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# Estimation of Climate Change Effects on Arid Land Afforestation Technologies for $CO_2$ Sequestration

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**Abstract:** Estimation of climate change effects on arid land afforestation for $CO_2$ sequestration was attempted. A tree growth model was prepared by modifying the 3-PG model to reproduce tree growth in an afforestation trial in Leonora, Western Australia. Data from CCSM3.0 were used as input data to the tree growth model and estimated the future trends in tree growth in the arid land of Western Australia. A reduction of rainfall and rising of average temperatures by climate change are predicted there, and these two factors are tending to reduce the tree growth.

Further investigations on the other arid area show tree growth in some area will be enhanced according to the global warming.

**Keywords:** Arid land afforestation, Carbon sequestration, Global climate change

## 1. Introduction

Carbon sequestration by arid land afforestation has been expected as an effective countermeasure for global warming problem. A research project of afforestaion was attempted in Leonora, Western Australia (Kojima *et al*., 2006), using some technologies, such as water management, tree species selection, and demonstrated its potentials. In this work, we attempted to examine the effect of climate change on the growth of trees planted in arid land. If the forests in arid lands are not vulnerable, the global warming process will be reduced as expected. However, if the climate changes will wilt the forests, the sequestrated carbon will be released again and speeding up global warming. Additionally, possibilities of afforestation in arid areas other than Western Australia, were examined, and response of the tree growth to the climate changes in the selected areas were also examined.

## 2. Materials and Methods

In this work, a tree growth simulator was executed using various weather data from a GCM (global climate/circulation model) simulation under various scenarios in SRES (Special Report on Emission Scenario) of IPCC (Intergovernmental Panel on Climate Change).

For GCM, the results of some simulations in "IPCC Data Distribution Centre" were compared to the observed weather data at the experimental site in the afforestation project, Leonora, Western Australia, during 2000 to 2006. As a result, CCSM 3.0 (Community Climate System Model) from the National Center for Atmospheric Research (http://www.ccsm.ucar.edu) was selected, because of its superior reproducibility for the temperatures and rainfalls in the arid area.

The tree growth simulator is similar to the 3-PG model (Landsberg and Waring, 1997). In this model, tree growth basically depends on the monthly solar radiation, and additionally functions of discount factors for some environmental effects, such as average rainfall and average temperature, are defined and parameters in these functions are adjusted to fit the observed data. Using parameter sets for *Eucalyptus globulus* from literature (Sands and Landsberg, 2002) as a default, parameters having a significant effect on the tree growth were selected and adjusted to reproduce the growth data of *Eucalyptus camaldulensis*, which obtained from the afforestation project at Leonora, Western Australia. It should be mentioned that, because of the limitation of empirical information, a positive effect of increased $CO_2$ concentration on the tree growth was not taking into account in this simulation model. The results obtained from this simulator should be considered as a pessimistic case from the view point of growing trees.

In the analysis of the other arid lands in the world, averages of annual rainfall data for past 10 years were calculated based on the "CPC Merged Analysis of Precipitation (CMAP)" (Xie and Arkin, 1996) from

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Climate Prediction Center (CPC http://www.cpc.noaa.gov), and arid regions within the world were selected on the basis of rainfall 200 to 300 mm/y of rainfall. Additionally, regions in a cold area were larger than 3 ˚C. Some groups of adjacent meshes of candidates were gathered and representation points for each group were selected to estimate the future trends.

## 3. Results and Discussion

To evaluate tree growth potential in Leonora, Western Australia, simulations of 5-year-growth of planted trees starting at various years until 2100 were attempted. From data sets of CCSM 3.0, the monthly average of minimum and maximum temperatures, monthly total rainfalls, and solar irradiation, were used to perform simulation. IPCC Data Distribution Center provides 3 to 4 data sets from CCSM 3.0 for each emission scenario in SRES for exploring the chaotic behavior of climatic simulations. So, the results of tree growth simulation performed using each data set from CCSM 3.0 were averaged for each emission scenario.

Tree growth at arid lands in Western Australia turned out to be reduced with global warming. As shown in **Figure 1**, under the scenario A1B, a case of significant climate change, growth of trees planted from 2096 to 2100 is less than 70% of that of from 2011 to 2015.

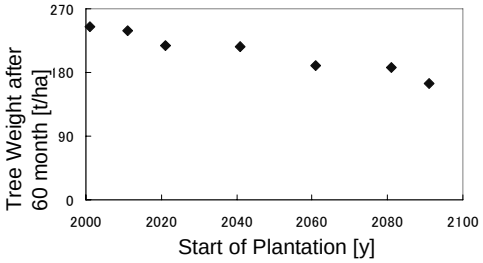


**Fig.1. The predicted tree growth of ations in Leonora, Western Australia, at various starting year.**

**Figure 2** shows the change of predicted rainfalls by CCSM 3.0, with the assumption of increasing green house gas emission in the scenario A1B. This data were selected from the simulation results provided by IPCC Data Distribution Center. The decreasing trend of rainfall shown in this figure is thought to be the cause of the decrease in simulated tree growth, because this growth evaluation is focused on arid region. Additionally, an increasing trend of temperature shown in **Figure 3**, is another candidate for this tree growth suppression. This is because, in the tree growth simulation, temperature for maximum tree growth is set to 15 ˚C, and the temperatures depart from this optimal value with its increasing. By comparing the factors expressing stresses of dryness and high temperature under meteorological conditions for the end of this century, it turned out that the reducing rainfall has more contribution to the reducing tree growth.

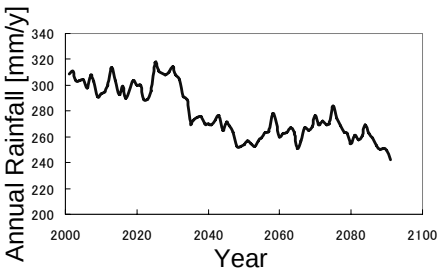


**Fig. 2. The predicted trend of annual rainfall at Leonora.**

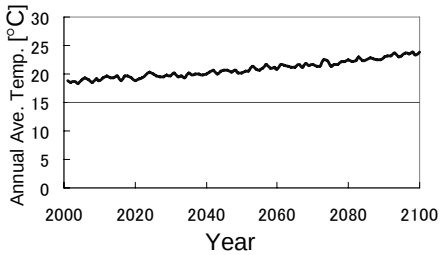


**Fig. 3. The predicted trend of annual average temperature at Leonora.** The horizontal line shows the optimal temperature for tree growth in the simulator.

The other arid areas in the world were selected as an afforestation candidate as mentioned before, and investigations on the effect of climate change were conducted. The factors for dryness and temperature of each representation point for the gathered mesh groups were examined. Comparing those factors of year 2000 and 2100, these groups were classified

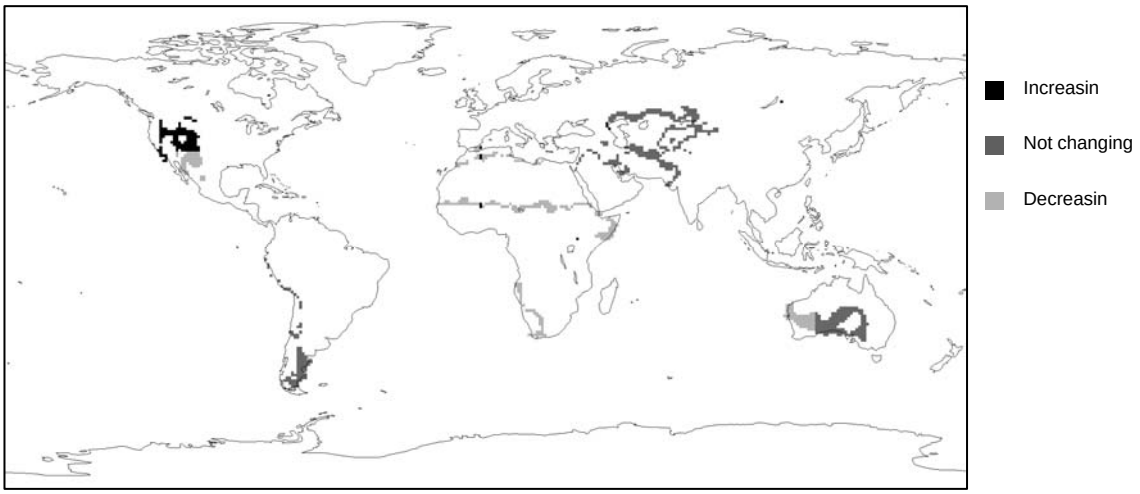


**Fig. 4. Results of future trend estimations that attempted for the afforestation candidate arid areas in the world.**

as decreasing, increasing, and not so affected areas, in the case of serious climate change.

**Figure 4** shows the results of climate change evaluation for arid lands in the world. Some areas, including Leonora, Western Australia, are classified as the group of decreasing ability on growth trees, and these areas may not be suitable for afforestation aimed at $CO_2$ sequestration. Afforestation in the other areas are not restricted by the climate change, and the such area will be selected as an afforestation target. Additionally, in some areas, including Colorado and Wyoming, will be enhanced according to the global warming although an excessive expectation should be restricted in considering uncertainty of simulation to the future. In addition, it should be again stressed that this is the pessimistic prediction because the positive effect of increased $CO_2$ concentration on photosynthetic activity is omitted.

## 4. Conclusions

The estimation of climate change effects on arid land afforestation for $CO_2$ sequestration was attempted by using a data from CCSM3.0 and a model of tree growth (similar to the 3-PG model) in Leonora, Western Australia. In Leonora, a reduction of rainfall and rising of average temperatures by climate change are predicted and these two factors are tending to reduce the tree growth. Further investigations on the other arid area show tree growth in some area will be enhanced according to the global warming. Though the more detailed evaluations of future trends are required, arid area with reducing trend for a tree growth ability should be avoided in afforestation.

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## References

Kojima T., Hamano H., Abe Y., Tanouchi H., Egashira Y., Saito M., Law J., Takahashi N.. Yamada K. (2006): Basic Data of Research Project on Large Scale Afforestation of Arid Land for Carbon Fixation near Leonora in Western Australia. *J. Arid Land Studies*, **16**(3): 167-174

Landsberg J.J., Warig R.H. (1997): A generalised model of forest productivity using simplified concepts of radiation-use efficiency, carbon balance and partitioning. *Forest Ecology and Management*, 95: 209-228

Sands P.J., Landsberg J.J. (2002): Parameterisation of 3-PG for plantation grown Eucalyptus globulus. *Forest Ecology and Management*, **163**: 273－292

Xie P., Arkin P.A. (1996): Global Precipitation: A 17-Year Monthly Analysis Based on Gauge Observations, Satellite Estimates, and Numerical Model Outputs. *Bull. Amer. Meteor. Soc.*, **78**: 2539-2558.