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Impact of Climate Change on Food Security of Rural Householders in Gibaish Locality of West Kordofan State, Sudan

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Abstract The current study focused on the linkage between climate change and food security of rural householders in Gibaish locality, western Sudan. The overall objective was to explore the level of food security and impacts of climate change variables on the food security of rural householders in the study area. Multistage-stratified random sampling technique was used to select 70 households. Data were obtained from both primary and secondary sources and analyzed using descriptive statistics, household economy approach, linear programming, partial crop budget, dominance analysis, marginal analysis, sensitivity analysis, linear regression and correlation coefficients analysis were employed. In this study, the household's economy approach for the daily energy received per person per day in K. calories was estimated as 2105. With respect to WHO, minimum rate of 2300 K. calories per person per day was set as standard level. Therefore, this result implies that the household is marginally food insecure. Linear programming results indicated that the maximum combination that maximized farmer's income was attained by millet, groundnut and okra crops combination with a total SDG 11,148 (1 $ = SDG 6.64). When taking into consideration the household's food consumption behavior it was found that increase over decrease was lesser by 184%. These results ensured that the proportional combination of the food items consumed at local level would not enable the households to meet their minimum energy requirement for a healthy and active life. It was also noted that climatic variation in year 2013 cropping season has negative impact on food security situation. Partial crop budget revealed that all crops gave positive net returns. Groundnut and okra gave maximum net benefits of SDG 2056 and SDG 1380, respectively. Dominance analysis showed that Gum Arabic and Roselle were dominated due to their lower net field benefits as compared to other treatments. Results of marginal analysis showed that maximum marginal rate of return of 13733.4% was obtained by groundnut). It is noted that farmers with poor resources can accomplish returns of SDG 1.00 benefits by sowing groundnut to obtain additional SDG 137.3.Sensitivity analysis that assumed costs over run and benefits shortfall revealed that groundnut and sorghum combination was of high Marginal Rate of Return (MRR) of 12,484.9, 12,360 and 537.9 and SDG 532.5, respectively. Linear regression ensured that maximum average temperature significantly ($P \leq 0.05$) affected millet production. Other food production crops were not affected by climatic factors. Correlation coefficients showed increasing temperature and rainfall fluctuation was reported as major threats to food production. Sorghum was negatively (-0.705, p=0.01) correlated with time and growing period, millet moderately correlated with time (-0.494). However, sesame, groundnut, Roselle, cowpea and watermelon were weakly and negatively correlated with time. Consequently, millet (-0.385), sorghum (-0.128), sesame (-0.266), groundnut (-0.185), Roselle (0.242), cowpea (0.185) and watermelon (0.034) were not significantly affected, and it has negative and positive minimum correlation with average maximum temperature.

Keywords Climate Change, Regression, West Kordofan, Linear Programming, Partial Budget

1. Introduction

FAO (2012) stated food security is likely to be affected by climate change (CC) in several ways: food security depends not only on the direct impact of CC on food production, but also on its indirect impacts on human development, economic growth, trade flows, and food aid policy. Agriculture is the practice of crop cultivation and livestock keeping. The choice of what to produce and how to produce is determined by the culture, traditions, market, water supply, climate, soil condition, plot size and distance from home (Denen, 2013). Gibaish locality lies in the western side of the state. According to FAO (2008), food security is the outcome of food system processes all along the food chain. Climate change will presumably affect food security through its impacts on all components of global, national and local food systems. Holt *et al* (2000) has pointed out that the aim of Household Economy Approach (HEA) was to find a method that could indicate the likely effect of crop failure or other shocks on future food supply. Food security is a situation that exists when all people at all times have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (Lobell, 2012). With reference to Yue, (2013) linear programming (LP) is a powerful analytical tool that can be used to determine an optimal solution that satisfies the constraints and requirements of the current situation. This method consists of three quantitative components: (1) objective function (maximization of profit or minimization of costs); (2) constraints (limitation of production sources); and (3) decision variables. The multiple linear regression models are an extension of a simple linear regression model to incorporate two or more explanatory variable in a prediction equation for a response variable. Multiple regression modeling is nowadays a mainstay of statistical analysis in most fields because of its power and flexibility (Brant, 2007).

Gibaish locality is located in the western part of the state with an estimated population of 929758 persons whom primarily rely on agricultural activities for their living. The area is occupied by arid agro-climatic zone. The study area receives an annual summer rainfall of 250 mm to 450 mm. The rainy season begins at about the end of June and lasts until early October, while the dry season begins in last October and ends in early June. Temperature is relatively lower and ranges between 23ºC and 25ºC in the wet season throughout the Ataman except in March – June when sun shine reached and ranged from 35ºC to 40ºC.

Virtually all householders in the study area rely solely on agricultural activities for their livelihoods. Small holders, rainfed subsistent farming is widely practiced. Groundnut, sesame, watermelon and Roselle are cultivated as cash crops added to Gum Arabic tree plantations. Millet and sorghum are grown as staple food crops. Food gaps and shortages are frequently encountered due to biotic and a biotic factors that curb their crop production. The overall objective of the current study was to evaluate the level of food security and impacts of climate change variables on the food security of rural householders in the study area.

2. Materials and Methods

The overall approach and methodology for the livelihood survey work carried out in Gibaish locality, West Kordofan State, based on both and primary secondary sources of data for climate change impact on food security. In particular, the field level householder questionnaires designed to gather information through multi-stage stratified random sample technique for 78 selected households. Climatic data on Average temperature and total rainfall were obtained from Khartoum and Elnuhood meteorological stations for statistical series data (2000 -2013). While crop yield data were sourced from Ministry of Agriculture in North and western Kordofan states.

Crops grown are watermelon, Gum Arabic, groundnut and Roselle

Descriptive statistics, Household Economy Approach, Linear programming, Partial crop budget, and multiple linear regression and correlation coefficient models were applied.

2.1. Descriptive Statistics

Descriptive statistics are most often used to examine, central tendency (location) of data, i.e. where data tend to fall, as measured by the mean, median, and mode. Dispersion (variability) of data, i.e. how spread out data was, as measured the variance and its square root, the standard deviation. skew (symmetry) of data, i.e. how concentrated data was at the low or high end of the scale, as measured by the skew index. kurtosis of data, i.e. how concentrated data was around a single value, as measured by the kurtosis index.

2.2. Household Economy Approach

Household economy approach is a method of analyzing the impact of crop failure and other shocks on household income and access to food (Holt *et al* 2000).

2.3. Linear Programming Model

Kernighan *et al* (2003) ensured that linear programs are particularly important because they accurately represent many practical applications of optimization. The simplicity of linear functions makes linear models easy to formulate, interpret, and analyze. They are also easy to solve; if you're a problem can be expressed as a linear program, even in thousands of constraints and variables, then one can be confident of finding an optimal solution accurately and quickly.

2.4. Partial Crop Budget

Partial budgeting is a planning and decision-making framework farm business owners can use to compare the costs and benefits of alternatives they face. It allows producers to get a better handle on how a decision will affect the profitability of the business enterprise and the farm itself. This publication explains how to use partial budgeting and explains its benefits in making farm business decisions. A partial budget helps farm owners/managers to evaluate the financial effect of incremental changes. A partial budget only includes resources that subject to changes. It does not consider the unchangeable resources in the business. Only the change under consideration is evaluated for its ability to increase or decrease income in the farm business (Tigner, 2006).

2.5. Multiple Linear Regressions

The multiple linear regression models are an extension of a simple linear regression model to incorporate two or more explanatory variable in a prediction equation for a response variable. Multiple regression modeling is now a mainstay of statistical analysis in most fields because of its power and flexibility (Brant, 2007).

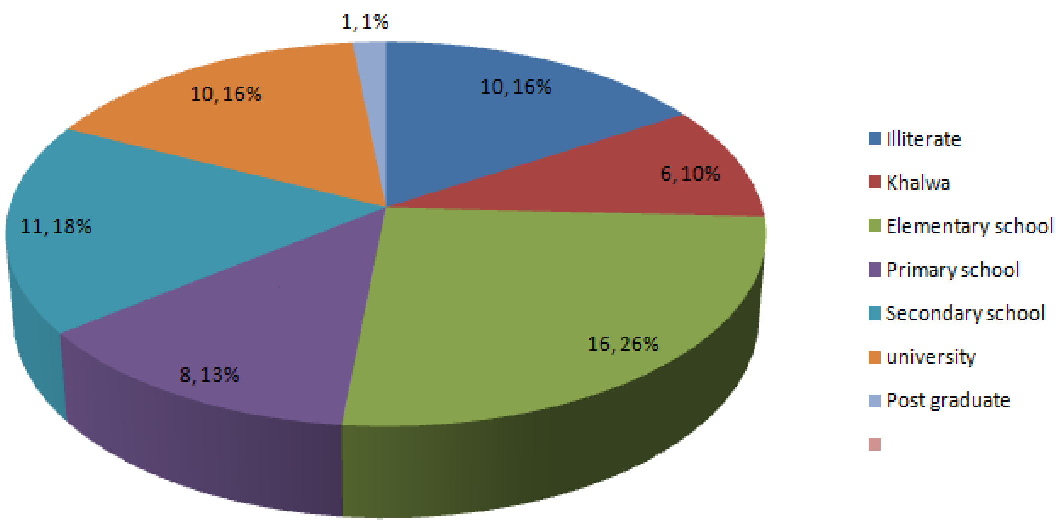
2.6. Correlation Model

A correlation coefficient is a statistical measure of the degree to which changes to the value of one variable predict change to the value of another. In positively correlated variables, the value increases or decreases in tandem, whereas for negatively correlated variables, the value of one increases as the value of the other decreases (Wigmore, 2013).

3. Results and Discussion

Socioeconomic characteristics of education level in the study area revealed that 84% of sample householders were exposed to some sort of education. This observation meant presence of literate farmers in the study area equipped with additional local knowledge to cope with climate change and food insecurity than those who had no formal education. These results reconciled with Hamilton (2010) whose opinion that climate change has decreased with education among Republicans, Figure 1.

Household economy approach results founded that the average quantity of energy received by a single householder per a week during summer, autumn and winter was calculated as being SDG 31404. While the daily energy received per person per day was found to be SDG 2105. This results highlight that household is marginally food insecure, (Table 1) based on the standard set by WHO (2300 K. calories).



Source: HH survey 2014

Figure 1. Socioeconomic distribution of education level in the study area

Table 1. Household Weekly minimum Food Need and the equivalent K.cal, Gibaish locality

Food items		Seasons								
		Summer			Autumn			Winter		
	Kcal/kg	qt.kg	total Kcal	%share	qt.kg	total Kcal	%share	qt.kg	total Kcal	%share
Millet	3350	9	30150	27.1	9.3	31155	26.3	10	33500	27.0
Sorghum	3350	5.5	18425	16.6	5.9	19765	16.7	6.6	22110	17.8
wheat	3320	4.7	15604	14.0	4.8	15936	13.5	4.8	15936	12.9
Meat	2020	2.9	5858	5.3	2.9	5858	4.9	2.9	5858	4.7
Milk	660	3.3	2178	1.9	3.3	2178	1.8	3.3	2178	1.8
Sugar	4000	4.0	16000	14.4	4.0	16000	13.5	4.2	16800	13.6
Tea	1080	0.35	378	0.3	0.32	346	0.3	0.32	346	0.3
Coffee	685	0.51	349	0.3	0.52	356	0.3	0.52	356	0.3
Onion	410	4.1	1681	1.5	4.4	1804	1.5	4.4	1804	1.5
Oil	8840	2.3	20332	18.3	2.8	24752	20.9	2.8	24752	19.9
Dry Okra	350	0.81	284	0.3	0.81	284	0.2	0.82	284	0.2
Total			111239			118434			123924	
Per person/day(8)									2105	

Source: HHS survey 2014

Results of linear programming model ensured that Production of one hectare requires 18, 20, 28, 17, 4, 28, 31, 18, and 60, 171, 176, 270, 122, 122, 85, 32, 23 and 45 of labor man hours and working capital for the above decision variables, respectively. A total of 383 man hours of labor were potentially available for providing family workers during the cropping season. Groundnut is more profitable with a gross margin of SDG6267.27.The minimum requirement of household's food expenditure for maintains a livelihood was found to be SDG31, 404. The maximum combination that maximizes farmers' income was reached by millet, groundnut and okra with a total SDG 11,148. When taking into consideration the household's food consumption behavior it was found that increase over decrease was lesser by 182%. These results indicated that the proportional combination of the food items consumed at local level will not enable the household to meet minimum energy requirement for a healthy and active life. It is also noted that climatic variation in year 2013 cropping season negatively impact food security situation, as shown in Table 2. Partial crop budget showed that all treatments gave positive net return. A high return (SDG 2056) was obtained by groundnut and okra (SDG1380). This result implies that profitability would make this farming practice both beneficial and desirable (Table 3). The dominance analysis showed that Gum Arabic and Roselle were dominant due to their lower net field benefits as compared to other crop combinations (Table 4). Marginal analysis, in turn, showed that maximum MRR of 13,733.4% was obtained by groundnut. It is noted that farmers with poor resources can accomplish returns of SDG 1.00 benefits by sowing the groundnut to obtain additional SDG 137.3, (Table 5). Sensitivity analysis that assumed costs over run and benefits shortfall revealed that groundnut and sorghum has high MRR of SDG12, 484.9, 12360, 537.9 and 532.5, respectively. This result indicated that these crops were not sensitive to climate variation, (Tables 6 and 7), respectively.

Table 2. Optimal solution or farm plan for the base model in SDG/ha

Crop	Coefficients	Area/ha	Optimal solution	Final value SDG
millet	701	4.908075438	3440.56	3440.56
sorghum	820	0	0	0
Groundnut	2056	3.048281754	6267.27	6267.27
Sesame	944	0	0	0
Roselle	152	0	0	0
Watermelon	536	0	0	0
Cowpea	614	0	0	0
Okra	1380	1.043642807	1440.23	1440.23
Gum Arabic	302	0	0	0
Total GM				11148

Source: HHS survey 2014, SDG= Sudanese Genih

Table 3. Partial crop budget analyses, (averages taken to represent season 2013 for2012/2013- 2013/2014 cropping seasons)

Crop	Yield kg/ha	Gross field benefit	Costs that vary	Net returns SDG/ha
Millet	123	867	166	701
Sorghum	164	910	90	820
Groundnut	592	2155	99	2056
Sesame	313	2164	1220	944
Roselle	37	271	119	152
Watermelon	116	578	42	536
Cowpea	205	1311	697	614
Okra	247	4323	2943	1380
Gum Arabic	548	369	67	302

Source: HHS survey 2014

Table 4. Dominance analysis, (averages taken to represent season 2013 for 2012/2013-2013/2014 cropping seasons)

Crop	Yield kg/ha	Gross field benefit	Costs that vary	Net returns SDG/ha
T1watermelon	116	578	42	536
T2 Gum Arabic	548	369	67	302 D
T3Sorghum	164	910	90	820
T4 Groundnut	592	2155	99	2056
T5 Roselle	37	271	119	152 D
T6 Millet	123	867	166	701
T7 Cowpea	205	1311	697	614
T8 Sesame	313	2164	1220	944
T9 Okra	247	4323	2943	1380

Source: HHS survey 2014

Table 5. Marginal analysis (averages taken to represent season 2013 for 2012/2013-2013/2014 cropping seasons)

Crop	Costs that vary	Marginal costs	Net returns SDG/ha	Incremental net benefit	MRR= V/III* 100
I	II	III	IV	V	
T1watermelon	42	-	536	-	
T3Sorghum	90	48	820	284	591.7
T4 Groundnut	99	9	2056	1236	13733.4
T6 Millet	166	67	701	-1355	D
T7 Cowpea	697	531	614	-87	D
T8 Sesame	1220	523	944	330	63.1
T9 Okra	2943	1723	1380	436	25.3

Source: HHS survey 2014

Table 6. Sensitivity analysis, of costs overrun (averages taken to represent season 2013 for 2012/2013-2013/2014 cropping seasons)

Crop	Costs that vary	Marginal costs	Net returns SDG/ha	Incremental net benefit	MRR= V/III* 100
I	II	III	IV	V	
T1watermelon	46.2	-	536	-	
T3Sorghum	99	52.8	820	284	537.9
T4 Groundnut	108.9	9.9	2056	1236	12484.9
T8 Sesame	1342.0	1233.1	944	-1112	D
T9 Okra	3237.3	1895.3	1380	436	23.0

Source: HHS survey 2014

Table 7. Sensitivity analysis, of benefit shortfall, (averages taken to represent season 2013 for 2012/2013-2013/2014 cropping seasons)

Crop	Costs that vary	Marginal costs	Net returns SDG/ha	Incremental net benefit	MRR= V/III* 100
I	II	III	IV	V	
T1watermelon	42	-	482.4	-	
T3Sorghum	90	48.0	738.0	255.6	532.5
T4 Groundnut	99	9	1850.4	1112.4	12360
T8 Sesame	1220	1121	849.6	-1000.8	-
T9 Okra	2943	1723	1242.0	392.4	22.8

Source: HHS survey 2014

Table 8. Regression analysis of total crop production across climatic variables

Crop	Explanatory variables	Coefficients	Standard error	T. value	P. value	R	R2 %
	Constant	405370.2	203718.7	1.98985	0.07204	26	13
Millet	Max. average temperature	-10830.9	5593.998	-1.9362	0.0789*		
	Total rain fall mm	-26.1021	24.59876	-1.0611	0.31138		
	Years (time)	-1078.4	504.78	-2.136	0.054*		
	Y = 405370.2-10830.9-26.1021 -1078.4+ E						
	Constant	129633	128323	1.01021	0.3341	9.1	7.5
Sorghum	Max. average temperature	-3387.4	3523.7	-0.9613	0.35704		
	Total rain fall mm	-11.559	15.495	-0.7456	0.47133		
	Years (time)	-032.3	236.2	-3.524	0.0042**		
		Y = 129633-3387.4-11.559 + E					
	Constant	-12368	58593.7	-0.2110	0.8367	4.2	13.2
sesame	Max. average temperature	427.468	1608.9	0.2657	0.7954		
	Total rain fall mm	-3.4575	7.0752	-0.4887	0.63467		
	Years (time)	-98.4	147.2	-0.668	0.5162		
		Y = -12368+427.468-3.4575 -3.4575-98.4+ E					
groundnut	Constant	240739.5	40898.4	0.5886	0.56799	18.3	3.4
	Max. average temperature	-6767.8	11230.4	-0.6026	0.55898		
	Total rain fall	54.503	49.384	1.10366	0.2933		
	Years (time)	559.9	1121.3	0.499	0.626		
		Y = 240739.5-6767.8+54.503 +559.9+ E					
Roselle	constant	4224.9	21488.3	0.1966	0.84772	11.0	5.2
	Av. Max. temp	-41.682	590.1	-0.0706	0.945		
	Total rainfall	-2.8589	2.59469	-1.1018	0.2941		
	Years (time)	-31.78	56.301	-0.564	0.583		
		Y = 4224.9-41.682-2.8589 -31.78+ E					
cowpea	constant	-276.2	30556.6	-0.0090	0.99296	1.9	0.6
	Av. Max. temp	49.293	839.1	0.0587	0.9543		
	Total rainfall	-1.485	3.6897	-0.4023	0.6951		
	Years (time)	-68.54	74.69	-0.918	0.3768		
		Y = -276.2+49.293-1.485 +-68.54 E					
W. Melon	constant	29331	32274.8	0.90879	0.38294	13.2	2.6
	Av. Max. temp	-728.9	886.24	-0.8225	0.4283		
	Total rainfall	-4.8131	3.8971	-1.2350	0.24255		
	Years (time)	-27.93	86.35	-0.323	0.7519		
		Y = 29331-728.9-4.8131 -27.93+ E					

Source: HHS survey 2014

Table 9. Correlation analysis (r)

Variables	millet	sorghum	sesame	g/nut	Roselle	cowpea	WM	years	Av. max. temp	Total RFL
Years	-0.494	-0.705**	0.117	0.341	-0.070	-0.190	-0.047	1	0.304	0.418
Av. max. temp	-0.385	-0.128	-0.266	-0.185	0.242	0.183	0.034	0.304	1	-0.347
Total RFL	-0.130	-0.162	-0.231	-0.362	-0.387	-0.179	-0.354	0.418	-0.347	1

Source: HHS survey 2014, WM=watermelon, av. max. temp = average maximum temperature, TRF=total rainfall

Multiple regressions exhibited that maximum average temperature significantly (P≤0.05, with 13% goodness of fit) affected millet production. These results indicated that 13% of variation on millet food production/ security was related to maximum average temperature. It was probable that climatic variables don't affect other food production crops. This is might be attributed to other production factors such as lack of credit, access to agricultural extension services as stated by households. These results coincide with Yang *et al* (2015) who pointed out that descriptive statistics could not reflect climate change and variability among climate parameters. Results of trend analysis revealed significant (P≤0.05) positive trend shown upon millet while it is higher (at ten percent) in sorghum food crops. This implies that climate change all over the period of the study impacted production of such food crops. Whereas there is no impact between time and the remaining crops produced, (Table 8). Correlation coefficients showed that increasing temperature and rainfall fluctuations were regarded by households as major threats to agricultural production including food production. Sorghum food crop was negatively (-0.705, p=0.01) correlated with time and growing period, whereas was millet moderately correlated with time (-0.494). However, sesame, groundnut, Roselle, cowpea and watermelon were weakly and negatively correlated with time. Consequently millet (-0.385), sorghum (-0.128), sesame (-0.266), groundnut (-0.185), Roselle (0.242), cowpea (0.185) and watermelon (0.034) were independent showing minimal negative and positive correlation with average maximum temperature. These results apparently indicate the importance of other intermingling factors such as soil fertility, access to credit and lack of improved technologies. This means that these crops require adequate minimum temperature to survive. The coefficients of food and other crop production across total rainfall were negatively correlated despite that they were not significant at 0.01 and 0.05 levels, (Table 9).

4. Conclusions

Socioeconomic indicators of households revealed that literate farmers in the study area were more successful in preventing and/or coping with climate change hazards and food insecurity than those who had no formal education. The maximum combination that maximized farmer's income indicated that the proportional combination of the food items consumed at local level would not enable the household to meet its minimum energy requirement for a healthy and active life. Partial budget ensured that all alternatives positively gave net returns and the minimum acceptable rate of returns can enable household farmers for further investment. Multiple linear regressions exhibited maximum average temperature significantly affected millet production. This is implies that 13% of variation on millet food production/ security was related to maximum average temperature. It is obvious that climatic variables didn't affect other food production crops. This might be attributed to other production factors such as lack of credit, access to agricultural extension services as stated by households. Correlation coefficient analysis displayed that increasing temperature and rainfall fluctuations were reported by households as major threats to agricultural production including food security.

REFERENCES

[1] Brant, R. (2007). Multiple linear regressions. P2

[2] Denen, A., T., (2013). Climate and grain crops yield in Kwara State, Nigeria. Department of Agricultural and Biosystems Engineering, Faculty of Engineering and Technology, University of IIorin, Nigeria. Journal of Emerging Trends in Engineering and Applied Science (JETEAS) 4 (5): 737-741. Scholar link Research Institute Journals (ISSN: 2141-7016). P 52.

[3] FAO, (2008). Climate change and food security: A Framework document. Food and Agricultural Organization of the United nations, Rome. P xi.

[4] FAO (2012). Potential impacts of climate change on food security in Mali. Natural Resources Management and Environment Department, Rome.

[5] Hamilton, L. (2010). Education, politics and opinions about climate change evidence for interaction effects. Springer Science + Business Media B.V.

[6] Holt, J., Seaman., J. Clarke, P. Boudreau. (2000). The household Economy Approach. A resource manual for practitioners. Save the Children Development Manual No. 6. Published by Save the Children 17 Grove Lane, London SE5 8 RD UK. P2.

[7] Kernighan, B. W. Fourer, R., and Brian, G. (2003). Linear programs: Objectives and constraints. P 129.

[8] Lobell, D and Burke, M. (2010). Climate Effects on food security: An Overview. Advances in Global Change Research 37, DOI: 10.1007/978-90-481-2953-9_2, Springer Science + Business Media, B.V.

[9] Tigner, R. (2006). Partial Budgeting: A tool to Analyze Farm Business Changes, Nebraska Extension Educator.

[10] Wigmore, I. (2013). Correlation coefficient. Part of the business intelligence-business analytics glossary.

[11] Yang, M., Amin, R. Md., Zhang, J. (2015). Effect of climate change on the yield and cropping area of Major food crops: A case of Bangladesh. College of Economics and Management, Huazhong Agricultural University, Wuhan 430070, China press.