Asian Journal of Advances in Agricultural Research

14(1): 35-42, 2020; Article no.AJAAR.59450
ISSN: 2456-8864

Modeling Techniques for Quantifying Climate Change Impacts on Agriculture Productions: Models Comparisons and Impact Assessment Research Framework

Liying Li[1,2*]

[1]Department of Environment, Tsinghua University, Beijing, China.
[2]Department of Geography and Environment, London School of Economics and Political Science, London, United Kingdom.

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/AJAAR/2020/v14i130123
Editor(s):
(1) Dr. Daniele De Wrachien, State University of Milan, Italy.
Reviewers:
(1) Mguidche Amel, Tunisia.
(2) Maria Iderlane de Freitas, Federal University of Sergipe, Brazil.
Complete Peer review History: http://www.sdiarticle4.com/review-history/59450

Original Research Article

Received 24 May 2020
Accepted 30 July 2020
Published 05 August 2020

ABSTRACT

Additional warming caused by climate change will negative impacts on agricultural sectors. The problem is expected to be most harsh in regions were lacking in adaptive capacity in terms of information needed to make adaptive decisions to combat climate change impacts. Many strides have been made to understand and quantify climate impact on sensitive regions to climate change. However, for many food-insecurity hot-spot areas, the comprehensive data for impact assessment are rarely available. This paper outlined a research framework for providing knowledge for policy-makers, local authorities, and agricultural organizations to make informative climate change adaptive decisions for such areas. Several models are compared and discussed to show their advantage and disadvantage for appropriate model applications. We propose a framework to facilitate future impact assessment research, especially for regions where relevant data are lacking. This paper provides a research method of linking different models and combines the useful information acquired from models to make climate policies and adaption schemes cost-effectively with limited local data and farm information.

**Corresponding author: Email: lilyhua2007@126.com, liliying88@gmail.com;*

Keywords: Impacts assessment framework; climate change adaptation; Global Climate Models; cropmodeling.

1. INTRODUCTION

The evidence that accumulating greenhouse gases will change our future climate has been growing for decades [1]. It has become a lasting research focus that climate change impact assessments are conducted, looking for appropriate decision support tools for climate change adaptation. The general objective of climate change impact assessments may be one or several targets, such as evaluating output, management, adaptation options, etc. What may be the impacts of climate change at a local level? How will they add to the development challenge? Which research and development activities are likely to help, and how can they be appropriately targeted? To answer such questions, this present study aims to improve the understanding of the potential effects of global climate change on agricultural systems in regions where comprehensive data are lacking. Impact assessments research need a combination of different models to incorporate the effect of changing weather data into crop production prediction under different scenarios. The models or methods used in the assessment research framework to address these questions could finally affect the significance and accuracy of the results, especially in the long term. We will propose a research framework containing models analyzed to be adequate to facilitate the understanding of global climate change impacts on agricultural production.

2. METHODS

This paper proposed a framework for global climate change impact assessment at a local scale to facilitate adaptation actions and climate policy-making, especially for regions that have limited data for modeling inputs. We compared several models and discussed to show their advantage and disadvantage for appropriate model application.

We did a literature review to draw lessons and experiences from previous impact assessment research and fabricate the framework that combines the best available models and data to predict possible climate change impacts on agricultural production globally, especially for regions lacking comprehensive data on weather and soil and growing technique. The models finally included in our framework have free online access to research scientists and other users, and they are eligible for large regions around the world. Such a framework will provide solid grounds for climate change adaptation decision-making tailored to local farms. To build such a framework, we compared different analysis methods, models, and crop-modeling tools to achieve a satisfying research pathway.

3. MODELING TECHNIQUES AND CLIMATE CHANGE IMPACT ASSESSMENT FRAMEWORK

3.1 Experimental-Simulations vs. Cross-Sectional Analyses

Two sets of methods have been developed when conducting climate impact assessments: experimental-simulations and cross-sectional studies. The optimal strategy to understand the climatic impact is, consequently, to employ both approaches. Since they depend on completely different assumptions, researchers and policy-makers can be confident that the effects have been accurately captured if the results agree [1].

Both sets of methods have strengths and weaknesses. The cross-sectional approach is good at capturing efficient adaptation because it precisely measures what people have decided to do to adjust to their situation. In the Ricardian framework, the farmer chooses the mix of species or crops to be grown and the inputs to maximize profits. The socio-economic model estimated climate change by regressing net revenue per hectare on a set of such variables. By comparing farmers' behavior in different climate zones, the Ricardian analysis estimates the likely long-run impact.

This approach has been employed to investigate the impact of some climate variables on the net revenue from commercial and subsistence farming [2]. This method provides important information about the role of technology, the change in prices in the future, etc. However, the cross-sectional approach has no way to measure carbon fertilization or discern exactly how each plant reacts to the climate. The experimental approach is the only way to gather evidence to incorporate the CO2 fertilization effect and explore mechanisms to understand precisely how the climate affects plants. The experimental approach can test scenarios that simply do not exist on the planet, such as higher levels of carbon dioxide [1].

With crop modeling, the experimental approach can estimate how climate change and increasing carbon dioxide levels alter the yields and water use of world crops in major production areas and vulnerable regions. CERES-Maize crop models in our framework to simulate maize yields were with the possible impact of climate change. CERES-Maize model has been applied in numerous climate change studies, including several focused on the data-limited African continent [3,4]. To assess climate change impacts for a country, as an example, we need to select several regions at a farm level that have representative roles for the cultivar of interest growing in that country in terms of production, climate features, soil conditions, and cropping routines.

3.2 Climate Change Projection

3.2.1 IPCC climate scenarios

Scenarios are quantitative constructions that are intended to challenge people to think about a range of alternative futures that might go beyond conventional expectations or business-as-usual (BAU). There are four different narrative storylines describing the way world population, economies, and political structure may evolve over the next few decades (SRES: [5]). They are used by a range of integrated assessment models [5]. In order to estimate the impacts of climate change on a system (agriculture in our case), it is common to employ climate change scenarios accounting for the uncertainties surrounding the prediction of climate change. Therefore, an impact study should include more than one scenario so that a range of effects may be defined [6]. The selection and application of baseline and scenario data occupy central roles in most standard methodological frameworks for conducting climate impact and adaptation assessment. Most of the impact research uses several scenarios to predict the different possibility of future productions with changing climates.

We propose to use two marker scenarios—SRES A2 and B1—to represent potential future climate conditions. Among existing scenarios, the SRES A2 scenario reflects a more divided world with higher GHG emissions, one the other hand, the SRES B1 scenario describes a more integrated and ecologically friendly world with low emissions.

3.2.2 Climate change scenarios generation and induction of global circulation models

The climate change scenarios generated fall into three categories: equilibrium scenarios, transient scenarios, and incremental scenarios.

3.2.2.1 Equilibrium scenarios

Climate change scenarios obtained from Equilibrium scenarios describe an average climate of the future. These scenarios assume an abrupt change in climate conditions between "now" and many decades in the future, often when 2CO2 concentrations are reached. Thus, they are the least favorable conditions for crop growth. There are two distinct disadvantages of equilibrium scenarios, particularly those derived from 2CO2 experiments using global circulation models (GCMs). The first is that even though greenhouse gas emissions go unabated, it is probable that atmospheric concentrations of greenhouse gases will substantially exceed 2CO2 levels [7]. Such equilibrium climate change will probably not be realized for many decades [8]. The second disadvantage is that it is unlikely that atmospheric greenhouse gas concentrations will remain constant enough to enable an equilibrium climate to be reached. These two restraints are overwhelmed by transient climate scenarios to a certain extent, as described below.

3.2.2.2 Transient climate scenarios

Transient climate projections are used to provide more specific (decadal) timeframes, which can be incorporated into studies of the effect on agriculture [9]. An abrupt doubling of the CO2 concentration in the atmosphere and allowing the simulated climate to come to a new equilibrium is unrealistic since trace gases are increasing gradually [10]. The transient climate scenarios simulate the response of increasing gases progressively and are more realistic in this regard. The use of a transient model allows the effect of the magnitude of climate change on food production to be assessed and the effects of the rate of change [11]. Therefore, transient scenarios are used in this study to better present the effect of the warming climate.

3.2.2.3 Incremental scenarios

Incremental scenarios are also referred to as arbitrary changes in climate and usually involve uniform changes in the annual climate such as +2 and +4°C combined with no change in precipitation or 10 and 20% changes in precipitation. Incremental scenarios complement GCM scenarios because they provide a more extensive range of potential climate change on a regional scale, and they are useful in identifying sensitivities to changes in specific variables, such as increased and decreased precipitation, thereby providing a better understanding of the factors which affect responses. Since the impact of the direction of climate change has been analyzed by an extensive range of literature (crop responses negatively to increased temperature and reduced rainfall), the present study will devote more time to analyzing how this effect varies across different agro-ecological zones and valuating the spatial advantage of crop-growing systems under climate change, accounting for the grand heterogeneous features of the region of interest.

3.3 Introduction of Global Circulation Models

Most assessment studies use climate scenarios generated from global circulation models (GCM) [10]. Varied selected GCMs can be used even though they may not necessarily be the "best" models. Therefore, a range of changes can be obtained from a combination of GCMs that includes a fairly typical of the population of GCM experiments, together with GCMs that give results at the low and high end of the range of results [12].

In the study of Dixon et al., [13], five GCM models were examined for use in the study: Canadian Climate Centre Model (CCCM); Geophysical Fluid Dynamics Laboratory R-30 model (GFDL-R30); Geophysical Fluid Dynamics Laboratory's transient model (GFDL-transient); United Kingdom Meteorological Office (UK89); and Goddard Institute for Space Since (GISS). Their results suggested that all models showed a bad representation of the rainfall, as only one rainfall maximum was simulated, whereas the actual shows three to four high rainfall pocket areas. This can be explained by one inherent feature of GCM that simulation of infiltration, runoff, and evaporation is highly simplified. Thus many smaller-scale elements of climate are not properly represented. Therefore, precipitation, in particular, is often poorly represented in GCM results [10].

Furthermore, due to the smoothed topography used, models cannot discriminate rainfall and temperature differences between the lowlands and the adjoining highlands. Besides, all models were weak in identifying the high rainfall zone in the eastern highlands and overestimated the rainfall of the northern Rift Valley. For these reasons, we assume that models would simulate absurd precipitation for certain months in the sites of interest in our study. Consequently, we have to drop the extreme values to avoid the yield damages done by the simulation deficiencies.

3.4 Crop Modeling

Assessment studies of the impacts of climate change on agriculture at farm to regional levels need to analyze complex interactions of climate, agro-ecosystem function, and human management. Therefore, the results generated by different scenario would be used as input to crop models and land management decision tools [14]. The most two popular crop models are statistical models and process-based models.

3.4.1 Statistical models

A common alternative physical approach to a process-based model is the use of statistical models trained on historical yields and some simplified measurements of the weather, such as growing season average temperature and precipitation [15]. Schlenker and Roberts [16] used the statistical model approach to estimate the link between weather and yields for the three crops with the largest production value in the United States: corn, soybeans, and cotton.

However, statistical models are inherently limited to the range of conditions for which they are trained. For example, they cannot be extrapolated to predict the impact on the production of future temperatures which are higher than any historical year, without making assumptions about the linearity of crop responses outside the historical range. This is a strong argument for using process-based models to predict the long-term effect of climate change [15]. Process-based models employ simplified functions to express the interaction between crops' growth and the major environmental factors that affect them (i.e., climate, soils, and management).

Another limit of statistical models is that the impact projections ignore the potential fertilization effects of elevated atmospheric CO2 on crop yields. Besides, the statistical crop models assume no adaptation to climate change beyond that which takes place in response to year-to-year weather variations. However, when defining the need for future investment, autonomous adaptation should be considered in addition to the projected impact without adaptation. This is especially true when considering longer timescales. Some researchers even use process-based models to test the predictive capabilities of statistical crop models. Minimum data requirements and ideal predictor variable aggregation for statistical models are sometimes concluded from comparing these two models [15].

Statistical crop models can be useful, if imperfect, tools for projecting future yield responses, with their usefulness higher at broader spatial scales [15]. However, since this study aims to identify the effective adaptive practices tailored to Ethiopian farms' local context in the relatively near-term, the results yielded by a process-based model will be more useful.

3.4.2 Process-based models and introduction of CERES models

Specific dynamic crop models such as DSSAT [17], EPIC [18], or simpler, modified ecosystem models, such as TEM [19], have been employed for computing crop growth, water dynamics, and harvest yield. With many details of a crop lifecycle, crop models enable the simulation of more realistic field management activities, such as type of water and fertilizer management, sowing and harvesting operations, etc. [20]. Some studies compare the results of different models for the same climate and soil data sets. Different models can also give differing results for differences in complexity, structure, and parameterization conditions [12].

A processed-based CERES-Maize model [3] was used in the present study. The Crop Environment Resource Synthesis (CERES) models embedded in DSSAT have been developed and utilized for the last 30 years to simulate crop growth in response to climate throughout the world. [21] Although it is not without limitations, CERES model is the most highly rated and used model in the USA. It has been validated and used to assess the impact of drought on maize in South Africa. Thornton et al. [4] employed CERES-Maize to simulate the growth, development, and yield of the maize crop in East Africa Lin et al. [22] used CERES-maize generating the results showed that flowering duration and maturity duration of maize would be shortened in the future climate and thus maize yield would reduce by 11–46% during 2011–2099 relative to 1981–2010. Increased CO2 concentration would not benefit maize production significantly. Combined with projected climate scenarios, CERES models can predict the change in accumulated biomass, water- and Nitrogen-use efficiencies. However, the CERES models should not be used without caution. It is critically important to update parameterization and code of the CERES crop models in DSSAT to have a sufficiently strong effect of CO2 on stomatal conductance and on transpiration [23].

Its widespread use among the modeling fraternity gave us the confidence to use it. The advantage of such a model has been described above, however, the model doesn't exist without limitations. Such limitations will be put into detail in the discussion section.

3.5 Simulation of the CO2 Fertilization Effect

The CO2 fertilization effect is an important factor [9]. The inclusion of this effect in yield studies significantly raises the estimate of the climate-affected yields of many crops. This is probably because CO2 reduces transpiration per unit leaf area while enhancing photosynthesis; thus, it may lead to improving water-use efficiency (the ratio of crop biomass to the amount of water used in evapotranspiration) [24]. Young and Long [25], however, believe that no direct effect of increased atmospheric [CO2] should be expected in C4 plants. CO2 will have a different impact on the crop growing of C3 (e.g., wheat, soybean, citrus) and C4 plants (e.g., maize, sorghum, plus several important agricultural weeds) [9]. The relative increase in the photosynthetic response of C4 plants is higher for limiting than increasing soil water conditions under increased atmospheric pressure [CO2] [26]. After all, crop production will be affected by different level of CO2, and the climate change scenarios are associated with a higher level of CO2 than in current climate GCM simulations (330 ppm), the physiological effects of alternative CO2 levels on crops should be included in our crop model simulation within the framework.

3.6 Simulation with Adaptation Strategies

Adaptation is considered to be an important policy option or response strategy to concerns about climate change. The reason for this lies in the fact that the impacts of climate change, and its seriousness or level of danger, can be modified by adaptation of various kinds. To this end, assuming no adaption to climate change would overestimate its effect, since farmers and the government will try to adapt to change. Therefore, a full set of practices, including adaptation strategies, should be tested for a better projection of climate change's impact, considering the pronounced variation of responses across different crop management practices.

3.7 Model Calibration and Validation

Model calibration and validation can modify the CERES model's prediction by considering the various sources of uncertainty in crop model simulation. Careful calibration and validation can commonly restrain the estimated yields within 10% of those observed [4]. Our framework presents no detailed testing of the models because for regions lacking comprehensive data that are of our interest, field trial data needed for model validation are rarely available. However, the simulated yield obtained is undoubtedly a reasonable implication for the characteristic of the levels of yield obtained by smallholders growing maize in low-input, rain-fed conditions both under current and future climate. This is regarded to be adequate for the proposed purpose of our framework.

3.8 Model Limitations

Although we could take representative sites that captured as many agrological features as possible for a region, caution should be applied to this framework's impact results. First of all, the bottleneck of drawing a precise prediction of the climate impact is the data of weather and soil information. Details of the daily weather, such as maximum and minimum temperatures, are not freely available in countries the framework was designed for; therefore, only general approaches can be taken by using downscaled simulated weather data as rough weather. This is likely to reduce the reliability of the results since uncertainties exist in the simulating and downscaling.

It is also widely accepted that many process-based crop models' inherent limitation is the inability to account for spatial variation, i.e., only one point of a district is evaluated, but the results are extrapolated to the whole region [27]. There are often extreme variations in soil and rainfall distribution within a district. To this end, accurate representation or detailed spatial scaled studies are required before up-scaling to the national or global level. Furthermore, for the tropics and subtropics, there are model limitations with respect to pests and diseases, multiple cropping, and the inclusion of animal interactions at the present time.

In addition to the modeling deficiencies, some applied agricultural research, including this one, can also be inappropriate in meeting farmers' needs. While the simulation of maize production with adaption can give some insight into how to mitigate climatic impacts, it should be borne in mind that farmers operate within a set ofconstraints (resource-related, political, and social) which may not be fully appreciated by crop modeling studies [28]. In other circumstances, farmers' objectives often do not coincide with those assumed by researchers and extension personnel; sometimes, even the farmers' objectives are not known. These are impediments to practical adaptation strategy research.

4. CONCLUSION

We proposed a framework using GCMs to generate climate data under two marker scenarios—SRES A2 and B1. The climate data will then be downscaled into weather data and used as input into crop modeling. The productions predicted under climate change scenarios will be compared with the modeling result acquired under the baseline scenario to assess the impacts of climate change on agricultural systems. We also incorporate different adaptation strategies into the modeling framework and compare the modeling results with baseline without adaptation. Then cost-effective strategies can be identifies through our framework. We also considered he fertilization effects of CO2 to increase the accuracy of impact assessment. To better capture the variations in different agrological zones in a country or region, as many sites as allowed should be selected. This paper hopes to produce a repeatable method that can be extrapolated into many different regions globally in future studies; hence, it more precisely assesses the aggregated impacts of climate change on agricultural systems all over the world.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Mendelsohn R. Measuring climate impacts with cross-sectional analysis. Clim. Change. 2007: 81:1–7. Available:https://dx.doi.org/10.1007/s10584-005-9007-0
2. Deressa TT. Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach (Policy Research Working Papers 4342). Washington, DC: The World Bank.
3. Jones PG, Thornton PK. The potential impacts of climate change on maize production in Africa and Latin America in 2055. Glob. Environ. Change. 2003;13:51–59. Available:https://dx.doi.org/10.1016/s0959-3780(02)00090-0
4. Thornton PK, Jones PG, Alagarswamy G, Andresen J. Spatial variation of crop yield response to climate change in East Africa. Glob. Environ. Change. 2009;19:54–65. Available:https://dx.doi.org/10.1016/j.gloenvcha.2008.08.005.
5. Watson RT, Noble IR, Bolin B, Ravindranath NH, Verardo DJ, Dokken DJ. Land use, land-use change and forestry: A special report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge; 2000.
6. Carter TR, La Rovere EL. Developing and applying scenarios, in: Climate Change 2001: Impacts, Adaptation and Vulnerability. Cambridge University Press, Cambridge. 2001;145–191.
7. Wigley TML, Richels R, Edmonds JA. Economic and environmental choices in the stabilization of atmospheric CO2 concentrations. Nature. 1996;379:240–243. Available:https://dx.doi.org/10.1038/379240a0
8. Kattenberg AF, Giogi F, Grassi H, Meehl GA, Mitchell JFB, Stouffer RJ, Tokioka T, Weaver AJ, TML Wigley. Climate models—projections of future climate, in: Houghton JT, Meira Filho LG, Callander BA, Harris N, Kattenberg A, Maskell K. (Eds.), Climate Change 1995: The Science of Climate Change. Cambridge University Press, Cambridge. 1996;285–358.
9. McCarl BA, Adams RM, Hurd BH. Global climate change and its impact on agriculture. Available:https://agecon2.tamu.edu/people/faculty/mccarl-bruce/papers/879.pdf (Accessed 1 August 2012)
10. Rosenzweig C, Iglesias A. Implication of climate change for international agriculture: Crop modeling study (Report 230-B-94-003). Washington, DC: EPA; 1994.
11. Parry M, C Rosenzweig, A Iglesias, G Fischer, M Livermore Climate change and world food security: A new assessment. Glob. Environ. Change. 1999;9:S51–S67. Available:https://dx.doi.org/10.1016/s0959-3780(99)00018-7.
12. JF Feenstra, I Burton, JB Smith, RSJ Tol. Handbook on Methods for climate change impact assessment and adaptation strategies. United Nations Environment Programme, Nairobi; 1998.
13. Dixon KW, Bullister JL, Gammon RH, Stouffer RJ. Examining a coupled climate model using CFC-11 as an ocean tracer. Geographical Research Letters. 1996;23(15):1957-1960. Available:https://doi.org/10.1029/96GL01470.
14. Kurukulasuriya P, Mendelsohn R. How will climate change shift agro-ecological zones and impact African agriculture? (Policy Research Working Papers 4717). Washington, DC: The World Bank; 2008.
15. Lobell DB, Burke MB. On the use of statistical models to predict crop yield responses to climate change. Agric. For. Meteorol. 2010;150:1443–1452. Available:https://dx.doi.org/10.1016/j.agrformet.2010.07.008.
16. Schlenker W, Roberts MJ. Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change. Proc. Natl. Acad. Sci. U. S. A. 2009;106:15594–15598. Available:https://dx.doi.org/10.1073/pnas.0906865106.

17. Tsuji GY, Uehara G, Balas S. DSSAT Version 3. University of Hawaii, Honolulu.
18. Williams JR, Renard KG, Dyke PT. EPIC: A new model for assessing erosion's effect on soil productivity. J. Soil Water Conserv. 1994;38:381–383.
19. Felzer B, Kicklighter D, Melillo J, Wang C, Zhuang Q, Prinn R. Effects of ozone on net primary production and carbon sequestration in the conterminous United States using a biogeochemistry model. Tellus B Chem. Phys. Meteorol. 2004;56:230–248. Available:https://dx.doi.org/10.1111/j.1600-0889.2004.00097.x
20. Fischer G, Shah M, Tubiello FN, van Velhuizen H. Socio-economic and climate change impacts on agriculture: An integrated assessment, 1990–2080. Philos. Trans. R. Soc. Lond. B Biol. Sci. 2005;360:2067–2083. Available:https://dx.doi.org/10.1098/rstb.2005.1744.
21. Basso B, Liu L, Ritchie JT. A comprehensive review of the CERES-Wheat, -Maize and Rice Models' Performances. Advances in Agronomy, Volume 136, 2016, Pages 27-132. https://doi.org/10.1016/bs.agron.2015.11.004
22. Lin Y, Wu W, Ge Q. CERES-Maize model-based simulation of climate change impacts on maize yields and potential adaptive measures in Heilongjiang Province, China. Journal of the Science of Food and Agriculture. 2015;95(14):2838-2849.
23. Amouzou KA, Lamers JPA, Naab JB, Borgemeister C, Vlek PLG, Becker M. Climate change impact on water- and nitrogen-use efficiencies and yields of maize and sorghum in the northern Benin dry savanna, West Africa. Field Crops Research. 2019;235:104-117. Available:https://doi.org/10.1016/j.fcr.2019.02.021
24. Parry ML, Rosenzweig C, Iglesias A, Livermore M, Fischer G. Effects of climate change on global food production under SRES emissions and socio-economic scenarios. Glob. Environ. Change. 2004;14:53–67. Available:https://dx.doi.org/10.1016/j.gloenvcha.2003.10.008
25. Young KJ, Long SP. Crop ecosystem responses to climatic change: Maize and sorghum, in: Reddy, K.R., Hodges, H.F. (Eds.), Climate Change and Global Crop Productivity. CABI, Wallingford. 2000;107–131.
26. Abraha MG, Savage MJ. Potential impacts of climate change on the grain yield of maize for the midlands of KwaZulu-Natal, South Africa. Agric. Ecosyst. Environ. 2006;115:150–160. Available:https://dx.doi.org/10.1016/j.agee.2005.12.020
27. Durand W. Assessing the impact of climate change on crop water use in South Africa (CEEPA Discussion Paper 28). Pretoria: University of Pretoria; 2006.
28. Thornton PK. Application of crop simulation models in agricultural research and development in the tropics and subtropics (Report P-15). Muscle Shoals, AL: IFDC; 1991.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/59450