SALINITY IMPACTS ON ENVIRONMENTAL EFFICIENCY OF WHEAT FARMS IN CENTRAL OF IRAQ

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ABSTRACT

A stochastic frontier approach is used for analyzing of the environmental impacts of soil salinity in Iraq. An econometric method based on the neoclassical production theory (stochastic frontier analysis) is transformed to enable the definition and estimation of environmental efficiency of wheat production farms in irrigated areas in central Iraq. The study is based on a sample of 360 farms. Farms were divided into three sub groups according to the soil salinity level - low salinity, medium salinity, and high salinity. The empirical results indicate that farmers are broadly environmentally inefficient. Based on an improved input mix, the average potential environmental impact reduction for low, medium, and high salinity farms is 24%, 36%, and 66 %, respectively, without compromising the economic returns. Moreover, the differences in environmental efficiencies between low and high level of soil salinity of farms were statistically significant. The second-stage regression analysis identifies that electric conductivity of soil and localization of farms have positive effects on efficiencies. Paradoxically, the formal education level is determined to affect the inefficiencies negatively, but insignificantly.

Key words: stochastic frontier analysis, soil salinity, environmental efficiency, wheat,
***Part of Ph.D. dissertation of the first author**

مجلة العلوم الزراعية العراقية -2018 :49(2):288-294 عبد الرضا وآخرون

تأثيرات الملوحة على الكفاءة البيئية لمزارع القمح في وسط العراق

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المستخلص

تم استخدام أسلوب تحليل الحدود العشوائية لغرض تقدير تأثيرات الملوحة على الكفاءة البيئية في العراق. وبالاعتماد على النظرية الاقتصادية في تفسير وتقدير الكفاءة البيئية لمزارع القمح في المناطق المروية وسط العراق. بالاعتماد على البيانات المقطعية التي تم جمعها من 360 مزارع. تم تقسيم المزارع وفق مستويات ملوحة التربة التي تم الحصول عليها من تحليل عينات التربة التي تم جمعها من تلك المزارع (منخفضة ومعتدلة ومرتفعه الملوحة). بصورة عامة كان مستوى الكفاءة البيئية منخفضا في اجمالي عينة البحث وحيث كان بالإمكان تحسين الكفاءة البيئية عن طريق الاستخدام الأمثل للموارد الضارة بيئيا وبذلك يمكن رفع الكفاءة البيئية بنسبة 24% و36% و66% لمستويات الملوحة المنخفضة والمعتدلة والمرتفعة بالتتابع. وأثبتت الدراسة بان هنالك فروق معنوية إحصائيا بين معدل الكفاءة البيئية في المستوى المنخفض وبين المستوى المرتفع. وكان كل من مستوى ملوحة التربة (التوصيل الكهربائي) وموقع المزرعة (تواجد المزرعة ضمن المشاريع المستصلحة) من المتغيرات المسببة لعدم الكفاءة البيئية. بينما كان المستوى التعليمي مؤثرا بصورة سلبية على عدم الكفاءة البيئية ولكن بصورة غير معنوية.

الكلمات المفتاحية: التحليل الحدودي العشوائي، ملوحة التربة، الكفاءة البيئية، القمح.
*** مستل من اطروحة الدكتوراه للباحث الاول.**

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INTRODUCTION

Globally, in 2050 there will be a 20% reduction in food production due to climate change factors (12). These factors, such as rainfall variation and increased temperatures give rise to the increase in soil salinity and land degradation (7). Abrol, calculated from various available data that the world as a whole is losing at least three hectares of arable land every minute because of salinization (1). Soil salinity has been affecting agricultural productivity in many countries worldwide especially in the developing arid countries and semiarid regions (15). In recent years, various regions have lost significant agricultural production due to soil salinity. There are no reliable estimates as to the effect of water logging and salinity on agricultural production at farm level, regional level, and global scale, as a result of human-environment interactions in arid and semi-arid regions (8). Iraq was self-sufficient in agricultural production in the 1950s, but in the decades of the 1960s, 1970s, and 1980s, the imported agricultural goods was about 15%, 33%, and 15%, respectively. In the last decade, Iraq has to rely on importing most of its agricultural needs (7). Nevertheless, the agriculture sector of Iraq supplies food, and generates work opportunities for more than 23.7 % of the population in which 50.3% are women (10).Iraqi Ministry of Planning (MOP) indicated that agricultural sector contributes to the Iraqi Gross Domestic Product (GDP) by 4.8,4.9, and 4.6 % in2013, 2014, and 2015,respectively (15). This contribution was very small comparing with the huge governmental support, and resources allocated to the Iraqi agricultural sector. The total land area of Iraq is 43 million ha, about 18.8% of it, is agricultural area, 9.2% is arable land, 9.5% is permanent meadows and pastures, 2% is forest and 39.5% represents areas not used for agricultural or forest purposes (9). The results from this study will help to opening a new dimension to farmers and policy makers on how to increase environmental efficiency (En.E) through reducing environmentally detrimental inputs in salt-affected areas by determining the extent to which it is possible to raise efficiency for salt-affected farmers with the existing resources base and available technology using resources to reach optimal level of allocative efficiency of inputs and resources. Environmental economics has made substantial progress in recent years in devising and refining non-market valuation methods. Externalities arise where there is no market connection between those taking an action, which has consequences on people social and economic welfare, and those affected by agricultural policy actions. The action studied is using fertilizers by farmers for crop production, where the run-off of nutrients from irrigated farmland into a river resulting in downstream pollution damage. The costs are borne by those whose welfare determined by the quality of water in the downstream. Using a frontier model for environmental efficiency estimation was pioneered by Reinhard and others in 1999. The ration of minimum feasible to actual observed use of environmental detrimental input is the Environmental Efficiency (13). In this study in Iraq, the environmentally detrimental inputs are Urea and DAP fertilizers. As fertilizer provide an increase in wheat yield, we hypothesis that fertilizers causes a decrease in environmental efficiency associated with different level of soil salinity. This research divided into five sections. Section one presents the methodological framework. The section two deals with sampling and data collection from wheat farmers in Iraq. In section three methodological framework will be discussed. Section four presents results and empirical findings. Finally, section five outlined the research conclusions including some relevant policy implications.

Data collection

The stratified random sampling technique is used. Household survey on wheat farmers for 2015/2016 production season was conducted in three districts (Aldboni, Alahrar, and Dujialy). Multi-stage sampling technique and Stevin Thomson Law[1]were used to calculate the sample size which was 360 households. Working with wheat farmers at Aldboni, Alahrar, and Dujialy districts, where 360 households were interviewed and soil samples were collected and analyzed. The face-to-face

[1] $n = \frac{N \times P(1-P)}{[[(N-1)\times(d^2 \div z^2)] + P(1-P)]}$.

interviews were conducted by the researcher. Based on secondary data assessment on the impact of salinity on wheat production and the share of wheat production, three districts have been selected in first stage, one district from each level of cultivable land affected by salinity. In addition, the selected districts have large share of wheat production as well, and geographical location was taken into the count based on the district position with respect to the Tigris River. Aldboni district is located in the upstream, while Dujialy district is on the downstream, and Alahrar district in the middle. In the second stage, we classify each district based on agricultural land types (1: Un-reclaimed land, 2: Un-reclaimed land located on the main river, 3: Semi-reclaimed land and 4: Reclaimed land. Only the villages totally inside each type have been included in the survey sample. In the third stage, a random sample in each selected village was used to choose randomly farmers of wheat proportional to the sample size of each district. The statistical analysis of socio-economic characteristics of wheat farmers, shows that there were three types of family in the study area, 45% of wheat farmers have a nuclear family structure, while 34 % and 21% have extended, and polygamous family structure, respectively. The descriptive analysis indicates also that About 54% of adults are women. Additionally, the age of interviewed wheat farmers ranged from 24 to 85 years, about 62% of farmers within the age group of 40 – 60 years, and 19 % of farmers classified in age category of over 60 years. Reflecting on age of wheat farmers on agricultural experiences,51% of farmers have over 30 years of agricultural experience. Table 1 presents statistical description of quantities of inputs and outputs, in which the impacts of soil salinity on resources used and productivity. The mean value of yield on wheat in the study area was around 2827 kg/ha. From the input side, the mean value of number of irrigation was 4 times/cropping season. The mean value of agricultural chemicals was 1.19 L/ha, applied in study area. Fertilizer Urea, fertilizer DAP, and seed used with mean values of 295 kg/ha, 230 kg/ ha and 253 kgha^{-1}, respectively. In fact, Table 1 shows the mean value of labour is 25 m-h-s/ha. Moreover, the one hectare of wheat was requiring an average of mechanization working for 7.32 hours during the production season of wheat. Soil testing laboratory provided the research with soil EC results which are included in table 1. In total samples, the EC analysis indicates an average of EC of4.77dS/m, which considered medium level of soil salinity.

Table 1: Impact of salinity on resource use and productivity

Variables [2] (Mean)	Salinity level[3]			
	S_1	S_2	S_3	Total
Yield (Kg/ha)	3574	2743	1416	2827
No. of Irrigation; NOI (number)	4.27	4.1	4.07	4.18
Agricultural Chemicals[4]CH(L/ha)	1.11	1.18	1.37	1.19
Urea Fertilizer; Fer U(Kg/ha)	289	300	303	295
DAP Fertilizer ; Fer D (Kg/ha)	238	227	217	230
Seed; SQ(Kg/ha)	247	258	257	253
Labour;L (Man-Days/ha)	24	23	31	25
Mechanization; M (Mach -hours/ha)	7.25	7.43	7.32	7.32
Electric Conductivity; EC (dS m^{-1})	1.27	4.54	12.1	4.77

Source: own elaboration from survey data (2017)

Based on soil salinity level, Figure 1 shows the relationship between soil salinity and yield for each farm. The figure shows that only farms belongs to S_1 category produced yield more than 5000 kgha^{-1}, and farms in S_3 category could not produce yield more than 3000 kgha^{-1}.

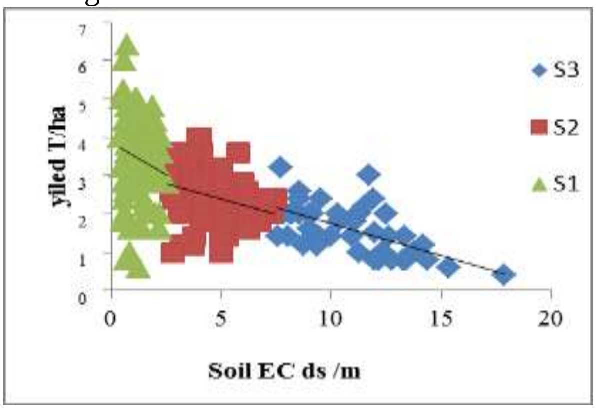

Figure 1. Yield and soil EC causality relationship

[2] Acronyms and units are the same in table 2

[3] Based on EC (Electric Conductivity) of the soil in the root zone, Irrigation water classification could be classified into three main classes (12):

a- S_1 is refer to LS (Low Salinity) less than 2.5 dS m^{-1}
b- S_2 is refer to MS (Medium Salinity) 2.5 – 7.5 dS m^{-1}
c- S_3 is refer to HS (High Salinity) higher than 7.5 dS m^{-1}

[4] Agricultural chemicals are also known as pesticides and include herbicides and fungicides.

MATERIALS AND METHODS

As well as different concepts about the production function, there are two main methods to calculate coefficient values for frontier models- parametric and non-parametric. Parametric approaches that comprise econometric models(Stochastic Frontier Analysis SFA), and Non-parametric models (Data Envelopment Analysis DEA), the latter DEA does not need to specify a functional form. The methodological framework used in this research is the parametric approach, which is one technique of estimating the farm's relative position to the frontier Figure 2.

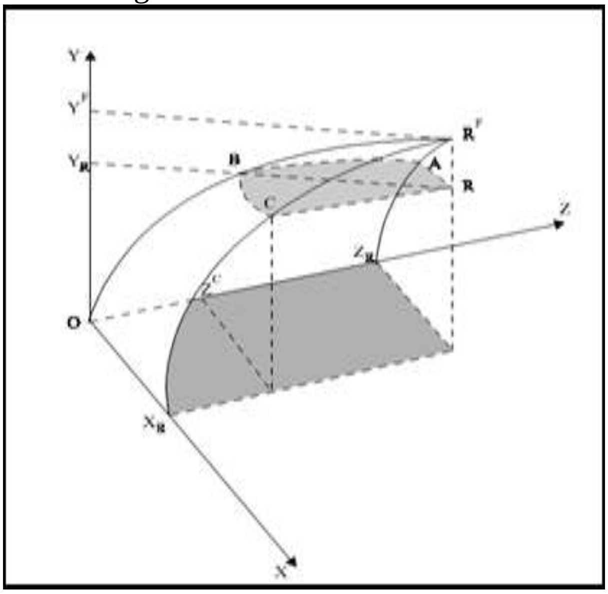

Figure 2. Environmental efficiency

Source: (6)

Figure 2 presents a basic idea of environmental variable. It shows, farm R used two inputs (x: environmentally safe or conventional input ,and z: environmentally detrimental input) to produce Y within best practice production frontier F(•), and Y ≤ F(X,Z). The frontier is the increasing, quasi-concave surface $0X_RR^FZ_R$. Y_R is the observed output, produced using X_R of the conventional input and Z_R of the environmentally detrimental input. ABCR is the surface with identical output quantity, Y_R, as farm R. Estimating the En.E of an individual farmer is defined in terms of the ratio of observed output to the corresponding frontier output with constant technology. So that the environmental efficiency of farm R is

$$En.E_R = \min\{\theta: F(X_R, \theta Z_R) \geq Y_R\} = |OZ^F|/|OZ_R|\ldots\ldots(1)$$

Where Z^F is the minimum feasible environmentally detrimental input use, given F(•)and the observed values of the conventional input X_R and output Y_R.

In Figure 2 the observed output Y_R is technically inefficient, since (Y_R, X_R, Z_R) lies beneath the best practice production frontier F(•). It is possible to measure technical efficiency using an input-conserving orientation, as the ratio of minimum feasible input to observe the input used, conditional on technology and observed output production. SFA approach used to estimate En.E level of wheat producers and the sources of inefficiency. The theoretical model of a SFA is defined by:

$$y_i = f(x_i; z_i; \beta_i)\exp(v_i - u_i)\ldots\ldots (2)$$

y_i= output of the ith far,$f(.)$is an appropriate function x_i is vector of input used by the ith farm,z_i is environmental input, and β_i is a vector of the unknown parameter to be estimated. i = 1.2.3 ,….. n (Number of farms),$v_i$is a random error which accounts for random variations in output because of factors out of the farmers' control such as weather, measurement error, etc, and$u_i$is a non-negative random variable representing inefficiency in output relative to the stochastic frontier. The error component v_i is assumed to be independently and identically distributed as $N\sim(0, \sigma_{v^2})$ were particularly concerned about the case of u_i where is derived from a distribution $N\sim(0, \sigma_{u^2})$ truncated at zero (i.e. an exponential or half normal distribution) (2),while Meeusen and Van den Broeck (14) considered only the case of Ui which has an exponential distribution (14). The independent variables were selected based on previous soil science studies consistently (3,4,5). Equation 3 is used to estimate En.E in the study area.

$$lnY_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln Z_3 + \beta_4 \ln Z_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + v_i - u_i\ldots\ldots (3)$$

The dependent variable, Y_i is the yield of wheat, measured in kilogram per hectare ($kgha^{-1}$), and$X_1$is a number of irrigation (NOI) during the cultivation season measure in number;X_2 is agricultural chemical which is quantity of chemical pesticide (CHP) measure in liters per hectare (lit/ha);Z_3 is the actual quantities used by farmers of Urea fertilizer used in wheat production measured in kilograms per hectare(kgha^{-1}) ;Z_4 is the actual quantities used by farmers of DAP fertilizer used in wheat production measured in kilograms per hectare (kgha^{-1}) ;X_5 is quantity of seed (SQ) used measure in kilograms per hectare (kgha^{-1}); X_6 is Labors quantity (L) employed during the season of wheat production, measured in man-days per hectare (man-days/ha); X_7 is mechanization (M) in wheat production measured in machine-hours per hectare (Mach-hours/ha). The maximum likelihood method was used to estimate the impact of these socio-economic factors on environmental efficiency of the farmers. The Maximum Likelihood Estimation (MLE) method used to estimate the inefficiency model below :

$$\boldsymbol{ui = \sigma_0 + \sigma_1 z_1 + \sigma_2 z_2 + \sigma_3 z_3 + \sigma_4 z_4 + \sigma_5 z_5 + \sigma_6 z_6 + \sigma_7 z_7}$$ [5]

$$\boldsymbol{\sigma_1, \sigma_2, \sigma_3, \ldots\ldots\ldots\ldots..\sigma_7}$$

Unknown parameters to be estimated.

$$lnY_i = \beta_0 + \beta_1 \, ln\, X_1 + \beta_2 \, ln\, X_2 + \beta_3 \, ln\, Z_3^F + \beta_4 \, ln\, Z_4^F + \beta_5 \, ln\, X_5 + \beta_6 \, ln\, X_6 + \beta_7 \, ln\, X_7 + v_i \ldots\ldots\ldots\ldots\ldots..(4)$$

In which Z_3^F and Z_4^F are minimum feasible inputs Urea and DAP fertilizers respectively. The yield in both equations are identical, so be rearrange equation 3 with 4 we gain

$$\boldsymbol{0 = ln(Z_3^F/Z_3) + ln(Z_4^F/Z_4) - u_i}\textbf{.......(5)}$$

So that

$$\boldsymbol{ln\, En.E = ln(Z_3^F/Z_3) + ln(Z_4^F/Z_4)}\textbf{....(6)}$$

RESULTS AND DISCUSSION

Quantitative analysis Table 2 presents the empirical results from the econometric estimation of the SF CD production function. Its show the results of stochastic frontier Cobb-Douglas production function analysis for wheat farmers in Central of Iraq.

TABLE 2. MAXIMUM LIKELIHOOD OF ESTIMATES OF STOCHASTIC FRONTIER PRODUCTION FUNCTION

Variable	Coefficient	St.
Constant	8.64***	0.57
ln NOI	0.25***	0.09
ln CH	-0.06	0.05
ln Z_3^{En}	-0.07**	0.03
ln Z_4^{En}	-0.01	0.01
ln SQ	-0.02	0.09
ln L	-0.10	0.06
ln M	-0.11	0.13
Inefficient model variable		
EC (dSm-1)	0.57***	0.06
Location	-0.03	0.10
Position	-0.35***	0.09
Level of Education	-0.0002	0.08
Agricultural Experiences	0.03	0.05
Wheat Variety	-0.02	0.03
Wheat share	0.07	0.08
σ^2	0.14***	0.02
γ	0.83***	0.05

The asterisks indicates levels of significant: * is significant at 1% level; ** is significant at 5% level**

The stochastic frontier production function analysis for environmental efficiency estimation of wheat farmers presents that, for an increase of En.E in study area by 1%, farmer needs to use Urea fertilizers with adequate and feasible quantities which will lead to yield reduction by 0.07%. Results also show that DAP fertilizers does not affect the environment significantly. There were two main sources of environmental inefficiency and both are related to soil salinity, the first was EC of soil. Farms with low level of soil salinity are more environmentally efficient. The second source was the location of the farm in which if farmer cultivated their wheat in reclaimed land, they will be more environmentally efficient than farmers who cultivated their land in semi-reclaimed and un-reclaimed land . Envronmental efficiency of wheat farms in the study area The average En.E for total sample was 0.65 indicating that, on average, they could obtain the same production level while at the same time reducing the pressures of their productive activity exertion on the environment by 35%. In other words, the economic-ecological

[5]Z1= EC of soil (Dummy: 1= less than 7.5 dS m^{-1}, 0= for equal or more than 7.5dS m^{-1})
Z2= Farm location (dummy: 1 for main river, 0 sub-river).
Z3= Experience (years).
Z4= Educational level dummy: 0 for primary school or less, 1 for secondary school or more
Z5= Position of farm (LF) (dummy: 1 in irrigation project and 0 for not)
Z6= Wheat share (wheat cultivated land /total cultivated land) %.
Z7 = Seed variety (Dummy: 0 IPA99, 1others)

management of farms analyzed is markedly inefficient. The En.E results are presented and discussed in the following section. Table 3shows the mean value of En.E, which was classified with respect to the different salinity zones. The En.E level on average was declining as the salinity level increasing. The results present that farm located in S_1 zone is more environmental efficient than once in S_3 zone by 42%,that is farmer in S_3 zone could increase their efficiency by 42% if soil salinity reduced within or less than 7.5 dSm^{-1}.

TABLE 3: ENVIRONMENTAL EFFICIENCY ESTIMATION

Soil salinity level	Mean En.E	#Farms
S_1	0.76	172
S_2	0.64	103
S_3	0.34	85
Total sample	0.65	360

Table 3 shows that the mean value of En.E of farms was 65%, while Fig. 3 shows that about 83 % of S_1 farmers have En.E more than 70%, and only about 5% of the S_1 farmers have En.E between 40-50%, which is lowest En.E at this salinity level.

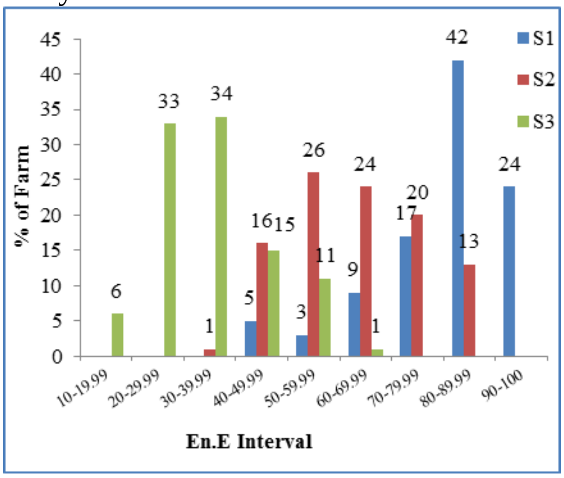

Figure 3. Percentage distribution of TE

The fact that S_1 farms record higher En.E could simply be due to the low level of soil EC. The farms in this salinity level have the potential to reduce their environmental impacts by 24%, while farms in S_2 and S_3 have the potential to reduce their environmental impacts by 36 and 66% respectively. In addition, only farms in S_1 reach higher than 90% En.E. Consequently, reducing soil salinity level entails a reducing in the environmental impacts of overuse of fertilizers in high salinity farms, while using feasible quantities of fertilizer in these farm to reduce environmental impacts entails a loss of value added per hectare through revenue reduction as a result of loss of production.

Concluding Remark and Implications

This research gives an analytical understanding on the salinity effects on environmental efficiency in irrigated wheat production system in Waist province, central of Iraq. Soil salinity has multi-sided impacts: The first impact is on the inputs side, in which farmers in salt-induced soil use more quantities of inputs compared with the farmers in the low salinity soil. Soil salinity causes different impacts on each input. Some of these impacts lead to reduce the productivity of that input. The second impact is on the production side in which farming in high salinity land tends to reduce wheat production by 50% in irrigated wheat system. Such results are affecting clearly farmers' revenue, and consequently their livelihoods. .The last impact is unaccounted ones, in which salinity has negative externalities on the environment such as downstream water pollution by the quantities of fertilizer and agricultural chemicals given their massive use by farmers to mitigate the high level of salinity. The comprehensive analysis of SFA shows the soil salinity impacts on environmental efficiency in the study area of Iraq. There were two main sources of environmental inefficiency and both are related to soil salinity, the first was the EC of soil. That is if EC of soil is reduced by less than 7.5dSm^{-1} leads to reduce the En.E. The second source was the location of the farm in which if farmers cultivated their wheat in reclaimed land, they will be more environmentally efficient. An average level of environmental efficiency estimated through using SFA, was 72%. Soil salinity has a clear impact on wheat yield and environmental efficiency level, in which even some farmers in high salinity area reach their maximum En.E, they could not reach yield gained by less efficient farmers in low salinity area. There is a space for recommendations that could be assist to improve En.E in the study area, such as, rising awareness on the use of adequate quantities of fertilizers through farmer training and workshops, and extension, enhancing wheat farming managements, reducing soil salinity in the course of reclaimation of land, reduce subsides level of fertilizers, and increase subsides level for other inputs in environmental farms.

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