Economic Loss Estimation of Water Supply Shortage Based on Questionnaire Survey in Industrial Sectors

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Abstract

The economic impacts assessment of water supply disruption using a general input-output model with mixed exogenous and endogenous variables are presented in this paper. There are six water supply reduction scenarios designed to explore the economic impacts of water shortage. The estimation of GDP Loss and loss percentage for 10%, 20%, and 30% water supply reduction scenario within one day, three days, one week, and one month has been conducted based on the questionnaire survey. It is obvious that longer and more water supply reductions may result in worse losses based on the survey and estimation. The estimation of GDP loss may be some 1.9 billion Yen for one-day 10% water reduction scenario, 2.7 billion Yen for 20%, and 3.8 billion Yen for 30% scenario in Aichi Prefecture. GDP loss will be some 29.6 billion Yen for 10% scenario, 37.6 billion Yen for 20%, and 52 billion Yen for 30% scenario for Aichi Prefecture one-week case. Mean GDP loss for one month scenario may be worst as 162 billion Yen for 10%, 192.9 billion for 20%, and 270.7 billion Yen for 30% scenario. However, loss percentage by water supply shortage is minimal to annual GDP in Aichi Prefecture. Estimated mean loss percentage of annual GDP may account for 0.4632%, 0.5515%, and 0.7742% for Aichi Prefecture case study during one month water supply scenario of 10%, 20%, and 30% reduction. Some suggestions may be useful to water supply policies during water shortage or drought events.

Key words : Drought, Water supply disruption, Economic loss, Input-output analysis

1. Climate change and drought impact

Continuing concern regarding global climate change is focusing on the climate forecast and impact assessment. American federal government launched the Climate Change Science Program for identifying the scientific information to assist the nation's evaluation of optimal strategies to address global change risks in 2003 (National Research Council, 2005). The Ministry of Education, Science and Technology of Japanese Government has also started the Humans, Nature and Globe Co-living Project for sophistication of wide-area water circulation prediction and countermeasures technologies. One of major targets is to conduct the study on extreme weather events and water disasters in the context of climate change for decision-making on water shortage or droughts preparedness and mitigation. This paper presents a general methodology for evaluation of economic losses caused by drought-induced disruption of water service in Aichi Prefecture.

Drought is a major natural disaster that is caused by a deficiency in precipitation that may lead to a deficiency in surface and subsurface water supplies and that causes or may cause substantial economic or social impact, or physical damage or injury to individuals, property, or the environment (US Senate and House, 2003). Although there are many types of droughts for diverse stakeholders or researchers, they can be classified as meteorological, agricultural, and stored water droughts. Meteorological drought means low precipitation. Agricultural

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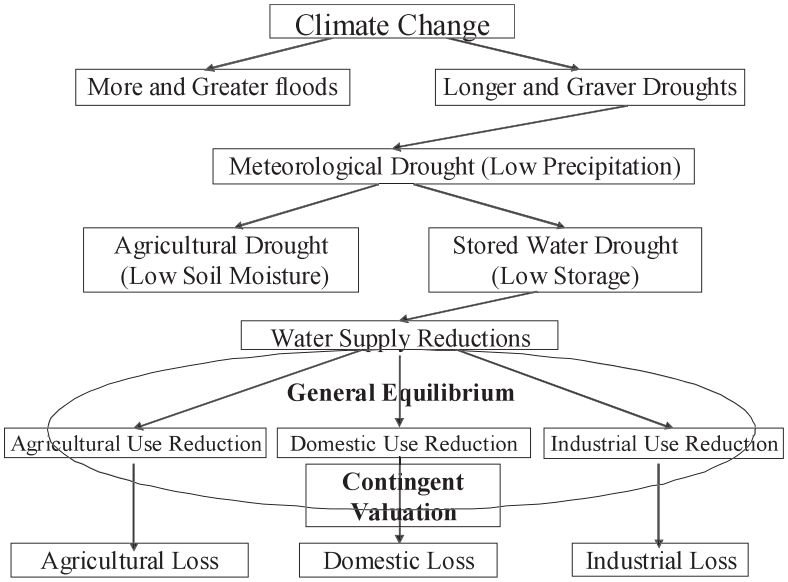

Fig. 1 Climate Change and Drought Impacts.

drought refers to the low soil moisture. Stored water drought can place great stress on water supplies for irrigational agricultural, domestic and industrial uses.

Drought is one of the major weather-related disasters persisting over months or years. It can and does last longer periods and extend to broader areas than hurricanes, tornadoes, floods, and earthquakes. There is an increasing risk related to drought along with population growth, economic development, and climatic change in the world. Larger inter- and/or intra-year variations in precipitation may be very likely covered most areas in the 21st century according to the 2001 Report of the Inter-governmental Panel on Climate Change (IPCC) with a wide range of scenarios based on global model simulations (IPCC, 2001). For the point of view of drought issue, it means that lower precipitation may occur likely and/or frequently to result in lower soil moisture in farmland or smaller runoff in river channels. Therefore, lower water volume stored in tanks and reservoirs stress on water supply via pumping stations and water aqueducts. Thus, low precipitation (drought) may trigger the water supply shortage and result in water supply reductions in agricultural, domestic and industrial use (**Fig. 1**).

Although the record drought of 1994 claimed over half of Japanese archipelago, there was minimal economic impact at national or even at prefecture level. However, when they are not impacted directly, people and businesses may be affected through damage to lifelines such as water supply reductions, or through indirect effects such as the loss of livelihood or markets. Moreover, there are some spill-over effects from one region to the others. Even in aggregate, the indirect effects on a community are often far larger than the direct effects (Eguchi *et al*., 1993). Ideally, an inter-industry economic model including input-output analysis and social accounting matrices should describe the situation of different sector groups and activities explicitly, as well as their links with the wider economy and region.

The social accounts using general equilibrium provide a region-by-region pre-drought picture of the network of domestic transactions and flows to and from neighboring regions. In a multi-region system, economic transactions spill over into neighboring regions and also feed back in the original economy (Shinozuka *et al*., 1998). In the event of a drought, some of the nodes and links in this multi-region economic network are disrupted, while others may take up the slack for the resilient equilibrium. Therefore there is a circular process of spillover and feedback until it diminishes.

As one of major lifelines, it is not necessarily that 100% disruption of water supply leads to 100% loss of economic output because a particular industry may depend upon the lifeline only to a limited degree. If the gross output changes can be converted into final demand changes in an input-output model as the conduits through which external shocks are transmitted (Shinozuka *et al*., 1998), the change in every industry is magnified and spread over the whole region affected. Typically, input output models are used to simulate events that are relatively simple compared to the circumstances of a great drought. Thus drought damage or loss should be introduced into the model that records the intensity of the impacts on each activity and transaction and resiliency of each activity or transaction. Therefore one should estimate drought impacts on economy in detail.

2. Model of input-output analysis

It is well known that utility lifeline supply disruptions can have significant impacts on regional economic activities in the aftermath

of natural and manmade disasters. The estimation of economic impacts of natural disasters for utility lifeline disruption may be dated back to the work of Cochrane (1974). Since then, Rose (1981) discussed the utility lifelines and economic activity in the context of earthquakes for minimizing losses from a utility lifeline disruption by reallocating resources across sectors. Other damage models have been developed by Davis *et al*. (1982), Applied Technology Council (ATC, 1985), and Shinozuka *et al*. (1992) to deal with the earthquake impacts in purely physical terms on water delivery system. In 1989, the National Research Council suggested that earthquake damage modeling needed to go beyond physical damage to capture the social and economic impacts of earthquakes (French, 1998). Several models for estimating the impacts of earthquakes on the social and economic functions of a specific region have been developed based on regional input-output models (ATC, 1991; and Rose *et al*., 1997) or computable general equilibrium models (Rose *et al*., 1999). However, these methodologies mentioned above did not discuss the estimation of economic impacts of water supply reduction without physical damage in water utilities. In this paper, we try to estimate the economic impacts of water supply disruptions triggered by water shortages or drought events based on regional input-output model.

The input-output analysis is the most widely applied modeling approach developed by Professor Wassily Leontief (1936, 1941) to provide insights into economic interdependence or inter-industry. In the usual form of the standard demand-side input-output model, the final-demand elements are considered exogenous. However, Tiebout (1969) developed a mixed type of I/O analysis with exogenous final demands for some sectors and gross outputs for the remaining sectors. Miller and Blair (1985) discussed a general input-output model with mixed exogenous and endogenous variables. For water shortage or drought case, the reduction of water supply may strike the regional economy. The basic input-output relationships are embodied in the follow equations if we assume 1 as water sector and 2 through N (N refers to total sector number) as other sectors based on the Miller and Blair model:

$$\begin{pmatrix} A_{11} & A_{12} & A_{13} & \cdots & A_{1n} \\ A_{21} & A_{22} & A_{23} & \cdots & A_{2n} \\ A_{31} & A_{32} & A_{33} & \cdots & A_{3n} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ A_{n1} & A_{n2} & A_{n3} & \cdots & A_{nn} \end{pmatrix} \begin{pmatrix} X_1 \\ \overline{X_2} \\ \overline{X_3} \\ \vdots \\ \overline{X_n} \end{pmatrix} + \begin{pmatrix} \overline{F_1} \\ F_2 \\ F_3 \\ \vdots \\ F_n \end{pmatrix} = \begin{pmatrix} X_1 \\ \overline{X_2} \\ \overline{X_3} \\ \vdots \\ \overline{X_n} \end{pmatrix} \tag{1}$$

where A_{ij} is input coefficient matrix, the final demand $\overline{F_1}$ in water sector is given, and output $\overline{X_2} \cdots \overline{X_n}$ in other sectors can be given by survey.

We rearrange the equation (1) as follows:

$$\begin{pmatrix} A_{11}-1 & 0 & 0 & \cdots & 0 \\ A_{21} & 1 & 0 & \cdots & 0 \\ A_{31} & 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ A_{n1} & 0 & 0 & \cdots & 1 \end{pmatrix} \begin{pmatrix} X_1 \\ F_2 \\ F_3 \\ \vdots \\ F_n \end{pmatrix} = \begin{pmatrix} -1 & -A_{12} & -A_{13} & \cdots & -A_{1n} \\ 0 & 1-A_{22} & -A_{23} & \cdots & -A_{2n} \\ 0 & -A_{32} & 1-A_{33} & \cdots & -A_{3n} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ 0 & -A_{n2} & -A_{n3} & \cdots & 1-A_{nn} \end{pmatrix} \begin{pmatrix} \overline{F_1} \\ \overline{X_2} \\ \overline{X_3} \\ \vdots \\ \overline{X_n} \end{pmatrix} \tag{2}$$

Then equation (2) can be rewritten as:

$$\begin{pmatrix} X_1 \\ F_2 \\ F_3 \\ \vdots \\ F_n \end{pmatrix} = \begin{pmatrix} \frac{1}{A_{11}-1} & 0 & 0 & \cdots & 0 \\ \frac{A_{21}}{1-A_{11}} & 1 & 0 & \cdots & 0 \\ \frac{A_{31}}{1-A_{11}} & 0 & 1 & \cdots & 0 \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ \frac{A_{n1}}{1-A_{11}} & 0 & 0 & \cdots & 1 \end{pmatrix} \begin{pmatrix} -1 & -A_{12} & -A_{13} & \cdots & -A_{1n} \\ 0 & 1-A_{22} & -A_{23} & \cdots & -A_{2n} \\ 0 & -A_{32} & 1-A_{33} & \cdots & -A_{3n} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ 0 & -A_{n2} & -A_{n3} & \cdots & 1-A_{nn} \end{pmatrix} \begin{pmatrix} \overline{F_1} \\ \overline{X_2} \\ \overline{X_3} \\ \vdots \\ \overline{X_n} \end{pmatrix} \tag{3}$$

Thus we have

$$\begin{pmatrix} X_1 \\ F_2 \\ F_3 \\ \vdots \\ F_n \end{pmatrix} = \begin{pmatrix} \frac{1}{1-A_{11}} & \frac{A_{12}}{1-A_{11}} & \frac{A_{13}}{1-A_{11}} & \cdots & \frac{A_{1n}}{1-A_{11}} \\ \frac{A_{21}}{1-A_{11}} & \frac{A_{21}A_{12}}{A_{11}-1}+1-A_{22} & \frac{A_{21}A_{13}}{A_{11}-1}-A_{23} & \cdots & \frac{A_{21}A_{1n}}{A_{11}-1}-A_{2n} \\ \frac{A_{31}}{1-A_{11}} & \frac{A_{31}A_{12}}{A_{11}-1}-A_{32} & \frac{A_{31}A_{13}}{A_{11}-1}+1-A_{33} & \cdots & \frac{A_{31}A_{1n}}{A_{11}-1}-A_{3n} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ \frac{A_{n1}}{1-A_{11}} & \frac{A_{n1}A_{12}}{A_{11}-1}-A_{n2} & \frac{A_{n1}A_{13}}{A_{11}-1}-A_{n3} & \cdots & \frac{A_{n1}A_{1n}}{A_{11}-1}+1-A_{nn} \end{pmatrix} \begin{pmatrix} \overline{F_1} \\ \overline{X_2} \\ \overline{X_3} \\ \vdots \\ \overline{X_n} \end{pmatrix} \tag{4}$$

Let

$$B=\begin{pmatrix} \frac{1}{1-A_{11}} & \frac{A_{12}}{1-A_{11}} & \frac{A_{13}}{1-A_{11}} & \cdots & \frac{A_{1n}}{1-A_{11}} \\ \frac{A_{21}}{1-A_{11}} & \frac{A_{21}A_{12}}{A_{11}-1}+1-A_{22} & \frac{A_{21}A_{13}}{A_{11}-1}-A_{23} & \cdots & \frac{A_{21}A_{1n}}{A_{11}-1}-A_{2n} \\ \frac{A_{31}}{1-A_{11}} & \frac{A_{31}A_{12}}{A_{11}-1}-A_{32} & \frac{A_{31}A_{13}}{A_{11}-1}+1-A_{33} & \cdots & \frac{A_{31}A_{1n}}{A_{11}-1}-A_{3n} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ \frac{A_{n1}}{1-A_{11}} & \frac{A_{n1}A_{12}}{A_{11}-1}-A_{n2} & \frac{A_{n1}A_{13}}{A_{11}-1}-A_{n3} & \cdots & \frac{A_{n1}A_{1n}}{A_{11}-1}+1-A_{nn} \end{pmatrix}$$ as water

impact matrix. The solution of water-induced inter-industry model will be then of the form

$$\begin{pmatrix} X_1 \\ F_2 \\ F_3 \\ \vdots \\ F_n \end{pmatrix} = B \begin{pmatrix} \overline{F_1} \\ \overline{X_2} \\ \overline{X_3} \\ \vdots \\ \overline{X_n} \end{pmatrix} \tag{5}$$

One can obtain the changes in final demands in selected sectors by the Equation (5) if the water impact matrix is fixed in a specific case. Thus the estimation of economic losses can be measured in the terms of GDP (i.e. final demand) if the production losses in each sector are available under certain condition of water supply.

3. Survey design and aggregate result analysis

Since there is a long history of drought events and water shortages in Aichi Prefecture, this study used a questionnaire survey conducted from June through November 2003 to obtain the output impact during different duration of three scenario water supply reductions in Aichi Prefecture. Ten geographical areas were targeted in Aichi prefecture shown in **Fig. 2**: Toyoake Town, Nishin City, Togo Town, Nagakute Town, Miyoshi Town, Obu City, Tokai City, Tita City, Higashiura Town, and Midori District of Nagoya City.

We selected the cities/towns experienced five-hour water supply per day (i.e. 19-hour suspended water supply) in Tokai City, Obu City, Tita City, and Higashiura Town, 12-hour in Toyoake City, Nishin City, Togo Town, Miyoshi Town and Nagakute Town, and 24-hour water supply (but water pressure reduction experienced) involves Midori District of Nagoya City during the drought of 1994. The industries with the input of more than 10 billion Japanese Yen based on the 1995 National Input-output Table in Japan are selected as the survey sectors to find the economic impacts of water service disruption in different major sectors.

The distribution and respondents of questionnaire survey are 4,252 and 720 respectively. However, respondents may make mistakes for filling the sector code in their questionnaire format since the industry (sector) classification is an academic issue. Since we are interest in the drought impacts of six scenario water supply reductions, the questionnaire sheet with incomplete or erroneous information on drought impacts are omitted for impact analysis. In final, 524 responded questionnaire sheets are used in our paper.

Fig. 2 Surveyed Regions in Aichi Ken.

ATC-25(1991) and Shinozuka *et al*. (1998) provide a conceptual framework to evaluate the economic losses caused by seismically-induced disruption of lifeline service in an urban area. However, several modifications should be refined in the analysis on the economic impacts of water service triggered by water shortages or drought events. In our investigation, we ask a question that how much the percentage of production or business loss under the condition of duration and magnitude of scenario water supply reductions. The duration of supply reductions is assumed to last about several hours, one day, 2-3days, within one week, within one month. The magnitude of water supply cutoff is assumed as 10%, 20%, 30%, daytime supply (from 9:00 through 21:00), nighttime supply (from 21:00 through 9:00), and 24-hour suspension (no water supply).

However, output losses or reductions in each company are different in same scenario water supply reduction. We assume that the loss or reduction percentage of all companies of a particular class or group have the same contribution in sectoral subtotal production. Therefore, the production losses percentage in a specific sector can be estimated by averaging over all companies of the same type in a specific sector using the following equation:

$$\Delta\overline{L_j} = \sum_{i=1}^{N_j} \Delta L_{ij} / N_j \tag{6}$$

where $\overline{\Delta L_j}$ is the average production loss percentage in sector j,, ΔL_{ij} is the loss or reduction percentage of production or business in company i in sector j, and N_j is the number of the company in sector j. Therefore, production loss can be estimated as equation (7)

$$\Delta\overline{X_j} = \Delta\overline{L_j} * X_j \tag{7}$$

where $\Delta\overline{X}_j$ is the production loss in sector j, and X_j is the total production in sector j before water supply disruption.

Then, final demands in every sector except water sector can be estimated as equation (8)

$$\begin{pmatrix} X_1 \\ F_2 \\ F_3 \\ \vdots \\ F_n \end{pmatrix} = B \begin{pmatrix} \Delta\overline{F_1} \\ \Delta\overline{X_2} \\ \Delta\overline{X_3} \\ \vdots \\ \Delta\overline{X_n} \end{pmatrix} \tag{8}$$

where $\Delta\overline{F}_1$ is the reduction of water supply, and $\Delta\overline{X}_j$ is the production loss in sector j during a specific water supply scenario.

Fig. 3 presents the average production loss under six different water supply policies and durations based on 524 responded questionnaire sheets. The data provided in **Fig. 3** suggests that production loss may be likely worse along with longer and larger reductions of water supply. Although 10 percent cutbacks of water supply within one month may affect the close percentage of production loss, 30 and 20 percent reductions of water service within one month may result in 15 and 11 percent production loss. One may find production loss in scenario daytime water supply is less than that in scenario 20% reduction after the supply duration lasts more than one day. This data suggests that most respondents prefer daytime supply to 20% water reduction.

In order to understand the drought impacts on different sectors, we selected the sectors with more than 8 respondents in our questionnaire survey according to the 2000 Aichi Industrial Classification System published in 2005. Therefore, there are 19 sectors used in our study shown in **Fig. 4** through 9 (ranking in the right part of the figures). It is very obvious that the percentage of production losses is very different during six scenario water supply disruptions. Food and drinking services sector ranks the worst loss percentage of production in all six scenarios. Steel products manufacturing sector may bear the 10%, 20%, and 30% reduction of water supply since it may use recycled water.

There are six sectors covered food and drinking services sector, other personal services, food manufacturing sector, automobile and machinery repair and maintenance sector, construction of building sector, final chemical manufacturing sector that may affect production losses of more than 10% during 10% water supply reduction scenario within one week or month shown in **Fig. 4**. We can find that even one day 10% water supply reduction may affect more than 10% production loss in three sectors. However, there is no obvious impact on public construction and steel products manufacturing sector.

Although there are only four sectors that may affect production losses of more than 20% during 20% water supply reduction scenario within one month shown in **Fig. 5**, only food manufacturing and food services and drinking places sector may be worse as more than 30% production loss even one day 20% water supply reduction scenario. However, only steel products manufacturing sector may not be affected during 20% water supply reduction scenario.

Based on our survey, only two sectors (food and drinking services, and other personal services) may be affected production losses of more than 30% during monthly 30% water supply reduction scenario shown in **Fig. 6**. There are three sectors (finance and insurance, public construction, and steel products manufacturing) may have no obvious impact within three-days 30% water supply reduction scenario.

Only food-related sectors (food services and drinking services sector and food manufacturing sector) may expose worst production losses of more than 30% during daytime water supply scenario shown in **Fig. 7**. Many other sectors prefer daytime water supply to 20% or 30% reduction. There is only one sector (real state and rental and leasing sector) prefer daytime supply to any other reduction.

Nighttime water supply may affect production loss worse than daytime supply in any sector since each organization has daytime working style shown in **Fig. 8**. Food and drinking services sector may result in the worst production losses during night water supply scenario. Only public construction sector may not be exposed production loss during nighttime water supply scenario within one week.

All food and drinking services companies may be closed during 24 hours water supply suspension within one month according to our questionnaire survey shown in **Fig. 9**. Public construction sector may be least production loss during 24 hours supply suspension scenario.

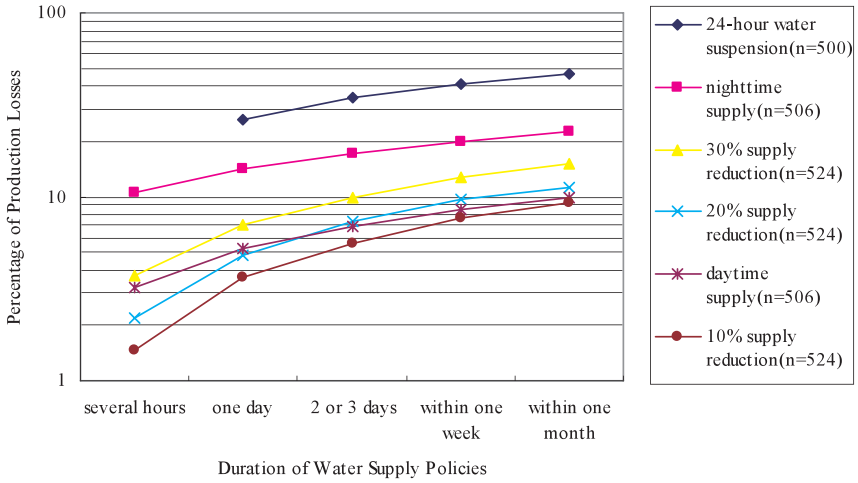

Fig. 3 Surveyed Average Production Losses During Six Scenario Water Supply Policies.

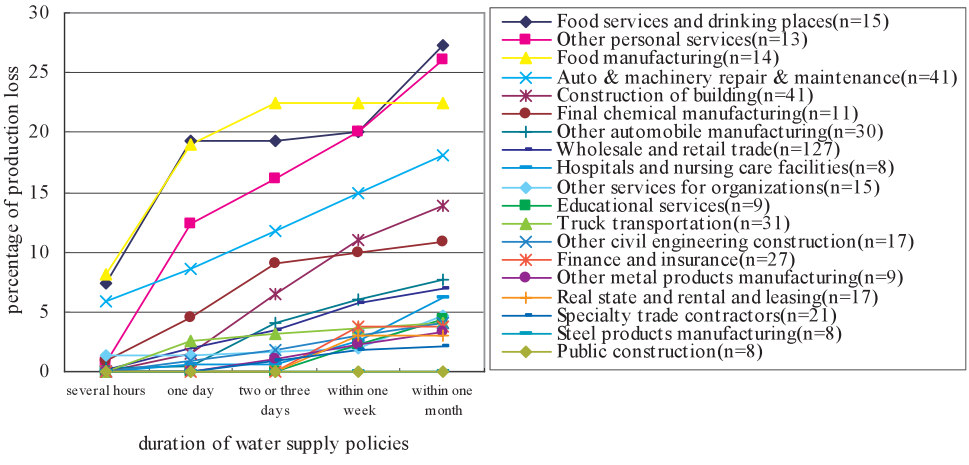

Fig. 4 Surveyed average production losses in 19 selected sectors during 10% water supply reduction scenario.

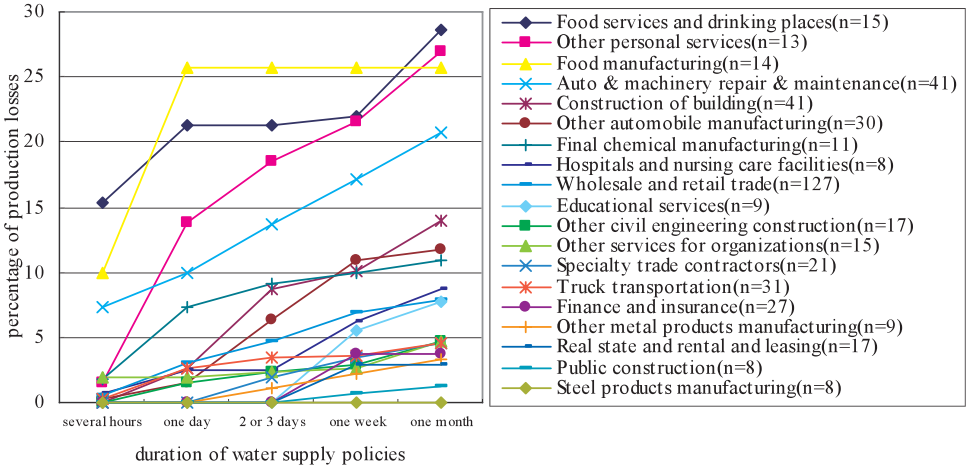

Fig. 5 Surveyed average production losses in 19 selected sectors during 20% water supply reduction scenario.

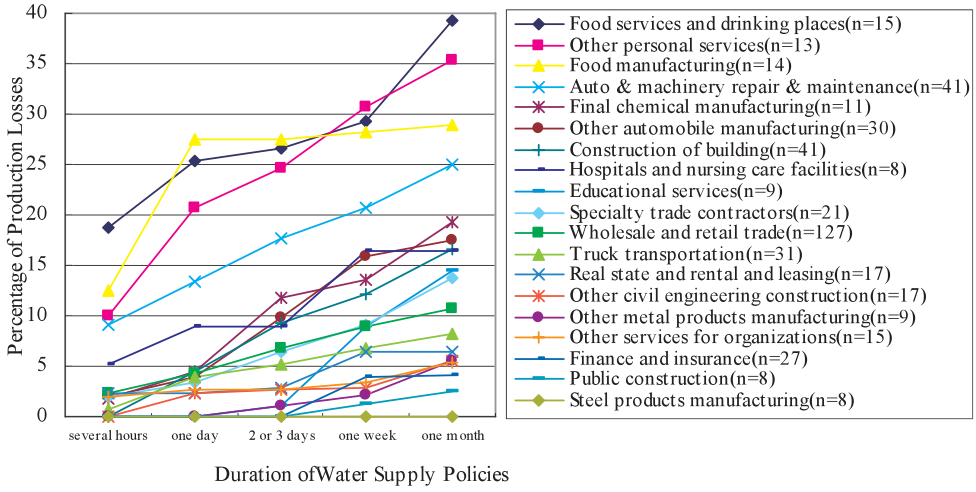

Fig. 6 Surveyed Average Production Losses in 19 Selected Sectors During 30% Water Supply Reduction Scenario.

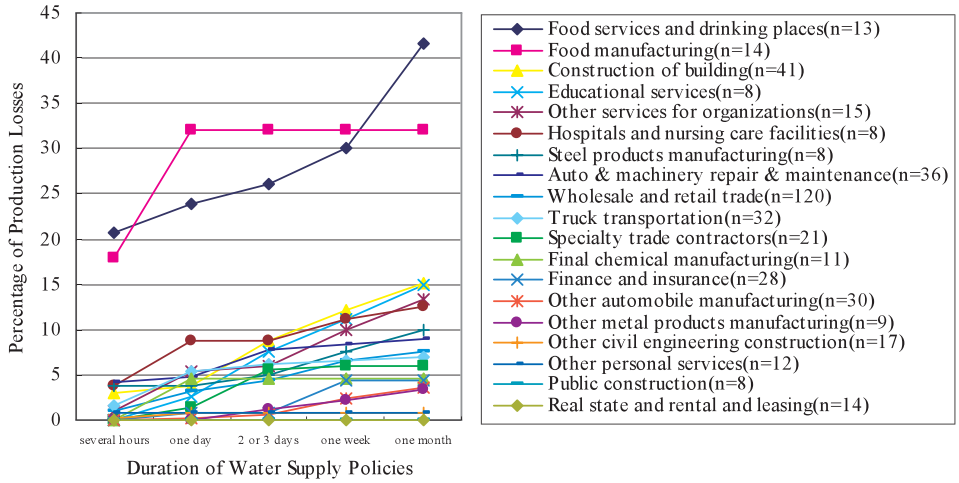

Fig. 7 Surveyed Average Production Losses in 19 Selected Sectors During Daytime Water Supply Scenario.

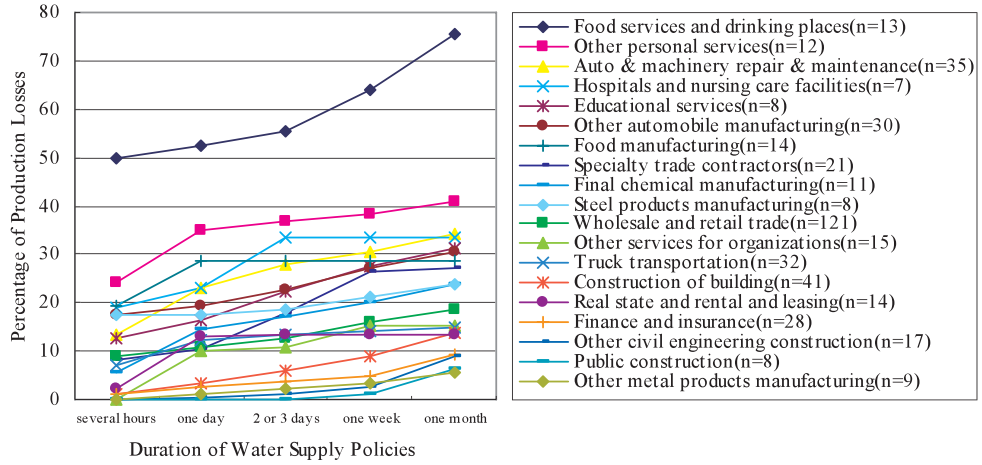

Fig. 8 Surveyed Average Production Losses in 19 Selected Sectors During Nighttime Water Supply Scenario.

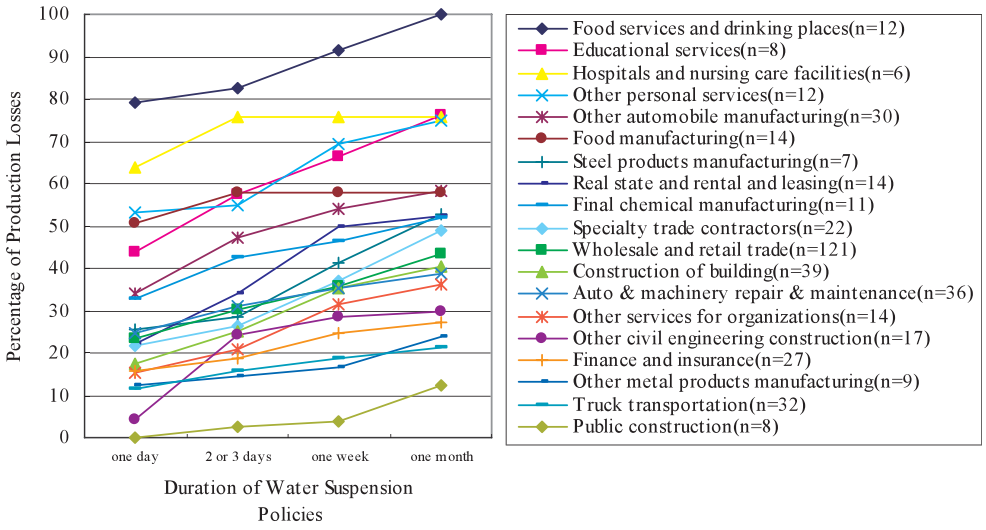

Fig. 9 Surveyed Average Production Losses in 19 Selected Sectors During 24 Hours Supply Suspension Scenario.

4. Drought impacts assessment

For empirical analysis, the 2000 Input-output Table in Aichi Prefecture (Planning Department of Aichi Prefecture, 2005) is modified to follow the equation (4). We assume the input coefficients are fixed during scenario water supply policies in one day, three days, one week, and one month. If scenario reduction percentage of water supply is assumed as the percentage of supply reduction in water sector, surveyed average production loss percentage as the percentage of production loss in other selected 19 sectors in 103-sector model. The 19 selected sectors mentioned above and water sector are given based on the results of questionnaire survey shown in **Fig. 4**, **5**, and 6, the other 83 sectors assumed no production loss, then the GDP (final demand) loss may be estimated. The negative value may be explained as the loss or shortage of final demand (i.e. GDP), the positive value as the abundance of final demand. The abundance of final demands can be stored as stocks or dropped as excess capacities in a closed region. Therefore, the sum of positive and negative values can be used as the lower bound of GDP loss during a specific water supply scenario, the sum of negative value as the upper bound of GDP loss. Thus, mean loss can be obtained as half of the sum of the lower and upper bound loss. The loss estimations of GDP are shown in **Table 1**, **2**, and **3**. It is obvious that longer and more water supply reductions may result in worse GDP losses. Thus suggests that the estimated loss of GDP in Aichi Prefecture will be some 130 billion Yen for lower bound loss and 194 billion Yen for upper bound loss during 10% water supply reduction scenario within one month. However, it may result in 217 billion Yen of GDP loss for lower bound loss and 324 billion Yen for upper bound loss during 30% water supply reduction scenario within one month.

We assume annual GDP in 2000 as normal state. Therefore loss percentage can be estimated as the ratio of GDP loss estimation to annual GDP shown in **Table 1**, **2** and **3**. However, loss percentage by water supply shortage is minimal to annual GDP in Aichi

Table 1 Estimated GDP loss during 10% water supply reduction scenario (unit: million Yen).

Code	Title	Suspension time during 10% water supply reduction			
		One day	Three days	One week	One month
001	crop production	96.88	337.49	795.75	3676.52
002	animal production	56.63	199.74	467.18	2082.33
003	support activities for agriculture and forestry	0	0	0.07	0.57
004	Forestry and logging	1.42	4.91	12.04	64.35
005	Fishing, hunting and trapping	33.31	114.22	268.95	1269.04
006	Metal ore mining	0	0	0	0
007	nonmetallic mineral mining	0.35	3.19	12.57	72.29
008	Coal mining	0.01	0.04	0.17	1.13
009	Oil and gas extraction	0	0.09	0.31	1.69
010	Food manufacturing	-536.35	-1980.33	-4585.53	-18530.88
011	Beverage	65.22	196.88	475.95	2813.04
012	Animal food manufacturing	-0.01	-0.04	0.03	0.57
013	Tobacco product manufacturing	0	0	0	0
014	Textile mills	0.97	11.39	43.34	254.74
015	Textile products mills	6.25	29.31	96.68	529.97
016	Wood products manufacturing	8.58	98.57	384.1	2119.88
017	Furniture and related products manufacturing	5.54	34.9	128.35	722.4
018	Pulp, paper, and paperboard mills	1.14	9.39	34.75	196.93
019	Paper products manufacturing	20.38	81.09	219.47	1062.72
020	Printing and publishing activities	19.79	83.28	291.27	1530.07
021	Fertilizer manufacturing	0.13	0.64	1.8	9.56
022	Basic inorganic chemical manufacturing	7.49	35.44	89.32	422.66
023	Basic organic chemical manufacturing	0.58	3.5	8.98	42.7
024	Organic chemical manufacturing	8.95	46.11	117.21	553.45
025	Synthetic rubber manufacturing	2.44	20.81	61.2	315.15
026	Chemical fibers manufacturing	0	0	0	0
027	Final chemical manufacturing	-41.34	-258.34	-521.52	-1476.98
028	Petroleum products manufacturing	15.17	61.9	174.37	930.3
029	Coal products manufacturing	0.49	2.26	7.22	42.32
030	Plastics products manufacturing	19.17	154.06	495.78	2630.45
031	Rubber products manufacturing	10.19	89.57	296.88	1633.28
032	Leather and allied products manufacturing	0.31	1.47	4.58	25.44
033	Glass and glass products manufacturing	4.58	22.91	67.83	357.97
034	Cement and concrete products manufacturing	3	34.54	136.89	765.78
035	Refractory manufacturing	6.25	34.37	113.87	647.94
036	Other clay and refractory manufacturing	1.5	18.49	69.73	389.44
037	Iron and steel mills manufacturing	-0.03	-0.83	-2.97	-16.84
038	Steel products manufacturing	4.55	100.75	372.42	2120.65
039	Forging and stamping products manufacturing	2.75	64.04	225.2	1257.76
040	Other iron and steel products manufacturing	1.46	39.35	145.79	842.63
041	Nonmetallic production and processing	0.43	9.91	35.11	197.5
042	Nonmetallic products manufacturing	5.49	83.96	294.76	1653.86
043	Architectural and structural metals manufacturing	6.95	87.25	346.47	1923.11
044	Other fabricated metal products manufacturing	16.17	17.61	-74.41	-916.21
045	General purpose machinery manufacturing	12.5	73.04	241.85	1308.95
046	Special machinery manufacturing	9.62	39.52	116.7	616.85
047	Other general purpose machinery manufacturing	5.28	49.45	165.08	908.35
048	Office products manufacturing	5.68	23.32	68.86	364.05
049	Household appliance manufacturing	3.19	19.4	63.58	343.95
050	Computer and parts manufacturing	1.22	5.01	14.79	78.15
051	Telecommunication machinery manufacturing	0.32	2.01	7.32	42.6
052	Electronic and electrical equipment manufacturing	0.5	2.25	6.96	37.63
053	Semiconductor equipment manufacturing	2.4	34.73	119.09	659.62
054	Electronic parts manufacturing	9.05	53.53	170.33	923.74
055	Electrical machinery manufacturing	2.74	13.21	41.12	220.77

056	Other electrical machinery manufacturing	6.6	101.85	355.25	1969.69
057	Passenger automobile manufacturing	0	0	0	0
058	Other automobile manufacturing	-50	-1787.32	-6321.98	-35298.47
059	Ship and boat building	0	0	0.02	0.16
060	Aerospace and parts manufacturing	0	0	0	0
061	Other transportation equipment manufacturing	0.91	3.77	11.11	58.97
062	Measuring and control instruments manufacturing	1.81	9.51	36.84	230.3
063	Other miscellaneous manufacturing	5.14	22.04	75.51	463.84
064	Recycled parts and processing	0.29	2.85	9.45	53.24
065	Construction of building	-83.19	-1102.28	-4367.51	-24104.4
066	Specialty trade contractors	5.88	-3.69	-30.84	-92.08
067	Public construction	0	0	0	0
068	Other civil engineering construction	-16.84	-101.06	-393.03	-2397.5
069	Electric power generation, transmission, and distribution	28.32	139.98	453.15	2550.09
070	Natural gas distribution and steam supply	12.45	44.33	122.11	698.88
071	Water system	-51.46	-154.39	-360.24	-1569.63
072	Waster treatment and disposal	9.59	33.27	96.08	570.32
073	Wholesale and retail trade	-202.4	-1221.3	-5662.28	-28865.32
074	Finance and insurance	60.25	285	-585.29	-1397.6
075	Real state and rental and leasing	23.27	98.59	79.36	732.94
076	Housing brokers	0	0	0	0
077	Housing brokers (visual brokers from government)	0	0	0	0
078	Rail transportation	7.62	34.89	136.28	724.11
079	Truck transportation	-54.89	-161.66	-320.19	-1465.01
080	Self motor transportation	27.66	146.42	525.98	2842.02
081	Waterway transportation	2.91	17.51	54.05	290.1
082	Air transportation	3.43	16.82	61.58	339.08
083	Warehousing and storage	2.82	11.1	28.5	137.61
084	Support activities for transportation	10.49	47.52	143.07	740.78
085	Telecommunications	22.25	98.42	356.91	1945.68
086	Broadcasting	4.5	14.52	37.41	219.06
087	Administrative and support services	0	0	0	0
088	Educational services	0.63	2.92	-523.21	-4586.89
089	Professional, scientific, and technical services	16.29	158.21	503.5	2678.23
090	Hospitals and nursing care facilities	-27.6	-82.76	-774.01	-8434.8
091	Social assistance	0	0	0	0
092	Nursing support activities	0	0	0	0
093	Other public support services	2.72	11.74	39.96	230.09
094	Advertising, investigation and information services	48.36	220.06	764.5	4023.21
095	Rental and leasing services	16.36	92.29	343.33	1908.98
096	Auto and machinery repair and maintenance	-213.68	-866.31	-2552.76	-13452.81
097	Other services for organizations	-10.33	36.23	394.31	-387.86
098	Amusement, gambling, and recreation industries	2.83	10.09	28.93	164.92
099	Food services and drinking places	-783.71	-2351.13	-5675.15	-33794.14
100	Hotels and other accommodation	0	0	0	0
101	Other personal services	-264.19	-1042.4	-3002.04	-17034.5
102	Office goods supplies	5.15	22.59	78.82	430.29
103	Other miscellaneous	12.88	56.12	192.58	1043.1
	Lower bound loss (total)	***-1507.59***	***-6926.3***	***-23512.3***	***-130111.38***
	Lower bound loss percentage of annual GDP	**0.004%**	**0.020%**	**0.067%**	**0.372%**
	Mean loss (lower and upper bound loss)	***-1921.81***	***-9020.07***	***-29632.63***	***-161966.65***
	Mean loss percentage of annual GDP	**0.005%**	**0.026%**	**0.085%**	**0.463%**
	Upper bound loss (sum negative values)	***-2336.02***	***-11113.84***	***-35752.96***	***-193821.92***
	Upper bound loss percentage of annual GDP	**0.007%**	**0.031%**	**0.102%**	**0.554%**

Table 2 Estimated GDP loss during 20% water supply reduction scenario (unit: million Yen).

Code	Title	Suspension time during 20% water supply reduction			
		One day	Three days	One week	One month
001	crop production	127.65	384.52	906.02	4139.76
002	animal production	75.96	227.88	533.04	2364.66
003	support activities for agriculture and forestry	0	0	0.16	1
004	Forestry and logging	1.73	5.43	13.19	68.75
005	Fishing, hunting and trapping	43.26	129.79	305.74	1419.52
006	Metal ore mining	0	0	0	0
007	nonmetallic mineral mining	0.62	4.28	14.68	100.98
008	Coal mining	0.01	0.04	0.26	1.54
009	Oil and gas extraction	0.01	0.14	0.54	2.54
010	Food manufacturing	-758.66	-2275.57	-5268.84	-21651.4
011	Beverage	72.58	217.9	525.75	2961.08
012	Animal food manufacturing	-0.01	-0.03	0.13	0.97
013	Tobacco product manufacturing	0	0	0	0
014	Textile mills	2.08	17.41	63.54	331.33
015	Textile products mills	8.4	36.73	113.06	592.33
016	Wood products manufacturing	14.83	132.44	362.49	2177.83
017	Furniture and related products manufacturing	7.68	45.46	138.53	789.52
018	Pulp, paper, and paperboard mills	1.8	12.47	38.39	218.76
019	Paper products manufacturing	28.04	94.41	252.79	1191.59
020	Printing and publishing activities	27.4	101.36	351.97	1754.41
021	Fertilizer manufacturing	0.17	0.72	2.04	10.48
022	Basic inorganic chemical manufacturing	10.41	36.22	91.68	431.65
023	Basic organic chemical manufacturing	0.93	3.5	8.98	42.7
024	Organic chemical manufacturing	13.53	48.4	124.21	581.74
025	Synthetic rubber manufacturing	4.41	25.78	84.87	400.62
026	Chemical fibers manufacturing	0	0	0	0
027	Final chemical manufacturing	-57.25	-188.54	-221.06	-521.39
028	Petroleum products manufacturing	17.44	70.16	200.44	1062.38
029	Coal products manufacturing	0.63	2.81	9.92	65.7
030	Plastics products manufacturing	30.95	209.92	736.82	3534.11
031	Rubber products manufacturing	16.51	129.24	475.62	2302.54
032	Leather and allied products manufacturing	0.39	1.8	5.66	29.06
033	Glass and glass products manufacturing	6.26	27.96	80.04	411.88
034	Cement and concrete products manufacturing	5.35	47.13	142.11	906.06
035	Refractory manufacturing	8.21	43.82	122.56	701.07
036	Other clay and refractory manufacturing	2.64	25.48	83.88	466.16
037	Iron and steel mills manufacturing	-0.1	-1.29	-5.16	-24.86
038	Steel products manufacturing	12	150.76	579.61	2910.4
039	Forging and stamping products manufacturing	8.21	101.83	403.71	1907.7
040	Other iron and steel products manufacturing	4.21	58.48	236.04	1170.47
041	Nonmetallic production and processing	1.23	15.32	60.83	290.53
042	Nonmetallic products manufacturing	12.48	127.65	486.75	2369.06
043	Architectural and structural metals manufacturing	12.53	119.43	338.42	2082.89
044	Other fabricated metal products manufacturing	24.62	55.6	42.77	-421.53
045	General purpose machinery manufacturing	16.33	92.57	280.87	1513.36
046	Special machinery manufacturing	11.21	45.91	134.88	708.54
047	Other general purpose machinery manufacturing	8.41	70.77	263.51	1274.41
048	Office products manufacturing	6.61	27.09	79.58	418.07
049	Household appliance manufacturing	4.26	25.17	79.94	416
050	Computer and parts manufacturing	1.42	5.82	17.09	89.77
051	Telecommunication machinery manufacturing	0.47	2.62	7.78	47.76
052	Electronic and electrical equipment manufacturing	0.61	2.68	7.93	43.74
053	Semiconductor equipment manufacturing	5.16	53.41	206.59	979.15
054	Electronic parts manufacturing	12.02	70.13	237.81	1190.71
055	Electrical machinery manufacturing	3.38	16.2	49.7	262.43

056	Other electrical machinery manufacturing	14.74	156.65	598.63	2871.64
057	Passenger automobile manufacturing	0	0	0	0
058	Other automobile manufacturing	-209.48	-2912.87	-11721.69	-54744.49
059	Ship and boat building	0	0	0.05	0.28
060	Aerospace and parts manufacturing	0	0	0	0
061	Other transportation equipment manufacturing	1.07	4.37	12.79	67.32
062	Measuring and control instruments manufacturing	3.31	14.31	55.05	290.76
063	Other miscellaneous manufacturing	6.39	27.14	99.54	564.97
064	Recycled parts and processing	0.49	4.17	15.7	76.92
065	Construction of building	-152.51	-1484.95	-3998.71	-24315.97
066	Specialty trade contractors	6.83	-32.8	-138.57	-827.87
067	Public construction	0	0	-129.82	-1131.3
068	Other civil engineering construction	-28.07	-134.75	-393.03	-2739.98
069	Electric power generation, transmission, and distribution	35.67	167.89	581.57	3000.34
070	Natural gas distribution and steam supply	14.89	51.81	145.22	778.07
071	Water system	-102.93	-308.78	-720.49	-3139.27
072	Waster treatment and disposal	11.27	38.72	113.52	629.4
073	Wholesale and retail trade	-364.28	-1727.31	-6622.42	-31792.29
074	Finance and insurance	84.92	367.74	-362.29	-626.54
075	Real state and rental and leasing	30.83	123.33	139.77	934.6
076	Housing brokers	0	0	0	0
077	Housing brokers (visual brokers from government)	0	0	0	0
078	Rail transportation	10.69	44.32	163.4	823.33
079	Truck transportation	-37.94	-126.24	-176.11	-1291.41
080	Self motor transportation	39.89	188.32	605.41	3189.72
081	Waterway transportation	4.15	22.9	75.15	372.89
082	Air transportation	5.03	21.89	77.77	395.98
083	Warehousing and storage	3.82	13.18	34.48	162.07
084	Support activities for transportation	12.64	56.88	170.85	868.16
085	Telecommunications	29.53	123.17	423.14	2195.87
086	Broadcasting	5	16.2	40.89	228.56
087	Administrative and support services	0	0	0	0
088	Educational services	0.84	3.7	-1319.06	-8057.2
089	Professional, scientific, and technical services	30.45	220.87	783.85	3704.67
090	Hospitals and nursing care facilities	-110.59	-331.75	-1936.01	-11810.17
091	Social assistance	0	0	0	0
092	Nursing support activities	0	0	0	0
093	Other public support services	3.02	12.75	44.25	242.57
094	Advertising, investigation and information services	65.87	266.02	905.06	4513.62
095	Rental and leasing services	23.94	121.37	430.19	2261.17
096	Auto and machinery repair and maintenance	-248.39	-1004.73	-2925.47	-15383.86
097	Other services for organizations	-17.43	29.07	390.05	337.77
098	Amusement, gambling, and recreation industries	3.21	11.46	31.86	173.37
099	Food services and drinking places	-864.78	-2594.35	-6242.67	-35442.72
100	Hotels and other accommodation	0	0	0	0
101	Other personal services	-295.58	-1186.77	-3210.89	-17467.18
102	Office goods supplies	6.94	28.31	96.59	492.46
103	Other miscellaneous	16.71	67.55	222.95	1151.48
	Lower bound loss (total)	***-2100.82***	***-8982***	***-29831.64***	***-154323.73***
	Lower bound loss percentage of annual GDP	**0.006%**	**0.026%**	**0.085%**	**0.441%**
	Mean loss (lower and upper bound loss)	***-2674.41***	***-11646.365***	***-37611.965***	***-192856.58***
	Mean loss percentage of annual GDP	**0.0076%**	**0.033%**	**0.107%**	**0.552%**
	Upper bound loss (sum negative values)	***-3248***	***-14310.73***	***-45392.29***	***-231389.43***
	Upper bound loss percentage of annual GDP	**0.009%**	**0.041%**	**0.129%**	**0.663%**

Table 3 Estimated GDP loss during 30% water supply reduction scenario (unit: million Yen).

Code	Title	Suspension time during 30% water supply reduction			
		One day	Three days	One week	One month
001	crop production	139.51	423.37	1033.74	4870.63
002	animal production	81.83	246.31	593.15	2706.72
003	support activities for agriculture and forestry	0	0.01	0.26	1.85
004	Forestry and logging	1.91	6.55	16.79	93.88
005	Fishing, hunting and trapping	47.54	144.3	353.08	1694.34
006	Metal ore mining	0	0	0	0
007	nonmetallic mineral mining	1.01	4.7	18.83	139.89
008	Coal mining	0.02	0.07	0.4	2.59
009	Oil and gas extraction	0.03	0.21	0.78	3.81
010	Food manufacturing	-793.23	-2352.82	-5523.74	-22904.43
011	Beverage	86.24	272.09	699.96	4051.44
012	Animal food manufacturing	-0.01	0.01	0.31	2.05
013	Tobacco product manufacturing	0	0	0	0
014	Textile mills	4.84	27.01	97.43	493.16
015	Textile products mills	12.03	49.34	153.3	797.6
016	Wood products manufacturing	24.36	146.42	446.62	2663.01
017	Furniture and related products manufacturing	12.41	59.3	191.44	1093.64
018	Pulp, paper, and paperboard mills	2.77	15.12	50.34	290.43
019	Paper products manufacturing	31.14	113.58	308.33	1557.36
020	Printing and publishing activities	34.58	132.64	455.6	2366.83
021	Fertilizer manufacturing	0.2	0.96	2.86	15.58
022	Basic inorganic chemical manufacturing	8.67	42.57	113.73	637.29
023	Basic organic chemical manufacturing	0.58	4.55	12.25	75.44
024	Organic chemical manufacturing	10.88	60.54	162.66	930.49
025	Synthetic rubber manufacturing	4.82	36.73	120.72	640.45
026	Chemical fibers manufacturing	0	0	0	0
027	Final chemical manufacturing	37.06	-106.59	127.94	-1330.67
028	Petroleum products manufacturing	24.74	99.32	314.74	1638.74
029	Coal products manufacturing	0.88	3.38	13.8	97.83
030	Plastics products manufacturing	48.49	290.17	1011.02	5037.52
031	Rubber products manufacturing	31.17	190.05	667.3	3283.4
032	Leather and allied products manufacturing	0.59	2.46	7.91	39.69
033	Glass and glass products manufacturing	7.89	35.25	104.34	558.53
034	Cement and concrete products manufacturing	9.95	55.4	187.87	1240.85
035	Refractory manufacturing	11.74	53.59	161.2	919.98
036	Other clay and refractory manufacturing	5.14	33.01	113.7	651.87
037	Iron and steel mills manufacturing	-0.25	-1.97	-7.43	-37.95
038	Steel products manufacturing	28.45	216.65	807.2	4309.14
039	Forging and stamping products manufacturing	20.68	155.6	584.04	2840.36
040	Other iron and steel products manufacturing	10.53	85.81	327.66	1779.91
041	Nonmetallic production and processing	2.98	23.14	87.03	437.15
042	Nonmetallic products manufacturing	27.26	188.21	690.22	3486.06
043	Architectural and structural metals manufacturing	24.2	142.2	444.07	2785.2
044	Other fabricated metal products manufacturing	38.56	111.99	230.82	-1219.35
045	General purpose machinery manufacturing	24.14	116.75	352.33	1896.97
046	Special machinery manufacturing	15.03	59.44	162.62	854.42
047	Other general purpose machinery manufacturing	16.2	103.7	367.41	1811.16
048	Office products manufacturing	8.87	35.08	95.98	504.23
049	Household appliance manufacturing	6.54	33.09	103.22	537.14
050	Computer and parts manufacturing	1.9	7.53	20.6	108.25
051	Telecommunication machinery manufacturing	0.7	3.1	9.65	61.04
052	Electronic and electrical equipment manufacturing	0.84	3.38	9.58	53.59
053	Semiconductor equipment manufacturing	11.51	80.65	295.82	1436.65
054	Electronic parts manufacturing	18.94	97.44	314.47	1603.41
055	Electrical machinery manufacturing	4.82	21.13	61.99	329.38

056	Other electrical machinery manufacturing	33.28	234.24	857.02	4204.66
057	Passenger automobile manufacturing	0	0	0	0
058	Other automobile manufacturing	-574.16	-4509.57	-17129.11	-82271.55
059	Ship and boat building	0	0	0.07	0.51
060	Aerospace and parts manufacturing	0	0	0	0
061	Other transportation equipment manufacturing	1.44	5.67	15.56	81.56
062	Measuring and control instruments manufacturing	6.44	25.84	92.48	441.91
063	Other miscellaneous manufacturing	9.26	38.19	142.74	844.43
064	Recycled parts and processing	0.96	6.2	22.75	116.04
065	Construction of building	-249.57	-1580.63	-4804.28	-28756.32
066	Specialty trade contractors	-29.4	-173	-538.91	-3703.94
067	Public construction	0	0	-259.64	-2262.6
068	Other civil engineering construction	-44.92	-151.6	-393.03	-3253.69
069	Electric power generation, transmission, and distribution	50.41	232.08	807.26	4252.03
070	Natural gas distribution and steam supply	19.29	68.42	200.99	1084.26
071	Water system	-154.39	-463.17	-1080.73	-4708.9
072	Waster treatment and disposal	15.39	53.51	164.68	894.81
073	Wholesale and retail trade	-517.25	-2639.86	-8338.72	-42963.5
074	Finance and insurance	120.75	521.64	-7.26	1076.06
075	Real state and rental and leasing	12.71	59.15	-36.77	311.78
076	Housing brokers	0	0	0	0
077	Housing brokers (visual brokers from government)	0	0	0	0
078	Rail transportation	14.6	62.04	215.94	1130.86
079	Truck transportation	-67.86	-267.06	-818.97	-4201.06
080	Self motor transportation	56.73	250.86	797.15	4292.25
081	Waterway transportation	6.18	31.56	105.22	539.54
082	Air transportation	7.05	31.2	104.93	553.45
083	Warehousing and storage	4.42	15.39	41.87	203.95
084	Support activities for transportation	18.64	84.22	266.39	1361.25
085	Telecommunications	41.11	173.01	567.7	3047.68
086	Broadcasting	6.31	20.67	55.66	309.32
087	Administrative and support services	0	0	0	0
088	Educational services	1.2	-109.02	-2113.13	-14992.4
089	Professional, scientific, and technical services	47.29	317.48	1104.67	5519.77
090	Hospitals and nursing care facilities	-392.79	-1194.93	-5112.09	-22272.82
091	Social assistance	0	0	0	0
092	Nursing support activities	0	0	0	0
093	Other public support services	4.05	17.03	60.41	332.68
094	Advertising, investigation and information services	83.05	353.81	1181.47	6147.84
095	Rental and leasing services	35.39	162.76	574.67	3083.21
096	Auto and machinery repair and maintenance	-331.07	-1291.96	-3455.8	-18143.42
097	Other services for organizations	-8.8	116.09	633.78	1783.29
098	Amusement, gambling, and recreation industries	4.3	15.09	44.03	234.38
099	Food services and drinking places	-1026.93	-3242.95	-8323.55	-48630.61
100	Hotels and other accommodation	0	0	0	0
101	Other personal services	-440.84	-1570.2	-4553.27	-22828.29
102	Office goods supplies	9.76	39.33	130.94	674.3
103	Other miscellaneous	22.12	91.23	294.13	1577.66
	Lower bound loss (total)	***-3054.17***	***-12594.72***	***-41506.81***	***-216951.07***
	Lower bound loss percentage of annual GDP	**0.009%**	**0.036%**	**0.119%**	**0.620%**
	Mean loss (lower and upper bound loss)	***-3842.82***	***-16125.025***	***-52001.62***	***-270716.285***
	Mean loss percentage of annual GDP	**0.011%**	**0.046%**	**0.149%**	**0.774%**
	Upper bound loss (sum negative values)	***-4631.47***	***-19655.33***	***-62496.43***	***-324481.5***
	Upper bound loss percentage of annual GDP	**0.013%**	**0.056%**	**0.179%**	**0.928%**

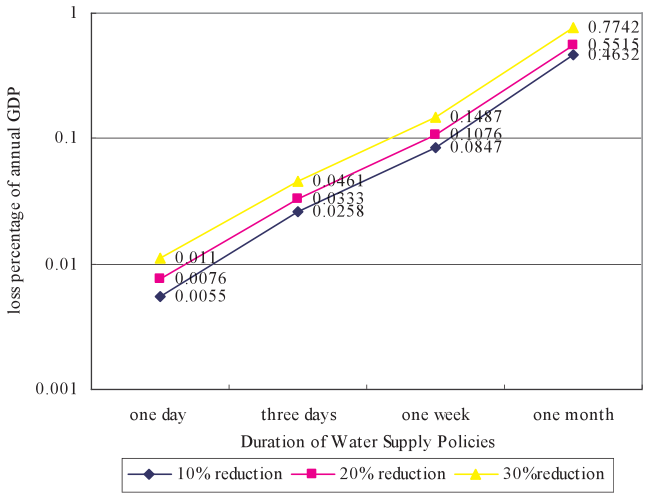

Fig. 10 Estimated Mean Loss Percentage of Annual GDP During Three Water Supply Reduction Secnarios.

Prefecture. It may be likely occurred that 30% water supply reduction within one month leads to 0.928% GDP loss in upper bound and 0.62% GDP loss in lower bound. However, there is very low loss during three scenario water supply reductions within one day. Estimated mean loss percentage of annual GDP may account for 0.4632%, 0.5515%, and 0.7742% for Aichi Prefecture case study during one month water supply scenario of 10%, 20%, and 30% reduction shown in **Fig. 10**.

5. Future research

Substantial advances on assessing the losses on society and economy provides helpful tools for developing a greater understanding of the expected losses triggered by water shortages or drought events. The estimation of drought economic impacts using input-output analysis might be used to aid decision makers for water shortages or droughts preparedness and mitigation. In the future, the quantitative relation between low precipitation and water supply reduction may be used in drought socioeconomic impacts in the context of climate change. The positive value of final demand change should employ to assess the spread effects of socioeconomic losses to other regions in the computable general equilibrium.

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Appendix

渇水被害による生産・営業活動への影響に関するアンケート

問３　渇水被害により、上水道について給水制限が行われた場合の状況についてお聞きいたします。

①渇水被害により、「上水道」の給水制限が実施されたとします。給水制限により、あなたの事業所で想定される営業上の被害（生産量または売上の減少等）について、お手数ですが、下欄の全ての回答欄にご記入ください。

制限期間 / 制限内容	数時間 制限	１日間 制限	２～３日間 制限	～１週間 制限	～１ヶ月間 制限
10%削減	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし
20%削減	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし
30%削減	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし
昼間(9:00～21:00) のみ通常利用可能	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし
夜間(21:00～9:00)のみ通常利用可能	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし
24 時間完全断水の場合	ー	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし	1. 生産・営業停止 2. 影響約 ＿＿＿ % 3. 問題なし

産業部門におけるアンケート調査に基づく給水不足の経済損失推定

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要　旨

この論文において，外生変数と内生変数が混在した産業連関分析の汎用モデルを使って，愛知県を研究対象として給水制限の経済影響評価を行った．渇水による経済影響を調査するために 6 つの給水制限シナリオが設定された．各 1 日以内，3 日以内，1 週間以内，1 か月以内において 10%，20%，30%の給水制限シナリオに対して GDP 損失と損失率の推定がアンケート調査結果に基づいて行われた．より長くてより厳しい給水制限はアンケート調査と本論文の推定に基づくとより悪い損失結果となることが明らかとなった．GDP の損失推定では，愛知県において，それぞれ 1 日 10%シナリオの場合 19 億円，20%シナリオの場合 27 億円，30%シナリオの場合 38 億円の損失となる．愛知県の 1 週間のシナリオに対しては，GDP 損失は 10%で 296 億円，20%で 376 億円，30%で 520 億円となる．一か月シナリオに対する平均 GDP 損失は 10%で 1620 億円，20%で 1929 億円，30%で 2707 億円と最悪となる．しかしながら，愛知県の年間 GDP に対する給水不足による損失率は極小となる．その平均損失率は，10%，20%，30%削減の一か月給水制限シナリオに対して，それぞれ 0.4632%，0.5515%，0.7742%となる．これらの結果は給水不足や渇水の時における給水政策の策定に役立つと考えられる．

キーワード：渇水，給水制限，経済損失，産業連関分析