1.80	1.80	1.40	1.26	1.22	0.85	1.25
The Uppe	Builsa	1.00	0.70	0.80	0.87	0.87	0.52	0.80	0.67	0.95	1.22	0.38	0.40	0.96	0.56	0.54	0.33	1.54
West	Kasena/N	1.29	0.71	1.10	0.78	0.88	0.43	0.90	0.65	0.60	0.94	1.30	1.41	1.40	0.98	0.94	0.37	1.67
Region	Bolgatang	1.00	0.90	0.90	1.06	0.90	0.45	0.82	0.68	1.50	1.37	2.07	2.02	0.86	1.26	1.13	0.44	1.74
	Bawku Ea	0.87	1.20	1.20	0.94	0.89	0.55	1.20	0.84	2.00	1.82	1.22	2.15	1.67	1.06	1.02	0.57	1.60
	Bawku We	1.00	1.00	1.00	0.86	0.87	0.56	0.88	0.63	0.64	0.83	1.10	1.52	1.68	1.50	1.42	0.64	1.41
	y=Aggrega	0.99	1.30	1.34	1.34	1.14	0.99	1.05	1.00	1.05	0.90	0.86	1.15	1.28	1.24	1.18	1.09	1.61

Table 5. District yield and aggregate area yield for 23 of North three regions in Ghana.

Districts and Aggregate Area Yield Descriptive Statistics from data in 1992-2008

DISTRICT	mean	SD=δ	skew	kurt	max	min
Bole/Sawla-Tuna-kalba	1.2305	0.5007	0.0558	-0.7168	2.0000	0.4000
East Gonja	1.1039	0.3457	0.7720	1.6221	2.0000	0.5132
East Mamprusi/BunkpuruguYunyoo	0.9913	0.3213	0.1640	0.4641	1.6915	0.3870
Gushiegu/Karaga	1.1314	0.3158	-0.2038	1.2180	1.7470	0.3989
Nanumba North/South	1.3154	0.2201	0.9245	0.4766	1.8000	1.0000
Saboba/Chereponi	1.2001	0.3738	0.5412	-0.3820	1.9387	0.5851
Savelugu/Nanton	1.0718	0.1782	-0.0807	-0.8548	1.4000	0.7752

Tamale Metropolitan	0.9450	0.3858	1.3838	1.0863	1.9000	0.6000
Tonlon/Kumbugu	1.1534	0.4163	0.1711	-0.3095	2.0000	0.4433
West Gonja/Central Gonja	1.0492	0.4645	0.6748	2.6775	2.2898	0.1200
West Mamprusi	1.2703	0.3013	0.2847	0.2779	1.9000	0.7000
Yendi	1.0387	0.4000	-0.4031	0.5742	1.6000	0.1000
Zabzugu/Tatale	0.8315	0.3723	1.5594	6.7779	2.0000	0.0750
Wa	1.2501	0.3633	-1.1339	1.5121	1.8000	0.3300
Lawra	0.7674	0.3206	0.7619	-0.5625	1.4100	0.3294
Sisara(Tumu)	1.4392	0.4340	-0.5401	1.6330	2.1000	0.3300
Jirapa	1.2064	0.3292	-0.9682	2.3174	1.7914	0.3300
Nadowli	1.2925	0.3877	-0.6831	1.1636	1.8926	0.3301
Builsa	0.7717	0.3155	0.7520	0.7908	1.5400	0.3300
Kasena/Nankana	0.9624	0.3633	0.2126	-0.5724	1.6700	0.3700
Bolgatanga(Bongo,Talensi Nabdab)	1.1238	0.4836	0.6803	-0.1628	2.0721	0.4430
Bawku East(Garu Tempane)	1.2245	0.4725	0.5761	-0.4878	2.1510	0.5479
Bawku West	1.0311	0.3529	0.4710	-0.9975	1.6800	0.5556
y- aggregate area yield	1.1480	0.1908	0.7078	0.7515	1.6148	0.8555

Table 6 : District yield and Aggregate area yield Ghana's north 3 region for maize (Mt/Ha)

DISTRICT as response variables	Intercept coef	Regression Coef	P-value
Bole/Sawla-Tuna-kalba	-1.05	1.99	0.0000
Zabzugu/Tatale	-0.97	1.57	0.0000
West Mamprusi	-0.16	1.24	0.0000
Gushiegu/Karaga	-0.11	1.08	0.0000
West Gonja/Central Gonja	-0.98	1.77	0.0010
East Mamprusi/Bunkpurugu-Yunyoo	-0.78	1.54	0.0020
Tamale Metropolitan	-0.62	1.37	0.0030
Savelugu/Nanton	0.37	0.61	0.0050
East Gonja	-0.68	1.56	0.0280
Tonlon/Kumbugu	-0.15	1.14	0.0320
Bawku West	0.01	0.89	0.0500
Saboba/Chereponi	0.23	0.85	0.0830
Builsa	-0.01	0.68	0.1020
Kasena/Nankana	0.17	0.69	0.1550
Yendi	0.17	0.75	0.1560
Lawra	0.19	0.5	0.2420
Nanumba North/South	0.98	0.29	0.3310
Wa	1.75	-0.4	0.3780
Jirapa	0.78	0.37	0.4050
Nadowli	0.88	0.36	0.4930
Sisara(Tumu)	1.89	-0.4	0.5060

Bawku East(Garu Tempane)	0.84	0.34	0.6040
Bolgatanga(Bongo,Talensi Nabdab)	0.99	0.12	0.8570

Table 7. 11 of 23 districts had P value of regression analysis less than 0.05. Only these 11 districts had a significant linear relation with aggregate area yield.

District name (total 23)	District expected yield μ_i (Mt/Ha)	$\beta_i = cov(y_i,y)/var(y)$	MSE= $(y_i-y_i')^2/n$ when $\beta_i = cov(y_i,y)/var(y)$	$\beta_i=\mu_i/\mu$	MSE= $(y_i-y_i')^2/n$ when $\beta_i=\mu_i/\mu$	Pearson correlation: Aggregate area yield vs. distrists	P-value
East Mamprusi/ Bunkpurugu-Yunyoo	0.99	1.45	0.02	0.86	0.03	0.917	0
East Gonja	1.1	1.46	0.03	0.96	0.04	0.858	0
Zabzugu/Tatale	0.83	1.47	0.05	0.72	0.07	0.802	0
West Mamprusi	1.27	1.17	0.03	1.11	0.03	0.788	0
Bole/Sawla-Tuna-kalba	1.23	1.87	0.1	1.07	0.13	0.757	0
West Gonja/Central Gonja	1.05	1.66	0.1	0.91	0.12	0.726	0.001
Tamale Metropolitan	0.95	1.29	0.08	0.82	0.09	0.676	0.003
Gushiegu/Karaga	1.13	1.02	0.05	0.99	0.05	0.655	0.004
Savelugu/Nanton	1.07	0.57	0.02	0.93	0.02	0.651	0.005
Tonlon/Kumbugu	1.15	1.07	0.12	1	0.12	0.522	0.032
Bawku West	1.03	0.84	0.09	0.9	0.09	0.482	0.05
Saboba/Chereponi	1.2	0.8	0.11	1.05	0.11	0.433	0.083
Builsa	0.77	0.64	0.08	0.67	0.08	0.41	0.102
Yendi	1.04	0.71	0.13	0.9	0.13	0.36	0.156
Kasena/Nankana	0.96	0.65	0.11	0.84	0.11	0.36	0.155
Lawra	0.77	0.47	0.09	0.67	0.09	0.3	0.242
Nanumba North/South	1.32	0.27	0.04	1.15	0.07	0.251	0.331
Jirapa	1.21	0.35	0.1	1.05	0.11	0.216	0.405
Nadowli	1.29	0.34	0.14	1.13	0.16	0.179	0.493
Bawku East(Garu Tempane)	1.22	0.32	0.21	1.07	0.22	0.136	0.604
Bolgatanga(Bongo,Talensi Nabdab)	1.12	0.11	0.22	0.98	0.24	0.047	0.857
Sisara(Tumu)	1.44	-0.37	0.17	1.25	0.26	-0.173	0.506
Wa	1.25	-0.41	0.12	1.09	0.2	-0.228	0.378
Expected Aggregate Area Yield μ=1.15		↑ 0.94 Avg. of column	↑ Avg 0.09 SD=0.054885	↑1.00 Avg. of column	↑Avg 0.11 SD=0.067321		

Table 8. Comparison of the MSE for two different estimates for the beta coefficient. The first estimate is preferred because its MSE is lower in all cases. and correlation analysis district vs. area yield. Here y_i actual i district yield, y_i^i estimated yield using different model for beta,y aggregate area yield.see table 5.

	District Beta $\beta_i = cov(y_i, y)/var(y)$	Premium P=EI(y) Actuarially fair	District Beta $\beta_i = \mu_i/\mu$	Premium P=EI(y) $P = \beta_i * (y_m - \mu)$ actuarially fair
	1.87	0.87	1.25	0.59
	1.66	0.78	1.15	0.53
	1.47	0.69	1.13	0.53
	1.46	0.68	1.11	0.52
	1.45	0.68	1.09	0.51
	1.29	0.60	1.07	0.50
	1.17	0.55	1.07	0.50
	1.07	0.50	1.05	0.49
	1.02	0.48	1.05	0.49
	0.84	0.39	1.00	0.47
	0.80	0.37	0.99	0.46
	0.71	0.33	0.98	0.46
	0.65	0.30	0.96	0.45
	0.64	0.30	0.93	0.44
	0.57	0.27	0.91	0.43
	0.47	0.22	0.90	0.42
	0.35	0.16	0.90	0.42
	0.34	0.16	0.86	0.40
	0.32	0.15	0.84	0.39
	0.27	0.13	0.82	0.38
	0.11	0.05	0.72	0.34
	-0.37	0.00	0.67	0.31
	-0.41	0.00	0.67	0.31
Average	0.77	0.38	0.96	0.45

Table 9. Premiums in metric ton per cropped hectare. Here y_m max area yield.

Percent mean area yield	Critical yield y_c (Mt/Ha)	Critical Beta $\beta c = -Var(I(y))/2Cov(y, I(y))$	Expected Indemnity P=E(I(y)) (Mt/Ha)
75.00%	0.86	0.01 min	0.00
80.00%	0.92	0.09	0.00
85.00%	0.98	0.18	0.01
90.00%	1.03	0.22	0.03
95.00%	1.09	0.27	0.05
100.00%	$\mu \approx 1.15$	0.32	0.07
105.00%	1.21	0.37	0.11

110.00%	1.26	0.42	0.15
115.00%	1.32	0.45	0.19
120.00%	1.38	0.47	0.24
125.00%	1.44	0.47	0.30
130.00%	1.49	0.49	0.35
135.00%	1.55	0.51	0.41
140.00%	μ_{max}≈1.61	0.53 theoretical max	0.46

Table 10. The critical beta rises as the critical yield is increased, the critical beta achieves its theoretical min of zero and its max of 0.53. Also shows that actuarially fair premium rises with critical yield level.

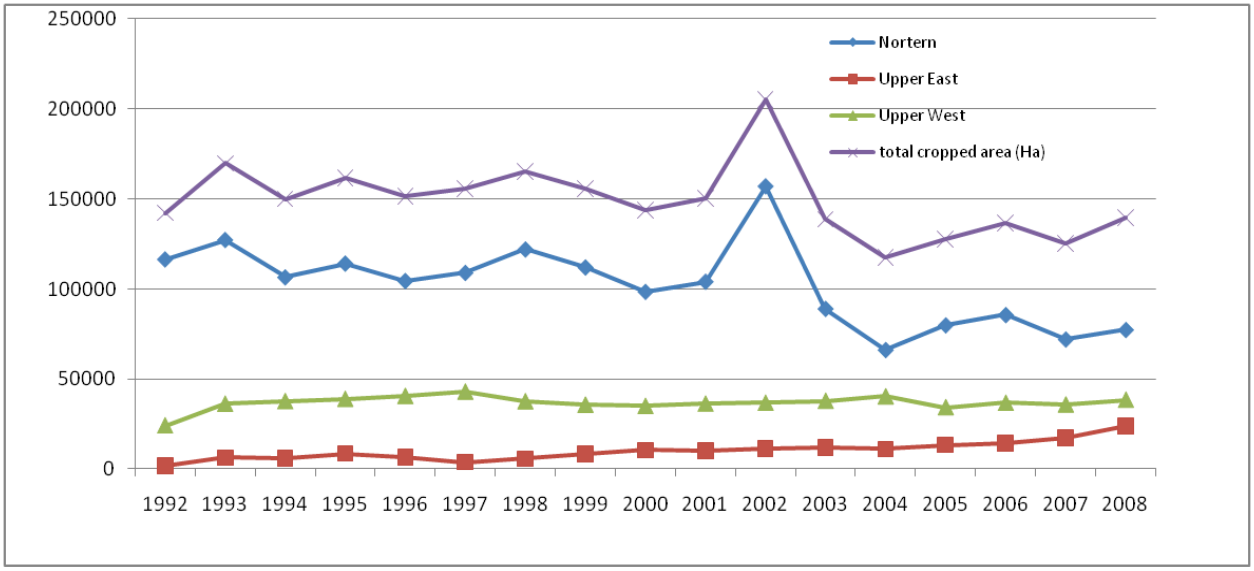
District beta β_i	95%	100%	105%	110%	115%	120%	125%	130%	**135%**	**140%**	**Premium**	**Premium**
1.87	3.46	2.89	2.55	2.25	2.07	2.01	1.97	1.92	**1.85**	**1.77**	**0.86**	**0.83**
1.66	3.08	2.57	2.27	2.00	1.84	1.79	1.76	1.71	**1.65**	**1.58**	**0.77**	**0.74**
1.47	2.72	2.27	2.01	1.77	1.63	1.58	1.55	1.51	**1.46**	**1.40**	**0.68**	**0.65**
1.46	2.71	2.26	2.00	1.76	1.62	1.57	1.54	1.50	**1.45**	**1.39**	**0.68**	**0.65**
1.45	2.69	2.24	1.98	1.75	1.61	1.56	1.53	1.49	**1.44**	**1.38**	**0.67**	**0.64**
1.29	2.38	1.99	1.75	1.55	1.42	1.38	1.36	1.32	**1.27**	**1.22**	**0.59**	**0.57**
1.17	2.16	1.81	1.60	1.41	1.30	1.26	1.23	1.20	**1.16**	**1.11**	**0.54**	**0.52**
1.07	1.98	1.65	1.46	1.29	1.19	1.15	1.13	1.10	**1.06**	**1.01**	**0.49**	**0.47**
1.02	1.89	1.57	1.39	1.23	1.13	1.09	1.08	1.05	**1.01**	**0.97**	**0.47**	**0.45**
0.84	1.55	1.29	1.14	1.01	0.93	0.90	0.88	0.86	**0.83**	**0.79**	**0.39**	**0.37**
0.80	1.48	1.23	1.09	0.96	0.88	0.86	0.84	0.82	**0.79**	**0.76**	**0.37**	**0.35**
0.71	1.31	1.09	0.97	0.85	0.79	0.76	0.75	0.73	**0.70**	**0.67**	**0.33**	**0.31**
0.65	1.19	1.00	0.88	0.78	0.71	0.69	0.68	0.66	**0.64**	**0.61**	**0.30**	**0.29**
0.64	1.18	0.98	0.87	0.77	0.71	0.68	0.67	0.65	**0.63**	**0.60**	**0.29**	**0.28**
0.57	1.06	0.88	0.78	0.69	0.63	0.61	0.60	0.59	**0.57**	**0.54**	**0.26**	**0.25**
0.47	0.88	0.73	0.65	0.57	0.53	0.51	0.50	0.49	**0.47**	**0.45**	**0.22**	**0.21**
0.35	0.65	0.54	0.48	0.42	0.39	0.38	0.37	0.36	**0.35**	**0.33**	**0.16**	**0.15**
0.34	0.63	0.53	0.47	0.41	0.38	0.37	0.36	0.35	**0.34**	**0.32**	**0.16**	**0.15**
0.32	0.58	0.49	0.43	0.38	0.35	0.34	0.33	0.32	**0.31**	**0.30**	**0.15**	**0.14**
0.27	0.50	0.42	0.37	0.33	0.30	0.29	0.29	0.28	**0.27**	**0.26**	**0.13**	**0.12**
0.11	0.21	0.17	0.15	0.14	0.12	0.12	0.12	0.12	**0.11**	**0.11**	**0.05**	**0.05**
-0.37	-0.69	-0.57	-0.51	-0.45	-0.41	-0.40	-0.39	-0.38	-0.37	-0.35	0.00	0.00
-0.41	-0.76	-0.63	-0.56	-0.49	-0.45	-0.44	-0.43	-0.42	-0.40	-0.39	0.00	0.00

Table 11. if critical yield less than 130% of mean aggregate area yield ($\mu \approx 1.15$) then The optimal coverage level is lower than district beta, $0 \le \phi_i \le \beta_i$ condition is not satisfied. So critical yield should be $y_c > 135\%$ of mean aggregate area yield in Northern Ghana maize data set. Farmer can choose the critical area yield between 1.55 and 1.61 Mt/Ha, but there is no deductable in this contract.

β_i=cov(y_i,y)/var(y)	Coverage level $\phi_i = \beta_i / 2\beta c$		The maximum risk deduction $\Delta_i=\rho^2 \beta_i^2$ var(y)		Premiums with coverage level ϕ_i	
	βc=0.51 135%	βc=0.53 140%	βc=0.51 135%	βc=0.53 140%	βc=0.51	βc=0.53
1.87	**1.85**	**1.77**	**0.1267**	**0.1273**	**0.86**	**0.83**
1.66	**1.65**	**1.58**	**0.1004**	**0.1009**	**0.77**	**0.74**
1.47	**1.46**	**1.40**	**0.0787**	**0.0790**	**0.68**	**0.65**
1.46	**1.45**	**1.39**	**0.0776**	**0.0780**	**0.68**	**0.65**
1.45	**1.44**	**1.38**	**0.0765**	**0.0768**	**0.67**	**0.64**
1.29	**1.27**	**1.22**	**0.0600**	**0.0603**	**0.59**	**0.57**
1.17	**1.16**	**1.11**	**0.0496**	**0.0499**	**0.54**	**0.52**
1.07	**1.06**	**1.01**	**0.0416**	**0.0418**	**0.49**	**0.47**
1.02	**1.01**	**0.97**	**0.0377**	**0.0379**	**0.47**	**0.45**
0.84	**0.83**	**0.79**	**0.0255**	**0.0256**	**0.39**	**0.37**
0.80	**0.79**	**0.76**	**0.0231**	**0.0232**	**0.37**	**0.35**
0.71	**0.70**	**0.67**	**0.0182**	**0.0183**	**0.33**	**0.31**
0.65	**0.64**	**0.61**	**0.0151**	**0.0152**	**0.30**	**0.29**
0.64	**0.63**	**0.60**	**0.0147**	**0.0148**	**0.29**	**0.28**
0.57	**0.57**	**0.54**	**0.0119**	**0.0119**	**0.26**	**0.25**
0.47	0.47	0.45	0.0082	0.0082	0.22	0.21
0.35	0.35	0.33	0.0045	0.0045	0.16	0.15
0.34	0.34	0.32	0.0042	0.0042	0.16	0.15
0.32	0.31	0.30	0.0036	0.0036	0.15	0.14
0.27	0.27	0.26	0.0027	0.0027	0.13	0.12
0.11	0.11	0.11	0.0005	0.0005	0.05	0.05
-0.37	-0.37	-0.35	0.0050	0.0050	0.00	0.00
-0.41	-0.40	-0.39	0.0061	0.0061	0.00	0.00
Average	**0.76**	**0.73**	**0.03**	**0.03**	**0.43**	**0.41**

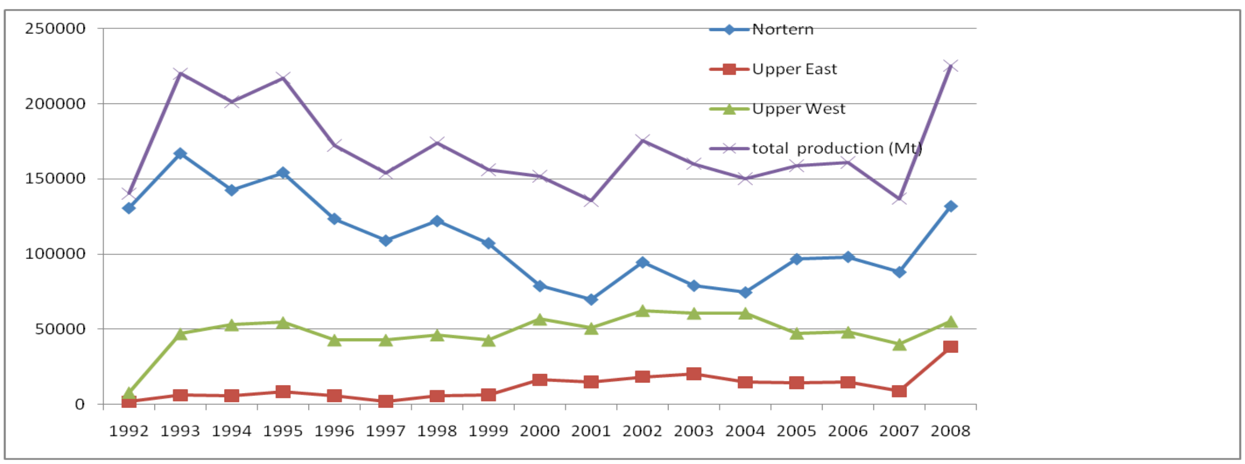
Table 12. 8 districts have β_i<0.51 which means 34.7% not optimally coverage, 6 of them have positive betas , where βc=0.51 is calculated for the critical yield 135% of expected area yield ,$y_c=1.35\mu$,ρ^2= 0.9954. βc=0.53 is calculated for the critical yield 140% of expected area yield, $y_c=1.4\mu$, ρ^2= 0.9999 ,ρ is the correlation coefficient between the indemnity I(y) and the area yield y

Graphs

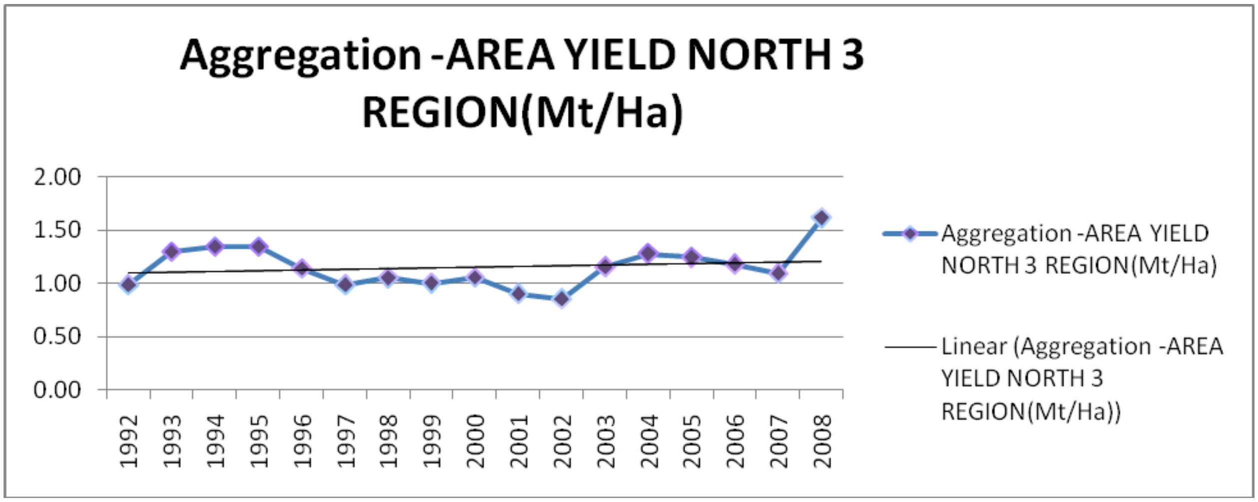


Production for maize

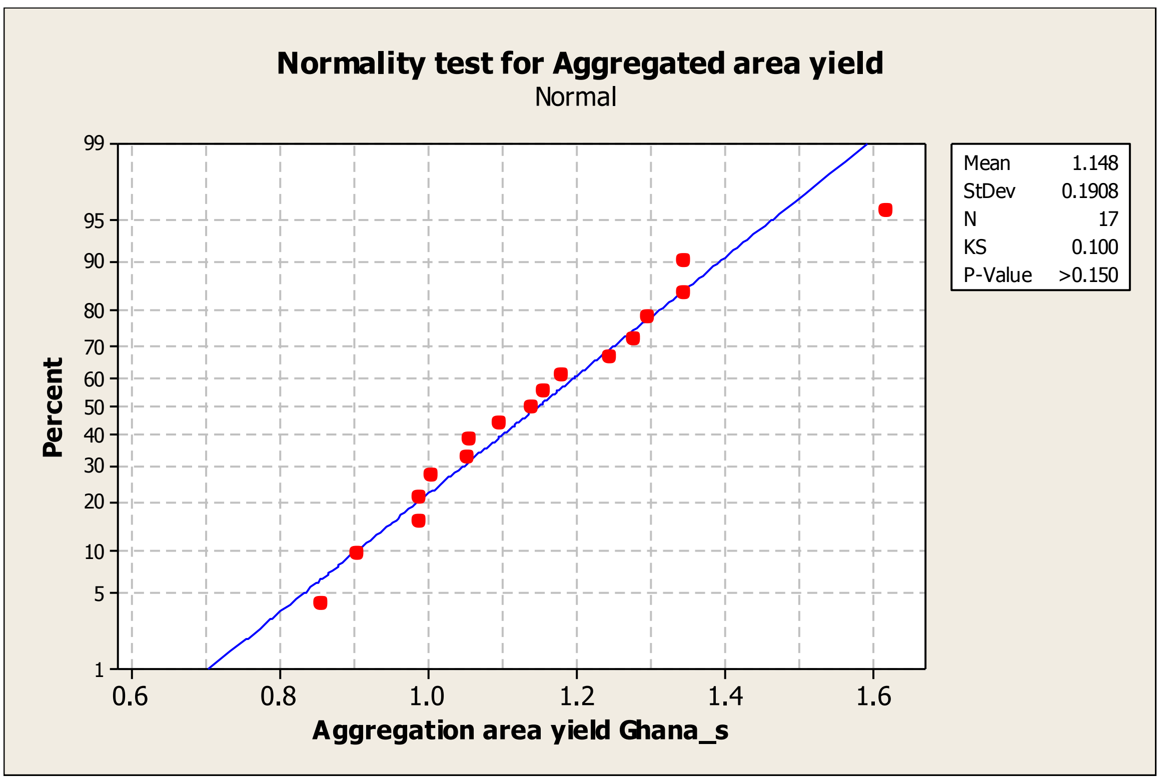
Graph 1. Region based production. Production for maize crop is measured in Metric Tons (Mt).



Graph 2. Region based cropped area for maize, measured in Hectare (Ha). 1 hectare = 2.471 acres



Graph 3. Yield for maize crop is measured in Metric Tons per Hectare (Mt/Ha). 1 hectare = 2.471 acres



Graph 4.

```
Test of mu = 1.148 vs. > 1.148

                                    95% Lower
 N     Mean    StDev  SE Mean       Bound      T      P
17   1.1480   0.1908   0.0463      1.0672   0.00  0.500
```

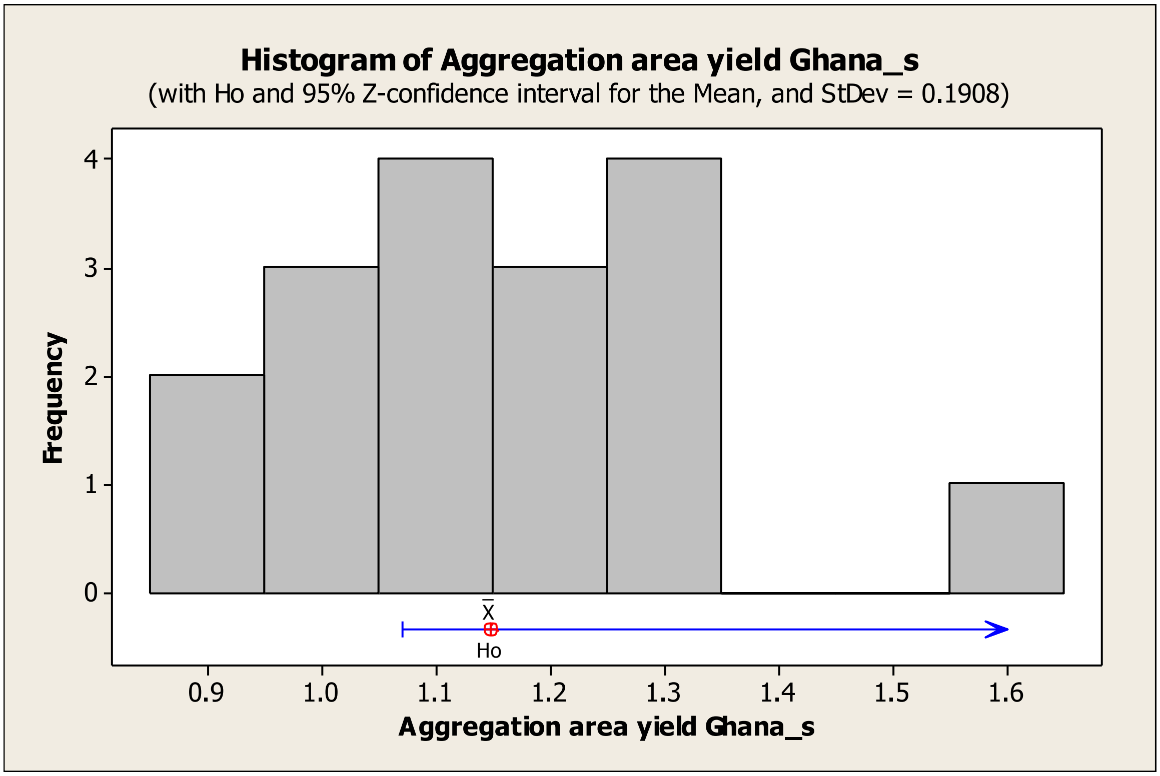
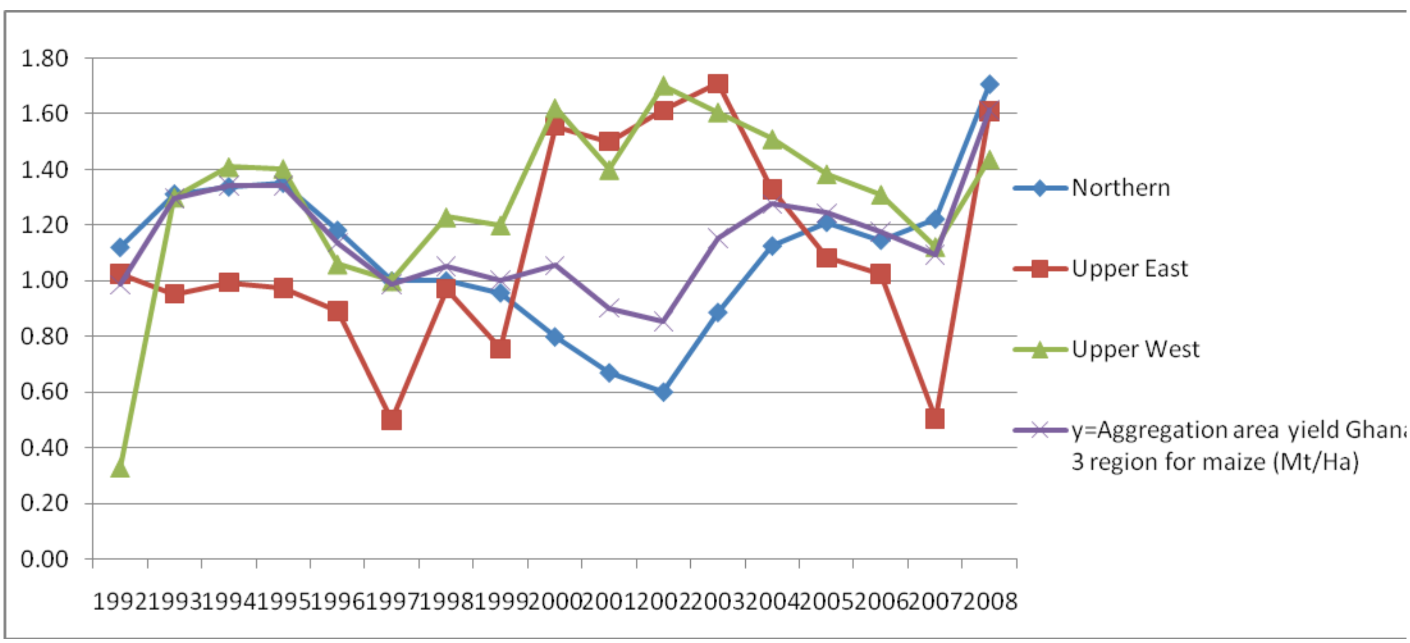


Figure 5



Graph 6.Each Region's aggregate area yield separately from total 3 regions' aggregate area yield.