

APPLICABILITY OF GINI COEFFICIENT AS A QUANTIFIER OF POTENTIALLY AVAILABLE WATER RESOURCES DISTRIBUTIONS

| | | |
|---------------------|------------------|-------------------------|
| Tohoku University | Graduate Student | O Nilupul K. GUNASEKARA |
| Tohoku University | Fellow Member | So KAZAMA |
| University of Tokyo | Graduate Student | Dai YAMAZAKI |
| University of Tokyo | Fellow Member | Taikan OKI |

1. INTRODUCTION

Present climatic models together with the future climate change scenarios enable us to have a glimpse of our possible futures. Innumerable researches on water resources bear evidence for worsened water scarcities in the near future, due to climate change.

These assessments focus on the quantity of water resources. Nonetheless, the distribution of water is also a vital factor for water resources management. Inequalities in the resource distributions often give rise to social conflict situations. This research is in the primary stages of developing an index which enables us to measure inequality in water distributions to be used in water resources management. The potentiality of the adopted index in measuring inequality of natural water distributions was evaluated on this phase of the research.

2. METHOD OF ANALYSIS

Assuming the annual average river discharges as the potentially available water resources, a rougher resolution map was produced using horizontal resolution 0.5 degrees annual average river discharge data of the globe, to examine the potentiality of the Gini coefficient to quantify the natural distribution of river discharges.

(1) Potentially Available Water Resources

The river discharge from a region, to the consecutive region, which is the combination of runoff from within the first region and the discharges from the regions upstream, was assumed as the potentially available water to the first region.

(2) The Gini Coefficient and Its Utilization in Inequality Measurement

The most prominent use of Gini is in the field of Economics, to measure inequality in distributions of welfare indicators of society. According to Gini, C. (1912), the Gini coefficient is defined as,

$$Gini = \frac{1}{2n^2 \bar{y}} \sum_{i=1}^n \sum_{j=1}^n |y_i - y_j| \quad (1a)$$

Here, n is the number of individuals in the sample, y_i and y_j are the incomes of individual i and j , while $i, j \in (1, 2, \dots, n)$ and $\bar{y} = (1/n) \sum y_i$ is the arithmetic mean income (Litchfield, J. A., 1999). The Gini coefficient varies from 0 to 1. The closer the Gini is to 1, the more is the inequality.

The Gini coefficient was applied to measure the

inequality of the potentially available water resources distributions over land. The Gini coefficients were calculated for horizontal resolution 5 degrees, using the horizontal resolution 0.5 degrees river discharge data. For the calculation of grid areas, **Eq. (1b)** below was employed.

a) Grid area Calculation

The area of each 0.5 x 0.5 degree grid of the globe was calculated as follows, as the surface area between two latitudes Φ_1 and Φ_2 ($S_{(\Phi_1, \Phi_2)}$) (Ok, T. et. al., 1998), per 0.5 degree of longitude.

$$S(\phi_1, \phi_2) = \left[\frac{\pi a^2 (1 - e^2)}{360e} \left(\frac{e \sin \phi}{2(1 - e^2 \sin^2 \phi)} \right) + \frac{1}{4} \ln \left| \frac{1 + e \sin \phi}{1 - e \sin \phi} \right| \right]_{\phi_1}^{\phi_2} \quad (1b)$$

Here, the radius of earth, $a = 6378.136$ km, and the ellipticity of earth, $e^2 = 0.00669447$. Along a longitude, grid areas maximize at the equator to 3077.229 km^2 , and minimize near the north and south poles to 13.609 km^2 .

(3) The Data Employed

The data set utilized is a 0.5 x 0.5 degree horizontal resolution gridded annual average river discharge data of the globe of the present climate scenario of the year 1999, produced by the Institute of Industrial Science, University of Tokyo, using Total Runoff Integrating Pathways (TRIP). The data from CCSM3 of the National Centre for Atmospheric Research, Colorado were employed for this study.

3. RESULTS AND DISCUSSION

The inequality in the distributions of potentially available water for the year 1999 for the present day climate scenario of CCSM3 is shown in **Fig.1**. While red indicates a higher inequality of the water distributions, low inequalities are designated by more bluish colors.

Automatically what we tend to expect is more inequality in the water distributions in the water scarce regions, and lesser inequality in the regions having plenty of water. Nevertheless, the close inspection of the **Fig.1** gives a completely different idea about the natural water distributions on the Earth. Most of the red grids are aligned with the major rivers of the Earth. If trailed along the Nile, Amazon, the Congo, Mississippi-Missouri, Indus and Ganges, this fact becomes very clear. This is because the river discharges are concentrated along the rivers, and the discharge in the main river is very large compared to those of its tributaries. Even in the desert

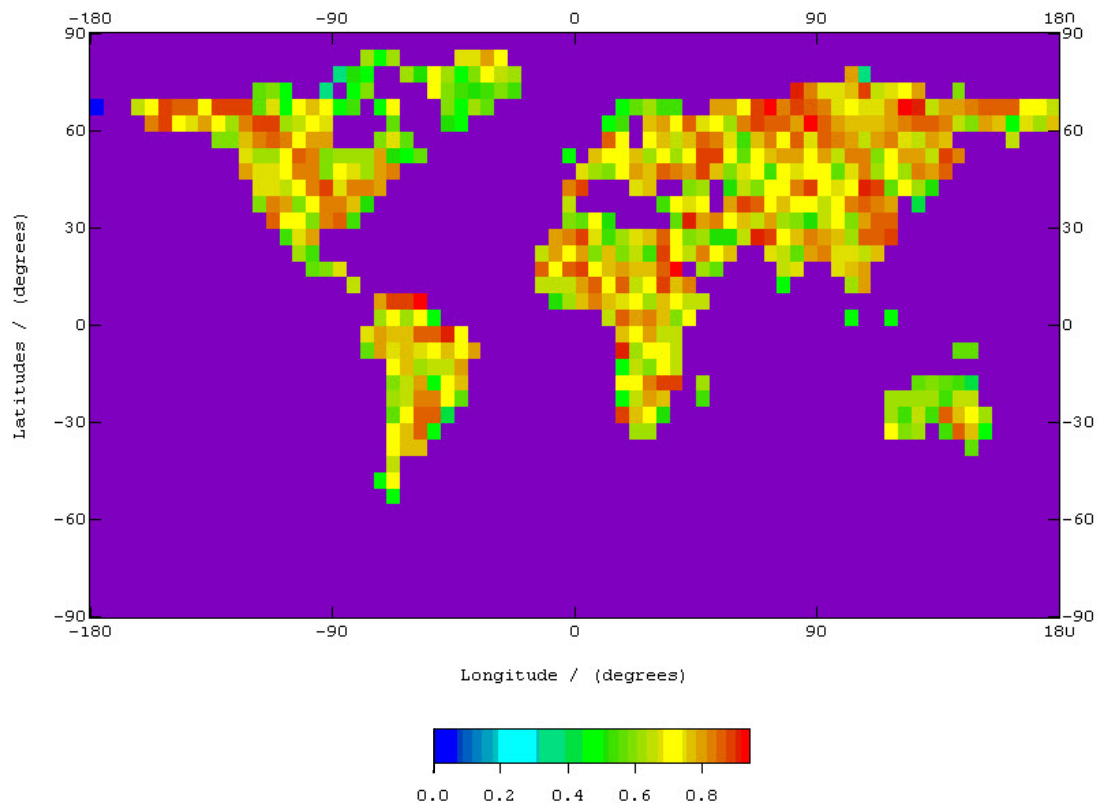


Fig. 1 The inequalities in potentially available water resources distribution for 1999 of horizontal resolution 5° (The data used are TRIP routed annual average river discharges of horizontal resolution 0.5° of CCSM3 present climate scenario).

regions as in Sahara in the Northern African continent in Australia, water is more equally distributed, according to the above analysis. Two grids of the same color don't necessarily claim that they suffer the exact water scarcity conditions; only the distribution of water is the same, regardless of the actual quantities of water the regions possess.

It is very clear that the Gini coefficient has a capability to measure the inequality of natural distributions, although it doesn't give an ample idea about the actual water availability, or the water scarcity, which could be equally critical measures to water management. A simple index as the Falkenmark water scarcity index which measures the water availability per head would be more potent in measuring water scarcity, although it doesn't give any idea about the distribution of water. We believe that the Gini coefficient has the potentiality to be developed into a robust tool of measuring water availability for water resource management.

(1) Uncertainties

Data from only one GCM-CCSM3 were utilized in this phase of the research. Nevertheless, as in 1970-1999 the model performances are better compared to other timelines, we presume this analysis is adequate to our purpose. The exclusion of the Antarctic and Arctic regions in the data set also doesn't affect our purpose.

4. CONCLUSIONS

The capability of the Gini coefficient as a quantifier of the inequalities of the natural water distributions was evaluated under this phase of the research.

According to this analysis, regions having rivers display higher inequalities in the water distributions; not the desert regions, regardless of their actual water availability. This is due to the natural concentration of discharge along the rivers.

The above analysis substantiates the Gini coefficient's potentiality to measure inequalities in the water distributions, although its ability to measure water scarcity is low. We believe this method could be further developed to produce a more competent and comprehensive tool for water availability measurement for water resource management.

ACKNOWLEDGMENT: The authors would like to thank the Global Environment Research Fund (S-4) of Ministry of Environment, Japan, and the Mitsubishi UFJ Trust Scholarship Foundation, Japan, for their immeasurable assistance in this research.

REFERENCES

- (1) Litchfield, J. A., *Inequality: Methods and Tools*, 1999.
- (2) Oki, T., and Sud, Y. C., Design of Total Runoff Integrating Pathways (TRIP) - A global river channel network, *Earth Interactions*, Vol.2, Paper no. 1, 1998.