Research and Development of Green ICT for a Sustainable World

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In 2015, the Sustainable Development Goals (SDGs) were adopted by the UN General Assembly as a global target to be met by 2030. The 21st session of the Conference of the Parties (COP21) of the UN Framework Convention on Climate Change (UNFCCC) was held in November 2016, when the Paris Agreement, aimed at the creation of a low-carbon society, came into force. The world is now taking steps toward solving the globally shared problem of climate change. In addition, it must address a multitude of emerging complex issues related to society, the environment, and the economy. Information and communications technology (ICT) has been a useful tool to tackle such issues and has been successfully applied in many areas. To enable faster response to complex issues, Fujitsu is developing Green ICT services that leverage prediction technology based on big data analysis. The aim is to develop services that offer logical and accurate decision making, with the flexibility of being applicable to a variety of contexts. In this paper, we present a methodology and a technology related to the area of environmental research: a "natural-capital accounting methodology" that can be used to assess natural resources for preserving biodiversity and an "environment, society, and economic analysis technology" that can be used to. Their use can help visualize local attributes, elucidate locally specific problems, and predict the effectiveness of alternative measures.

1. Introduction

In 2015, the UN General Assembly adopted Sustainable Development Goals (SDGs) as a global target to be met by 2030. In addition, the Paris Agreement, aimed at the creation of a low-carbon society, went into effect in November 2016 after being adopted by the Paris Agreement, aimed at the creation of a low-carbon society, went into effect in November 2016 after being adopted by the UN General Assembly held in December 2015. These actions reflect a growing trend in solving problems shared by the entire world.

Achieving a balance among the environment, society, and the economy is essential to achieving the sustainable world targeted by these SDGs and the Paris Agreement. Historically, the world has placed priority on economic development, which has unfortunately led to excessive use of forests, water, and other resources, destruction of the natural environment, and significant emission of greenhouse gases (GHGs). As a result, the regenerative ability of nature is reaching its limit, and this, along with global warming and resource depletion, is creating a major risk to the survival of mankind on Earth. To mitigate this risk and achieve a truly sustainable world, a major change in the way we think about society and the economy must be made from an environmental perspective.

We can explain this by taking the development of a new industrial park as an example. **Figure 1 (a)** shows the conventional process of developing a new industrial park. This process includes predicting the development cost, the scale, etc. on the basis of the economic effects on the land and community and determining the development conditions.

However, this process basically ignores the effects of such a development on society; that is, there is little concern about the effects on the population, the number of traffic accidents, etc. over the long term and even less concern about the effects on the environment. Consequently, while an environmental impact

assessment may be made after a decision has been made on a development plan, it is rare that the results of such an assessment will force the development to be modified or suspended. This process makes it difficult to put a halt to global warming and resource depletion.

An example of a development process for achieving a sustainable world, which must be considered from here on, is shown in **Figure 1 (b)**. This process goes further than the conventional one in that it also calculates the effects on the environment and society and predicts conditions after development on the basis of the concept of "natural capital," which means living organisms making up an ecosystem, elements of nature such as soil, atmosphere, and water sources, etc. The idea here is to formulate a plan that can avoid risks to the environment and highlight the effects on society and the economy. Predicting a variety of patterns that are separately environment-focused, society-focused, or economy-focused in this way enables planning that seeks a balance among the environment, society, and economy, taking regional characteristics into account.

Formulating such a plan makes use of a core methodology and a core technology developed by Fujitsu Laboratories: a "natural-capital accounting methodology" and an "environment, society, and economy analysis technology" (prediction based on causal relationships). To achieve a balance among the environment, society, and economy, value associated with the environment must be assessed in the same units as the economy. The methodology for assessing value related to nature as one dimension of the environment is "natural-capital accounting methodology." The technology for comparing environmental, social, and economic indices in the same units and predicting future changes is "prediction based on causal relationships." Their integration enables development and forecasting that achieves a balance among the environment, society, and economy.

In this paper, we report on trends in the preservation of biodiversity, the source of value in nature,

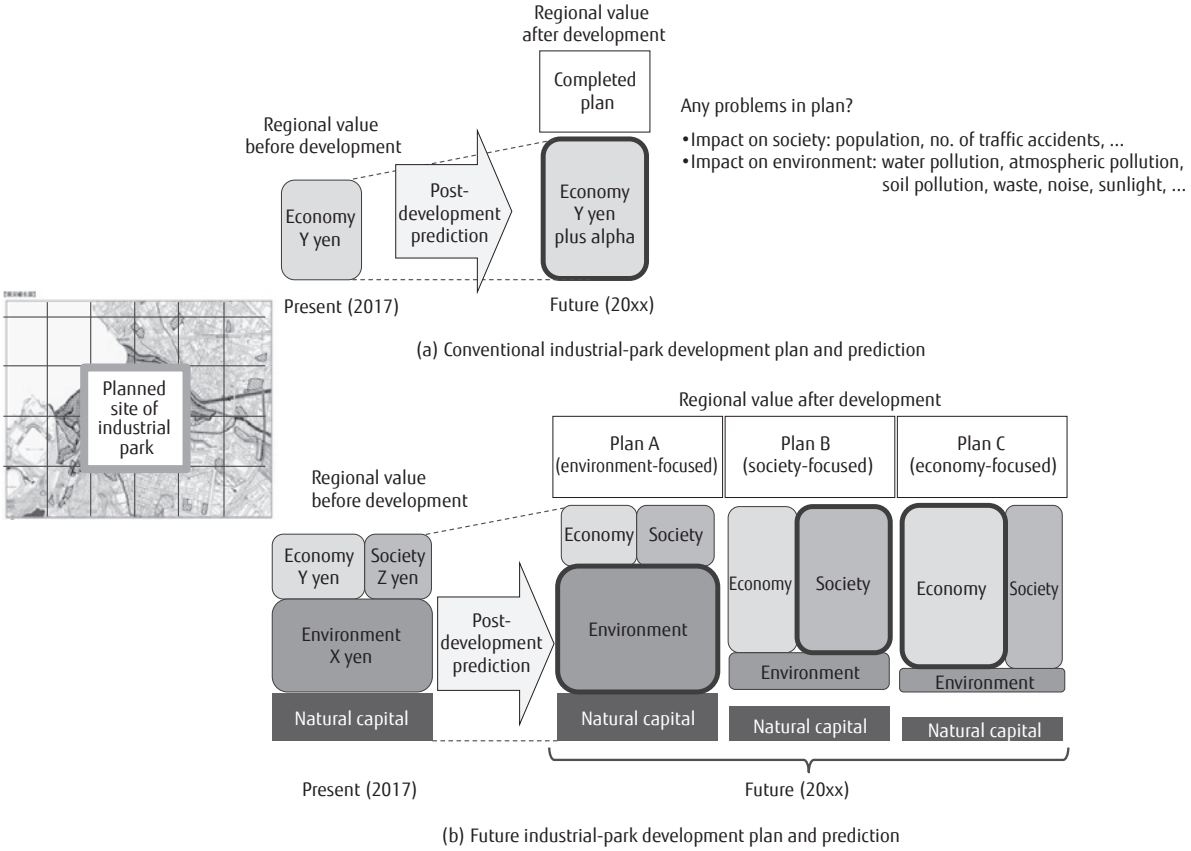

Figure 1
Industrial-park development plan and impact prediction.

and on the state of development of our natural-capital accounting methodology. Additionally, as examples of analyzing regional characteristics, we present an example of analyzing the environment, society, and economy and an example of developing prediction technology using causal relationships.

2. Natural-capital accounting methodology

In this section, we explain the importance of biodiversity, outline current global efforts in preserving biodiversity, and describe our natural-capital accounting methodology, which is essential for implementing natural-capital accounting as one way of promoting biodiversity preservation.

1) Trends in biodiversity preservation

Our lives are supported by the benefits provided by nature (clean water and air, resources and energy, food supplies, etc.). These benefits, which spring from the interaction among a variety of living organisms, i.e., biodiversity, can be referred to as "ecosystem services." However, biodiversity is being lost due to environmental destruction brought on by excessive development, and ecosystem services are deteriorating both qualitatively and quantitatively.[1)]

With the aim of preserving biodiversity, the Sixth Meeting of the Conference of the Parties to the Convention on Biological Diversity (CBD COP6) held in 2002 adopted a strategic plan to "substantially reduce the rate of biodiversity loss by 2010 as a contribution to poverty alleviation and to the benefit of all life on Earth."[2)] Unfortunately, this biodiversity target for 2010 could not be met. Then, at CBD COP10 held in Aichi Prefecture, Japan, in 2010, the Aichi Biodiversity Targets forming the core of "Strategic Plan for Biodiversity 2011–2020" were adopted, including the "incorporation of biodiversity values into national accounting and reporting systems" as one of those targets. As a result, efforts at incorporating natural capital (for example, water, air, soil, fauna, and flora as classified by the United Nations Environment Programme – Finance Initiative [UNEP FI]) into accounting have been accelerating, and a variety of activities have been moving forward, including the creation of frameworks and development of assessment techniques.[3)–6)]

2) Natural-capital accounting methodology

Among the different types of natural capital, it is important to visualize the existing value of flora and fauna and other elements that contribute to biodiversity and to recognize them as things having value. To this end, Fujitsu developed a web application called EvaCva ("a-va-see-va"), which uses open data associated with the environment, society, and economy to visualize regional characteristics.[7)] As an application that presents the value of natural capital, EvaCva can be used to calculate the value of certain ecosystem services from map information, public information, and other types of data, present the results of those calculations to local governments, and provide those results for public consumption (**Figure 2**). Using previously proposed techniques,[8),9)] EvaCva applies a market-value approach to provisioning services such as agricultural crops and lumber supply and a replacement cost approach to regulating services such as filtering and recharging groundwater and mitigating climate change as a way to monetize these services.

Visualizing the value of ecosystem services in this way enables the value of nature, which generally has low visibility, to be ranked and recognized as capital possessed by society. If that value can be utilized for industrial development and regional revitalization, we can expect to see an acceleration of appropriate investment in the preservation of biodiversity.

Fujitsu is working to achieve natural-capital accounting through the development of a methodology for quantifying the state of habitation, focusing on flora and fauna (described below), for converting ecosystem services into economic value, and for assessing the capital value of flora and fauna.

3) Animal habitability prediction technology

To determine the qualitative and quantitative state of flora-and-fauna habitation, information on those ecologies has been collected and stored in databases through ongoing on-site surveys requiring a commensurate amount of expenses and person-hours.[10)] With this approach, however, there is a limit to the amount of funds and labor that can be applied, and at the same time, there is a need for personnel with expert knowledge to ensure the reliability of the data collected. In addition, habitat surveys with respect to animals tend to be difficult compared with those of plant life.

In response to these problems, Fujitsu Laboratories developed technology for predicting

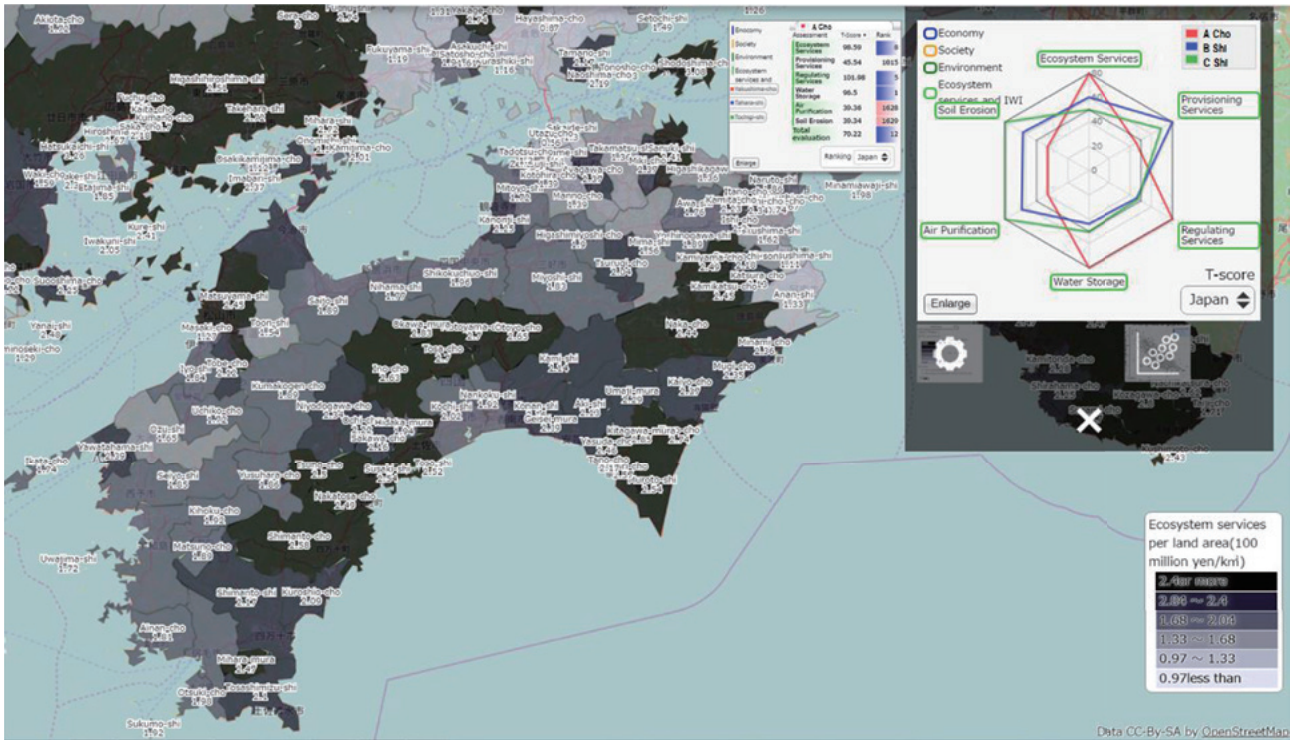

Figure 2
Assessment of local-government ecosystem services on Shikoku Island, Japan (EvaCva screenshot).

mammal habitability using existing data on vegetation, topography, etc. without having to carry out new on-site surveys. Based on animal energy metabolism, the method used calculates mammalian population density[11] from average animal weight and takes the inverse of that density to be the area needed for habitation. It then compares that value with the area in the target region applicable to habitation and predicts habitability for that region.

4) Trial and rollout of habitability prediction technology

Damage to forests caused by the recent and rapid increase in the population of Japanese deer has become a problem. This damage includes harm to alpine vegetation and trees due to overgrazing as well as loss of biodiversity, occurrence of landslides, and other disasters. To address this problem, Fujitsu teamed up with the Yamanashi Forest Research Institute to conduct a verification trial of this prediction technology using Japanese deer as an example.[12]

In the trial, we predicted habitability using ecological information unique to the target animal, such as the feeding habits (palatable plants) and easy-to-inhabit terrain (grade) for Japanese deer, as conditions for extracting suitable habitable areas. We also made use of information estimated by the Yamanashi Forest Research Institute using a statistical model based on data on actual Japanese deer, such as the population of deer in eight locations, each 10 km square. A comparison of this information with our predictions revealed a correlation between the number of deer predicted to inhabit an area and data on their actual number.

To enable this prediction technology to be used in practice for efficient and effective measures for preserving biodiversity, we developed a prototype application for predicting habitability throughout Japan for a variety of mammals. As shown in **Figure 3**, improvements are being made so that prediction results can be analyzed and the fixed habitats, migration routes, etc. of animals can be estimated.

3. Environment, society, and economy analysis technology

Local governments such as cities, wards, towns, and villages require ongoing measures for meeting

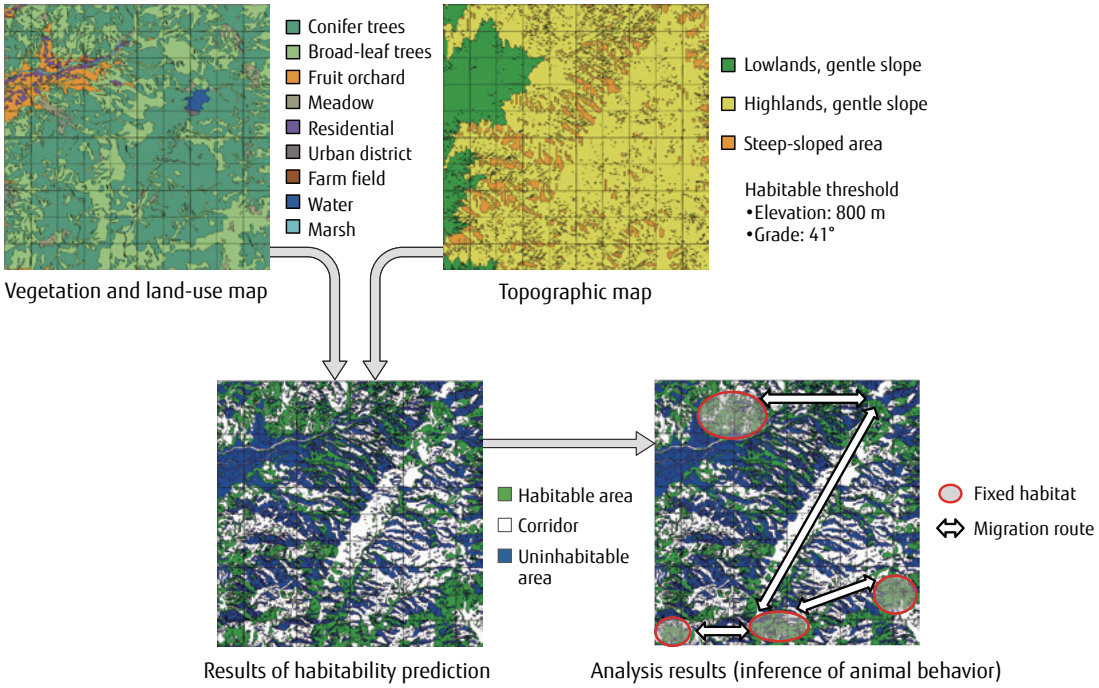

Figure 3
Habitability prediction technology.

targets toward a sustainable community based on a balance among the environment, society, and economy. There is therefore a need to formulate effective measures for accurately determining and solving regional problems.

To this end, it is important to make an objective analysis of current conditions in the region from data and to identify which items constitute problems and which items need to be improved. The EvaCva application can clearly display the characteristics (strong points, weak points, etc.) of each of Japan's local government areas (1,741 as of April 1, 2016) by using open data that is freely available to the public over the Internet. An EvaCva user selects the name of a local government area, selects certain indicators of regional characteristics from a total of 182 indicators, and obtains the values of those indicators displayed in the form of a radar chart, scatter plot, etc. In short, EvaCva makes it easy to understand regional characteristics (Figure 2). In addition, technology related to linked open data (LOD) is put to use in EvaCva, so treating open-data indicator values as LOD makes it easy to perform analysis of those values combined with other data held by the user.

The EvaCva application is also equipped with a function for searching for similar local government areas. In this case, the user selects the indicator for testing similarity and the application extracts similar local government areas on the basis of the deviation value of that indicator. In addition to simply similarity, taking into account the deviation of an indicator deemed to be a problem makes it possible to search from among similar local government areas those that can be inferred to have already solved that problem. In this way, using data to quantitatively predict the effect of introducing certain measures should lead to objective investment evaluation and enable effective measures to be efficiently prioritized and implemented.

The difficulty of using data to predict the effect of a measure lies in determining the direction of cause and effect. Conventional prediction techniques use data having a strong correlation. For example, when predicting the number of births as shown in **Figure 4 (a)**, a prediction can be made using the number of marriages and number of day-care centers for children, which have a strong correlation with number of births. However, while calculations could be made assuming that the number of births will change given a change in the number of day-care centers for children, it can also be considered that, in actuality, the number

of day-care centers for children will change because of a change in the number of births. In other words, predicting the effect of a change simply on the basis of a strong correlation can lead to an erroneous decision and create the risk of implementing a useless measure.

In light of the above, we devised a technique that performs causal inference by calculating a correlation coefficient taking into account the time delay (time difference) of changes between indicators from time-series data.[13] As shown in **Figure 4 (b)**, this approach enables the direction of cause and effect to be inferred, which in this example can be stated as follows: a change in the number of marriages causes the number of births to change, and a change in the number of births causes the number of day-care centers to change.

Causal relationships were inferred using this technique from uniform statistical data from 2000 to 2013 released by 1,741 local governments throughout Japan. Causal relationships were inferred to exist for 232 items, which enabled the creation of a causal network based on those relationships (**Figure 5**). For example, it was inferred that a change in the number of marriages in a region and a change in the number of people moving into the region caused the number of births to change.

This causal network can be used to calculate the impact of a measure. First, a multivariate time-series analysis is performed on all causal relationships in the network to predict an indicator posing a problem. The predicted value *X* of such a problem indicator takes on values corresponding to no measure implemented. Next, indicators supporting introduction of that measure are changed to the values planned for that measure over the first and subsequent years of implementation. Predicted value *Y* of the problem indicator is then obtained by performing time-series analysis over the entire network in the same way. The difference between *X* and *Y* is taken to be the impact of that measure, taking into account the effect of the entire causal network.

The results of testing this technique using past data for City A in Miyagi Prefecture are shown in **Figure 6**. This city undertook residential development from 2007 on, and the population increased as more people moved into the city. The graph in the figure, however, predicted the effect of this measure in 2006 at a prior point in time. The results of predicting the population from 2007 on using actual results from 2000 to 2006 and data on actual move-ins from 2007 on revealed that the population increase could be inferred with an average yearly error of 1.1%.

In this way, adding prediction that takes causal relationships into account to predictions on the effect of measures during local government planning enables priority implementation of those measures that are expected to have a major impact.

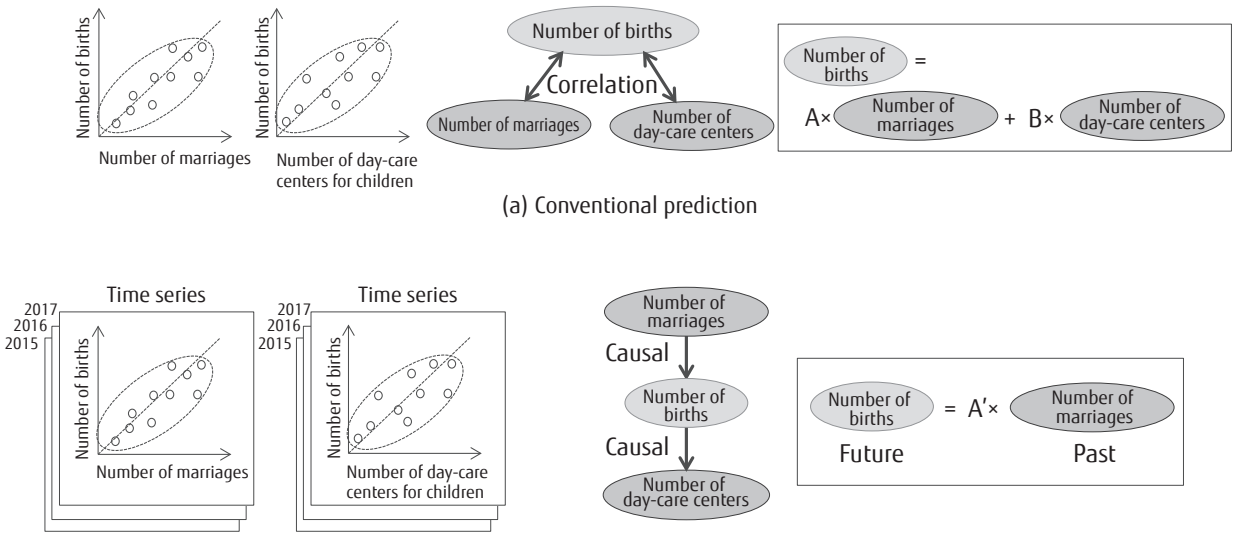

Figure 4
Prediction of number of births.

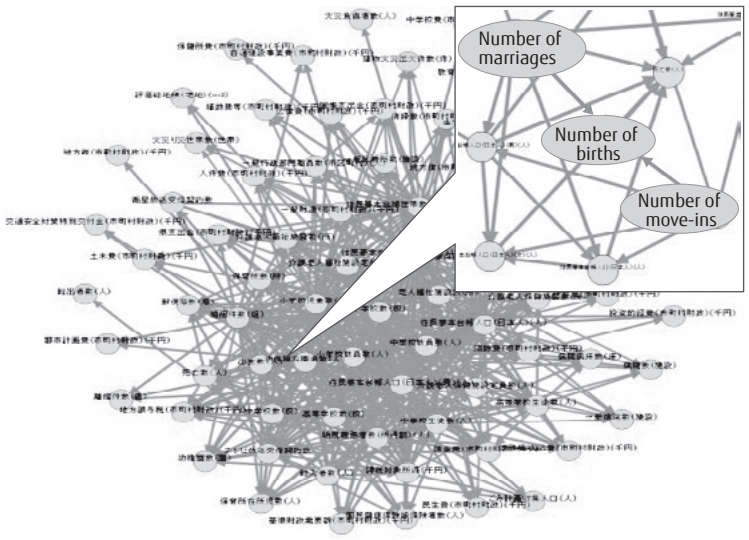

Figure 5
Causal network based on results of causal inference.

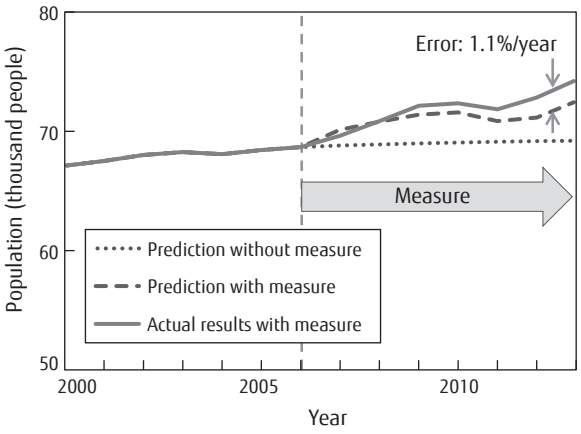

Figure 6
Predicted values versus actual values for population of City A in Miyagi Prefecture.

4. Conclusion

Fujitsu is focused on finding new ways of using Green ICT to help achieve a sustainable world. This paper introduced examples of research and development toward global sustainability.

With the aim of achieving natural-capital accounting, one of the Aichi Biodiversity Targets, Fujitsu has undertaken the development of an economic-value conversion methodology for flora and fauna, the valuation of which is particularly difficult among the various types of natural capital. Relevance analysis plays an important role in converting flora and fauna into economic values, and Fujitsu has developed technology for indicating such relevancy by predicting animal habitability from vegetation. Going forward, we seek to achieve natural-capital accounting through such technology development and to contribute to accelerated preservation of biodiversity.

To make predictions while comprehensively taking the environment, society, and economy into account, a multifaceted approach based on the relevancy of multiple factors is needed as opposed to one that simply makes individual predictions. With this in mind, we have been researching prediction techniques based on causal relationships. We have so far developed technology for automatically inferring cause-and-effect relationships by investigating the correlation coefficient between two sets of time-series data, and we have successfully created a causal network consisting of 232 items related to the environment, society, and economy. This network has made it possible to make predictions about the future based on causal relationships. We are presently conducting trials focused on predicting the effect of measures designed to counter the falling birth rate problem, for which data are abundant and needs are high.

We plan to test predictions targeting a variety of issues and to apply our developed methodology and technologies to the causal analysis of environmental

issues and predictions about the future state of the environment. Additionally, by integrating these technologies and achieving a balance among environmental, social, and economic factors in development planning, Fujitsu aims to contribute to the creation of a sustainable society through the effective use of Green ICT.

References

1) Japan Biodiversity Outlook 2 (JBO2)-Report of Comprehensive Assessment of Biodiversity and Ecosystem Services in Japan Committee for the Comprehensive Assessment of Biodiversity and Ecosystem Services. March 2016. *http://www.env.go.jp/nature/biodic/jbo2/pamph04.pdf*
2) Ministry of the Environment: Global Biodiversity Outlook 3 (GBO3) Overview. 1st Advisory Meeting on Human Coexistence with Nature, Materials. July 11, 2011 (in Japanese).
3) United Nations et al.: System of Environmental-Economic Accounting 2012 Central Framework. 2014. *http://unstats.un.org/unsd/envaccounting/seeaRev/SEEA_CF_Final_en.pdf*
4) European Commission et al.: System of Environmental-Economic Accounting 2012 Experimental Ecosystem Accounting. *http://unstats.un.org/unsd/envaccounting/eea_white_cover.pdf*
5) World Bank: Wealth Accounting and the Valuation of Ecosystem Services (WAVES). *https://www.wavespartnership.org/*
6) Natural Capital Coalition: Natural Capital Protocol. 2016. *http://naturalcapitalcoalition.org/protocol/*
7) Fujitsu, Fujitsu Laboratories: Release of Tool for Assessing Regional Characteristics through Application of Linked Open Data Technology. December 11, 2014 (in Japanese). *http://pr.fujitsu.com/jp/news/2014/12/11.html*
8) Mitsubishi Research Institute (MRI): Evaluation of Multifunctionality associated with Agriculture and Forestry related to the Global Environment and Human Life. November 2001 (in Japanese).
9) Policy Research Institute, Ministry of Agriculture, Forestry and Fisheries, Team for Evaluating and Studying Publically Beneficial Functions of Agriculture and Agricultural Communities: Evaluation of Publically Beneficial Functions of Agriculture and Agricultural Communities by Alternative Methods. Quarterly Journal of Agricultural Economics, Vol. 52, No. 4, pp. 113-138 (in Japanese). *http://www.maff.go.jp/primaff/koho/seika/nosoken/nogyosogokenkyu/pdf/nriae1998-52-4-4.pdf*
10) Comprehensive Environmental Information Database: Natural Environment Survey. *http://www.biodic.go.jp/ne_research_e.html*
11) R. H. Peters et al.: Relations between Individual Size and Mammalian Population Density. The American Naturalist, Vol. 124, No. 4, pp. 498–517, 1984.
12) Fujitsu Laboratories: Fujitsu Works to Conserve Biodiversity with Start of Technology Trial to Predict Deer Populations in Yamanashi. January 18, 2016. *http://www.fujitsu.com/global/about/resources/news/press-releases/2016/0118-03.html*
13) K. Nakazawa et al.: Future Prediction of Regional City Based on Causal Inference Using Time-Series Data. Proceedings of the 6th International Conference on Simulation and Modeling Methodologies, Technologies and Applications, pp. 203–210. June 2016.

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