Water Footprint Analysis in Kanto basin zone, Japan by compiling the Kanto Interregional Input-Output Table

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Abstract
We have a detailed picture of water indu cement of Kanto region, Japan as water footprint. To analyze water footprint in Kanto region we compile the Kanto Interregional Input-Output Table. Previously we have interregional input output table in Japan among Kanto Hokkaido Tohoku Chubu Kinki Chugoku Shikoku Kyushu and Okinawa made by Ministry of Economy Trade, and Industry. However we don’t have interregional input output table within the Kanto region, compared to Kinki region which is made by KISER. Therefore it is significant to compile the Kanto Interregional Input-Output Table. We decide the range of Kanto region, Tokyo Kanagawa Chiba Saitama Ibaraki Gunma Tochigi Niigata Nagano Yamanashi and Shizuoka. Therefore we compile the Kanto Interregional Input-Output Table as 11 regions by 28 sectors. Kanto region include Tokyo Metropolitan area which have 30 Million inhabitants.

Basically the estimation about interregional trade of Kanto region is operated by the census of logistics in Japan. Secondly we estimate the water use by sector about 11 regions by census of manufactures. The method of calculation of regional water footprint is based on the model of interregional inducement by input output analysis. The result is that Tokyo Metropolitan area such as Tokyo Kanagawa Saitama Chiba leave water footprint towards surrounding area such as Ibaraki Tochigi Niigata Shizuoka. The result has important information that some region uses their water for other region. The result also gives useful information for regional water management.

Keywords: Compilation of Interregional input output table, Water footprint, Water inducement of regional linkages.
1. Introduction
The 10th meeting of the Conference of the Parties (COP10) to the Convention on Biological Diversity (CBD) ended in Nagoya, Aichi Prefecture, on Oct. 30, 2010. Previously, The Millennium Ecosystem Assessment (MA) concluded concludes that human activity is having a significant and escalating impact on the biodiversity of world ecosystems, reducing both their resilience and biocapacity. Additionally, MA included the sub-global assessment (SGA) that is the assessment of regional, watershed, state as well as the global scale. In Japan SATOYAMA SATOMI SGA is put into practice by using SGA framework. We chose the Hokkaido Tohoku Kanto-Chubu Hokuriku Nishi-nihon cluster as the area of SATOYAMA SATOMI SGA. Above all, Kanto-Chubu cluster has four sites that is Kanagawa Tochigi Chiba Tokyo and the scope of target is Tokyo Bay, Naka River, Ise Bay, Mikawa Bay.

The author collaborates with the researcher of Kanagawa site and studies the impact of ecological system through the change of socio-economy of Kanagawa, Ishiro and Hasebe (2010).

The Objective of this paper is to clarify the relation between economic activity and structure of water usage in Kanto region, based on SATOYMA SATOMI SGA.

Especially, having regard to the fact that trade with other regions is essential to regional activity, the main purpose is to see how trading of each region within Kanto region affects the water usage of Kanto area.

There is previous study, Okadera, Fujita, Watanabe and Suzuki (2005), that has common awareness of the issues. They made Kanto interregional input output table including seven regions of Kanto area, the year 1995 and estimated the water demand of this region. On the other hand, our study made Kanto interregional input output table including 11 regions.

2. Previous study
There are many studies that analyze the CO₂ emission Land and Waste by using interregional input output tables. As for water, the studies of Niizawa (1988), Okadera, Fujita, Watanabe and Suzuki (2005), Shimoda Watanabe Yue , and Fujikawa (2009) are representative research in Japan. Or there is earlier research of input output study, Carter and Ireli (1970). Niizawa (1988) reveals the balance of water inducement between Chiba and Ibaraki by using regional input output tables. Judging from the result of this analysis he speculates the high water dependency of Tokyo to other region.

In Okadera, Fujita, Watanabe and Suzuki (2005) they target six regions including
Tokyo as Tokyo Bay Basin and estimate the structure of water demand of this area by compiling the interregional input output table of six regions. They conclude water demand of Chiba Kanagawa Ibaraki is high compared to the one of Tokyo however water inducement from consumption of Tokyo derives from other region over 50 percent. In Shimoda Watanabe Yue, and Fujikawa(2009), they analyze the embedded water trade with CO2 energy land by using Asian international input output table made by IDE-JETRO. They concluded the maximum user of water is China, and the maximum transfer of embed water is transfer from China to Japan. Additionally Japan support oneself through domestic water about only 66%, they import largest amount of water from China. In Carter and Ireli(1970), they calculate water transfer between Arizona and California by using two interregional input-output table between Arizona and California in 1958. They conclude in the actual trade of goods between Arizona and California export from California to Arizona is four times larger than import from Arizona to California, on the other hand in water transfer import from Arizona to California is three times larger than export from California to Arizona.

In the study, we expand the geographical area from seven regions in Okadera, Fujita, Watanabe and Suzuki (2005) to eleven regions and expand the estimation of sectoral water use from Kanagawa in Ishiro and Hasebe(2010) to other regions. In method of analysis we refer to the method of Shimoda Watanabe Yue, and Fujikawa(2009). Additionally we have same problem consciousness that in water transfer considering interregional economic activity the region have large scale of economic activity depends on other region have water resource in earlier work of Carter and Ireli(1970).

3. The compilation of Kanto interregional input output table and water usage data

In this paper we compile the Kanto interregional input output table about 11 regions. Additionally we made the sectoral water usage data in accordance with the sector of Kanto interregional input output table that we made. As for the compilation of Kanto interregional input output table we noted appendix1. As for the compilation of the sectoral water usage data we noted appendix 2. As for the area classification we noted figure1. As for the sector classification of input output table we noted figure 2. As for the tabular form of Kanto interregional input output tables we noted figure 3. As for the water usage data of 11 regions we noted figure 4.
**Figure 1**, Area classification of Kanto region

![Area classification of Kanto region](image)

**Figure 2**, Sector classification

<table>
<thead>
<tr>
<th></th>
<th>Category</th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Agriculture, forestry and fishery</td>
<td>15</td>
<td>Precision instruments</td>
</tr>
<tr>
<td>2</td>
<td>Mining</td>
<td>16</td>
<td>Miscellaneous manufacturing products</td>
</tr>
<tr>
<td>3</td>
<td>Beverages and Foods</td>
<td>17</td>
<td>Construction</td>
</tr>
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<td>4</td>
<td>Textile products</td>
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<td>Chemical products</td>
<td>20</td>
<td>Finance and insurance</td>
</tr>
<tr>
<td>7</td>
<td>Petroleum and coal products</td>
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<td>Real estate</td>
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<tr>
<td>8</td>
<td>Ceramic, stone and clay products</td>
<td>22</td>
<td>Transport</td>
</tr>
<tr>
<td>9</td>
<td>Iron and steel</td>
<td>23</td>
<td>Information and communications</td>
</tr>
<tr>
<td>10</td>
<td>Non-ferrous metals</td>
<td>24</td>
<td>Education and research</td>
</tr>
<tr>
<td>11</td>
<td>Metal products</td>
<td>25</td>
<td>Public administration</td>
</tr>
<tr>
<td>12</td>
<td>General machinery</td>
<td>26</td>
<td>Business services</td>
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<td>13</td>
<td>Electrical machinery</td>
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<td>Personal services</td>
</tr>
<tr>
<td>14</td>
<td>Transportation equipment</td>
<td>28</td>
<td>Activities not elsewhere classified</td>
</tr>
</tbody>
</table>
4. The models

We use basically the same model of the one of Ishiro and Hasebe(2010). However in Ishiro and Hasebe(2010) we consider the single region model because we use the single input-output table in Kanagawa. Meanwhile in this time we apply the interregional input output about water inducement models because we use the Kanto interregional input output tables that we compile.

We indicate the model of simplified version about two endogenous regions and one exogenous region. The formula 1 denote as follows.

\[
\begin{bmatrix}
    x_1 \\
    x_2
\end{bmatrix} =
\begin{bmatrix}
    A_{11} & A_{12} \\
    A_{21} & A_{22}
\end{bmatrix}
\begin{bmatrix}
    x_1 \\
    x_2
\end{bmatrix} +
\begin{bmatrix}
    f_{11} + f_{12} + f_{13} \\
    f_{21} + f_{22} + f_{23}
\end{bmatrix}
\]  

(1)

\( x_i \) denotes domestic products of \( i \) regions, \( A_{ij} \) denotes input coefficient if \( i=j \) it represents intermediate goods within this region, if \( i \neq j \) input coefficient of import intermediate goods from \( i \) region to \( j \) region. \( f_j \) denotes final demand of \( j \) region about the goods of \( i \) region. \( f_j \) denotes...
the export to exogenous region. \( \mathbf{I} \) denotes unit matrix.

If we development formula 1, we get formula 2 as follows.

\[
\begin{bmatrix}
  x_1 \\
  x_2
\end{bmatrix} = \begin{bmatrix}
  1 - \mathbf{A}_{11} & \mathbf{A}_{12} \\
  \mathbf{A}_{21} & \mathbf{A}_{22}
\end{bmatrix}^{-1} \begin{bmatrix}
  f_{11} + f_{12} + f_{13} \\
  f_{21} + f_{22} + f_{23}
\end{bmatrix} = \begin{bmatrix}
  \mathbf{B}_{11} & \mathbf{B}_{12} & f_{11} + f_{12} + f_{13} \\
  \mathbf{B}_{21} & \mathbf{B}_{22} & f_{21} + f_{22} + f_{23}
\end{bmatrix}
\]

(2)

If \( \mathbf{w}_i \) denotes unit of water use of \( i \) region, \( \mathbf{h}_i \) represents water intensity formula 3 as follows.

\[
\begin{bmatrix}
  h_1 \\
  h_2
\end{bmatrix} = \begin{bmatrix}
  \mathbf{w}_1 \\
  \mathbf{w}_2
\end{bmatrix} \begin{bmatrix}
  \mathbf{B}_{11} & \mathbf{B}_{12} \\
  \mathbf{B}_{21} & \mathbf{B}_{22}
\end{bmatrix}
\]

(3)

About water inducement in each region, we divide the final demand of formula 2 into region 1 region 2 and region 3 and if \( \mathbf{W}_i \) denotes diagonal matrix of \( \mathbf{w}_i \), we get formula 4 as follows.

\[
\mathbf{L} = \begin{bmatrix}
  \mathbf{W}_1 & 0 & \mathbf{B}_{11} & \mathbf{B}_{12} & f_{11} & f_{12} & f_{13} \\
  0 & \mathbf{W}_2 & \mathbf{B}_{21} & \mathbf{B}_{22} & f_{21} & f_{22} & f_{23}
\end{bmatrix}
\]

(4)

\( \mathbf{L} \) denotes two by three matrix. The column side of the matrix means the region that generates final demand. The Row side of the matrix means the region that is done by water inducement. In the analysis of this thesis there are eleven endogenous regions and two exogenous regions including rest of Japan and abroad therefore \( \mathbf{L} \) denotes eleven by thirteen matrix.

5. The result of analysis

In this chapter we summarize the analysis of water footprint of Kanto region. Figure 5 shows the result of calculation based on formula (3). Grey cells shows the diagonal factor that represents water inducement of its own demand in its own region additionally the non-diagonal factor that represents top 10 score of water inducement within the Kanto region except diagonal factor. Furthermore in the row direction figure 5 shows the water inducement that occurs in the other regions based on demand in its region in the column direction water inducement that occurs in its region based on demand in other regions.
First of all we focus on Tokyo. There are seven billion cubic meter of water inducement in its region out of water demand in its region. However there are eight billion cubic meter of water inducement in Ibaraki and five billion cubic meter of water inducement in Chiba because of water demand of Tokyo. Therefore the fact shows that water demand of Tokyo caused large water inducement in other region like Ibaraki and Chiba etc. On the other hand the fact that water demand of other regions caused comparatively small water inducement in Tokyo leads to the Tokyo’s dependency of water resource to other regions. Secondly in Kanagawa there is water inducement in Ibaraki Chiba and Shizuoka because of water demand of Kanagawa. On the other hand water inducement in Kanagawa for the other region is largest amount to Tokyo. In this regard Kanagawa have same characteristic as Tokyo that water demand in its region cause the large water inducement in other region. For that reason Kanagawa also have large dependency on water resources of other region same as Tokyo. In contrast Chiba have different feature as Tokyo metropolitan district. The water inducement in other region by water demand of Chiba is comparatively small. On the other hand in Chiba water inducement in its region for water demand of other region is large such as for water demand of Tokyo Kanagawa Ibaraki Saitama. For this reason Chiba assume water use of other region. This trend is especially obvious in Ibaraki. Ibaraki assume the most water use of other endogenous region in Kanto area. On one hand Saitama causes large water inducement in Tochigi Niigata by its water demand and assume the water demand in Tokyo. Additionally Niigata has a high self sufficiency of water because it has the most powerful trend that water inducement in Niigata is largely attribute to the its own water demand. As for the water inducement of its own region by the water demand of other region, water inducement in Niigata causes by water demand of rest of Japan. For that reason it would appear that geographical proximity of

<table>
<thead>
<tr>
<th></th>
<th>Tokyo</th>
<th>Kanagawa</th>
<th>Chiba</th>
<th>Saitama</th>
<th>Ibaraki</th>
<th>Tochigi</th>
<th>Gunma</th>
<th>Niigata</th>
<th>Nagano</th>
<th>Yamanashi</th>
<th>Shizuoka</th>
<th>ROJ</th>
<th>ROW</th>
<th>Total</th>
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<td>3</td>
<td>16</td>
<td>198</td>
<td>73</td>
<td>802</td>
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<tr>
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<td>537</td>
<td>150</td>
<td>708</td>
<td>117</td>
<td>117</td>
<td>38</td>
<td>39</td>
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<td>7</td>
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<td>472</td>
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<tr>
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<td>77</td>
<td>99</td>
<td>578</td>
<td>36</td>
<td>20</td>
<td>45</td>
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<td>2</td>
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<td>135</td>
<td>430</td>
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<td>76</td>
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<td>4</td>
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<td>679</td>
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<td>95</td>
<td>260</td>
<td>55</td>
<td>387</td>
<td>181</td>
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<td>7</td>
<td>30</td>
<td>780</td>
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<td>33</td>
<td>65</td>
<td>31</td>
<td>34</td>
<td>273</td>
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<td>2</td>
<td>7</td>
<td>337</td>
<td>20</td>
<td>935</td>
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<tr>
<td>Niigata</td>
<td>166</td>
<td>122</td>
<td>65</td>
<td>210</td>
<td>38</td>
<td>44</td>
<td>62</td>
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<td>Nagano</td>
<td>94</td>
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<td>48</td>
<td>67</td>
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<td>50</td>
<td>20</td>
<td>547</td>
<td>31</td>
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<tr>
<td>Yamanashi</td>
<td>56</td>
<td>12</td>
<td>13</td>
<td>31</td>
<td>3</td>
<td>1</td>
<td>3</td>
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<td>2</td>
<td>6</td>
<td>75</td>
<td>15</td>
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<tr>
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<td>98</td>
<td>160</td>
<td>63</td>
<td>109</td>
<td>37</td>
<td>18</td>
<td>20</td>
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<td>17</td>
<td>30</td>
<td>752</td>
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<tr>
<td>Total</td>
<td>3,248</td>
<td>1,327</td>
<td>1,365</td>
<td>1,674</td>
<td>784</td>
<td>643</td>
<td>744</td>
<td>1,267</td>
<td>646</td>
<td>168</td>
<td>493</td>
<td>5,697</td>
<td>664</td>
<td>20,577</td>
</tr>
</tbody>
</table>
Niigata to exogenous region, rest of Japan leads to strong linkage between Niigata and exogenous region. These things apply to Shizuoka. It shows from the column sum of figure 5 that in the total water inducement by its own water demand Tokyo is 1st Saitama is 2st Chiba Kanagawa. It shows from the column sum of figure 5 that in the total water inducement by its own water demand Tokyo is 1st Saitama is 2st Chiba Kanagawa. It shows from the row direction of figure 5 that in total water inducement in its own region by water demand of other region Niigata is 1st Ibaraki is 2st Chiba Tochigi. The water inducement in Tochigi largely causes by water demand of Saitama however there is hardly any water inducement in Saitama by water demand of Tochigi. For that reason we find that Saitama depends on water resources of Tochigi. The largest water inducement among the Kanto endogenous region is water inducement in Ibaraki by demand of Tokyo. The second largest is inducement in Chiba by Tokyo. The third largest is in Saitama by Tokyo. Next are in Tochigi by Tokyo, Tochigi by Saitama and so on. In the water inducement by demand of rest of Japan Niigata is 1st. Next is Tochigi Shizuoka Ibaraki. In the water inducement by demand of foreign country Chiba is 1st. Next is Niigata Ibaraki Shizuoka.

We plot the information of figure 5 on geographical information for the sake of understandable way. We can see the water inducement in each region by the demand of the region that is noted on the map including its own region. For instance water inducement in other region by demand of Tokyo is largest in Ibaraki. Next is Chiba.

This information easily figures out the contrasting density on the map.

These results of analysis by the calculation of water footprint among Kanto region considering input output linkages of each region give us important suggestion to SATOYAMA SATOMI SGA that analyze the burden of socio-economic activity toward ecological systems. In broad point of view these result give us important information about region that receives the burden of water use and gives it the burden of water use.

These results request that considering the whole water resources of Kanto region the region that gives other regions the burden of water use should work on conservation and maintenance of water environment in the region that receives the burden of water use.
Figure 6, Water inducement from demand of each region

Tokyo

Kanagawa

Chiba

Saitama

Ibaraki

Tochigi
6. Conclusion

In this study about Kanto region after we made Kanto interregional input output table including 11 regions and made the sectoral water usage data in accordance with such input output table we analyze the water inducement within Kanto region and among Kanto region and rest of Japan and foreign country. The result of this study is as follows.

First in Tokyo water inducement in its region by demand of other region is small however water inducement in other region such as Ibaraki and Chiba by demand of Tokyo is large. Kanagawa has same trend that water inducement in other region such as Ibaraki and Chiba and Shizuoka by demand of Kanagawa is large. Secondly Saitama has different trend in Tokyo metropolitan district that water inducement in other regions such as Tochigi and Niigata and Ibaraki. On the other hand water inducement in its region by demand of Tokyo is large. Thirdly in Chiba water inducement in its region by demand of Tokyo is large. On the other hand the water inducement in Ibaraki by demand of Chiba is large. Fourthly for that reason Ibaraki assume the water demand of Tokyo metropolitan district. It has large water trade surplus. In other words Tokyo metropolitan district give Ibaraki “water footprint.”

Previous study using input output analysis about water indicate the same feature that because the region has the large economic scale has also large scale of consuming region and in the generality rarely has enough water resources, it depends on water resources of other regions. Even as the result of this study basically shows same feature we find that a central focus on Tokyo gives surrounding area the burden of water inducement. On that basis for the situation of footprint we indicate the stuff that the region that give
other region burden of water inducement should positively act for the reform of water environment.

Reference

Appendix 1
In this study for the analysis of water footprint in Kanto region we made Kanto interregional input output table. The target year for input output table is in 2000. As Kanto region we choose the 11 regions about Tokyo Kanagawa Chiba Saitama Ibaraki Tochigi Gunma Niigata Nagano Yamanashi Shizuoka. First we aggregate each regional input output table about 11 regions into 28 sectors within the common sector code. As for the estimation of trade within Kanto region, we do as follows. From 1 Agriculture, forestry and fishery to 16 Miscellaneous manufacturing products we divide the export to rest of Japan in each region according to the ratio compiling from census of logistics in 2000. From 17 Construction to 28 Activities not elsewhere classified we distribute the export to rest of Japan based on the assumption that export to each Kanto region is proportional to regional demand in each region. Finally we adjust the balance of column and row of the table we made. We complete the Kanto interregional input output table.

Appendix 2
In this research we made sectoral water usage data in accordance with Kanto interregional input output table based on the method of Ishiro and Hasebe(2010)
which made sectoral water usage data of single region, Kanagawa.

As for the water usage data of agriculture from the data of irrigation water for paddy field and irrigation water for dry field in Japan and the data of cultivated acreage of paddy fields or dry fields we calculate the unit water usage data per hectare of each field in Japan. Then multiplying the unit water usage in Japan by the data of cultivated acreage of paddy fields or dry fields in each region gives the water usage data by each region. As for the water usage data of manufactures from the industrial water of each region in census of manufactures we can acquire the data of new water usage per day by removing the recovered from the fresh water. Afterward multiplying the data of new water usage per day by the number of operating day, 250 days that we assume that every sectors has same operating day same as Ishiro and Hasebe(2010), gives the data of new industrial water usage per year. As for other sector by using the data of unit water use by sector in Tsurumaki and Noike(1997) multiplying the unit water use by sector by the volume of production in each sector of each region gives the water usage data by sector.