A COUNTRY CLASSIFICATION TO IDENTIFY WATER CONFLICTS

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1. INTRODUCTION

Population growth and climate change (Vorosmarty et al., 2000) together with increased quality of life wich demands increased access to freshwater incur an added risk of international water conflicts (Gleick, 1993). Conflicts disrupt the development of nations and hinder the efforts to enhance the quality of life (Wolf, 2007). Therefore, identification of water conflict vulnerabilities is a prompt neccessity.

Gleick (1993) proposed four indicators of water resource vulnerability of countries. They were annual water withdrawals to availability, annual water availability per capita, the dependance on imported surface water and the dependance on hydroelectricity. However, economically developed countries such as the USA, Kuwait, the UAE possess high resilience over water scarcities and conflicts both, due to their affordability of technologycal and institutional solutions. This research accounts for this adaptive capacity of countries in the developed classification.

2. METHOD OF ANALYSIS

(1) Classification of countries into water conflict vulnerability groups

Countries were classified according to five indicators (**Table. 1**). Glieck's (1993) Annual water availability per capita per year and the dependency of external water resources were adapted to this research as well. The Gross National Income (GNI) per capita of countries was employed as indicating the adaptive capacity over water related issues. Ground water dependency of a country is considered as well, as ground water cannot be considered as a sustainable resource in the face of booming populations. Therefore, ground water dependant countries tend to seek increased access to shared waters with another country. The near future demand for water was accounted for by taking countries' population growth rates. FAO Aquastat 2005 database provided the water related data of 136 continental countries (Nations sharing at least one border with another country) for the classification. For large aquifers such as that shared by Tunisia, Algeria and Libya, the external ground water flow has been utilized in calculating external water resources. In calculating external water resources, the flow reserved by upstream country with any existing water agreements has been accounted. All values provide annual estimates. Population growth rates were obtained from the US Census Bureau and the GNI per capita were from the World Bank. All utilized data sets belong to the period 1998-2005. The classification uses combined decision tree and multivariate analysis method (**Table. 1**). Multivariate analysis of water resources per capita, GNI per capita and population growth rates was performed in simple classification rules produced by exploring the possible plots between the three parameters and clustering by their statistical distances (**Table. 2**). Statistical distance (Johnson and Wichern, 2007) $d(P, Q)$ between two points P and Q with coordinates $P(x_{1i}, x_{2i}, x_{3i})$ of cluster i (identified by exploring plots) and $Q(y_{1j}, y_{2j}, y_{3j})$ of cluster j belonging to multivariate parameters 1, 2 and 3 (Here x and y are parameter values at points P and Q respectively).

$$d(P,Q)=\sqrt{\frac{(x_{1i}-y_{1j})^2}{(s_{1i}.s_{1j})^{0.5}}+\frac{(x_{2i}-y_{2j})^2}{(s_{2i}.s_{2j})^{0.5}}+\frac{(x_{3i}-y_{3j})^2}{(s_{3i}.s_{3j})^{0.5}}} \quad (1)$$

Here, s_{kl} are the sample variances of parameter k (k=1, 2, 3) and of cluster l (l=i,j); i,j = I, II, III, IV, V(**Table. 2**). The five clusters agreed with each other more than 80% for the two methods (**Table. 2**).These clusters consisted the third level of the decision tree (**Table. 1**).

(2) Comparison with actual water conflict occurrences

The groups resulted from the above classification were then checked against the actual occurrences of water conflicts in a yes/no mode. Non-cooperative international relations over shared water were assumed to indicate water conflicts. The water event database of the Transboundary Fresh Water Dispute Database of Oregon State University

Table. 1 Conceptualizing the influence of parameters to water conflicts

Parameter	Water conflict vulnerability when the parameter is		Contribution to the classification
	High	Low	
Ground water dependency >50%	High	Low	Decision tree first level
External resource dependency >30%	High	Low	Decision tree second level
Water resources per capita (10^{-12}hm^3/year)	Low	High	Multivariate analysis
GNI per capita (PPP, International Dollars)	Low	High	Multivariate analysis
Population growth rates (%)	High	Low	Multivariate analysis

GNI is the Gross National Income measured in the purchasing power parity terms.

Table. 2 The classification rules compared to multivariate analysis classification

Country classes by classification rules	Parameters		Agreement with the clustering (%)
	Water resources per capita per year (10^{-12}hm^3/year)	GNI per capita (PPP, International Dollars)	
I	< 17 610	< 13 195	91
II	< 17 610	> 13 195, <23 085	86
III	> 17 610	< 13 195	81
IV	< 17 610	> 23 085	80
V	> 17 610	>13 195	

was employed for the comparison. For a particular year of concern, all countries sharing an international river may not be involved in conflicting events or cooperative efforts. Therefore, the latest international relations were occupied from the period 1990-2000. Considered the Nile basin, the international relations over sharing the Nile waters between Egypt and Sudan were non-cooperative for this period in the database. Nevertheless, the relations between other basin countries and the joint basin management efforts were still cooperative. However, the only interaction recorded for the year 2000 was a cooperative effort between Uganda and Egypt.

3. RESULTS AND DISCUSSION

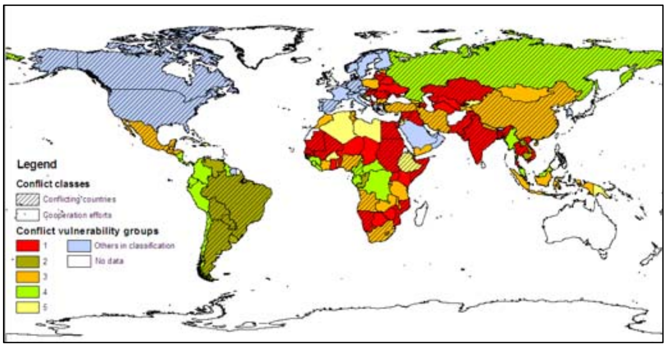

Fig.1 Water conflict vulnerability country groups identified by the classification.

Table. 3 The percentages correctly classified of the major conflict vulnerability groups

Vulnerability group	Total number of countries	Percent of conflicting countries (%)
1	37	54
2	11	55
3	31	48
4	19	21
5	10	30

The conflict vulnerability groups of countries resulted in by the classification is shown in **Fig.1**. Country groups 1,2,3,4 and 5 (**Table. 3**) are the country groups with the highest numbers of members. Nevertheless, in accordance with our conceptualization (**Table. 1**) they are the most vulnerable to water conflicts. Therefore, our focus for the discussion will be these five country groups. They have a common feature of GNI per capita lower than 13195 international dollars. These five groups are able to explain water conflict vulnerabilities of 108 countries, covering Africa, South America and Asia. The most vulnerable are the groups 1and 3 which suffer from the lowest per capita water availabilities as well. The classification can explain 54% (**Table. 3**) of the water conflict occurrences of this group. These countries are vulnerable to both water quantity and quality issues. The next vulnerability groups are 2 and 4. The external water dependency is the highest in group 2. They are the most downstream countries in South America, of which all the upstream countries belong to group 4. These have comparatively higher per capita water, although their adaptive capacity to water related issues as low as in the other groups. Therefore, these could be more vulnerable to water quality issues. The 5th group's water conflict vulnerability is due to their high dependence on ground water resources. These countries facing rapid population growths will tend to seek increased access to the shared water resources. Therefore, water conflicts could ignite.

If focused on internationally shared river basins, the meaning of the classification becomes straight forward. Indus basin countries; India and Pakistan belong to vulnerability group 1 and they were in conflict by year 2000. The four most downstream countries of Mekong basin consists of group 1and 2 countries; among them, Thailand and Laos were already in conflict by 2000. The other two; Vietnam and Cambodia are therefore susceptible to renounce their cooperative efforts as well. In the Nile basin, four out of ten basin countries belong to vulnerability group 1. Out of them, Uganda and Kenya is highly vulnerable to water conflicts while Sudan and Egypt were conflicting even at present. For these three basins, not only the water quantity, but also water quality issues pose a greater threat of conflicts due to their very low adaptive capacities.

Nevertheless, water conflict vulnerabilities of countries with large territories such as China, the Russian Federation, USA and Canada could not be explained well, due to their extremely uneven population distributions.

4. CONCLUSIONS

A combined decision tree and multivariate analysis was utilized to classify 136 countries into conflict vulnerability groups. Five parameters including adaptive capacity of a country to water related issues indicated by the GNI per capita (PPP) provided the basis for the classification in this research. The country groups were then tested for their present actual conflict occurrences on a yes/ no mode. Out of the five highest vulnerability groups identified, the two most vulnerable country groups were more than 54% accurately classified. These five groups are capable of explaining water conflict vulnerabilities of 108 countries, including Africa, Asia and South America.

The highest vulnerable to water conflicts are Vietnam and Cambodia in the Mekong and Uganda and Kenya in the Nile, in accordance with our analysis. They are highly vulnerable to both water quantity and quality issues. More open international food trade options could be capable of reducing the risks of water conflict ignition in these countries.

ACKNOWLEDGMENT: The authors would like to thank the Global Environment Research Fund (S-8) of Ministry of Environment, Japan for their immeasurable assistance in this research.

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