A Forestry Management Game as a Learning Support System for Increased Understanding of Vegetation Succession

Effective Environmental Education Towards a Sustainable Society

Shuya Kawaguchi[1], Hiroshi Mizoguchi[1] Ryohei Egusa[2,3], Yoshiaki Takeda[3], Etsuji Yamaguchi[3], Shigenori Inagaki[3], Fusako Kusunoki[4], Hideo Funaoi[5] and Masanori Sugimoto[6]

[1]*Department of Mechanical Engineering, Tokyo University of Science, 2641 Yamazaki, Noda-shi, Chida-ken, Japan*
[2]*Research Fellow of Japan Society for the Promotion of Science, Tokyo, Japan*
[3]*Graduate School of Human Development and Environment, Kobe University, Hyogo, Japan*
[4]*Department of Information Design, Tama Art University, Tokyo, Japan*
[5]*Faculty of Education, Soka University, Tokyo, Japan*
[6]*Graduate School of Information Science and Technology, Hokkaido University, Hokkaido, Japan*

Keywords: Environmental Problems, Simulation, Virtual World, Score, Clear-Cut Logging, Evergreen Tree Logging, Tree Size, Children, Problem-solving Skills.

Abstract: At present, there are many environmental problems, and environmental education is necessary to realize a sustainable society. The most important element of education is practical application of what has been learned, as this will deepen our understanding of the topic. As a part of environmental education, field work is conducted to encourage children to learn vegetation succession. However, because vegetation successions occur over an extended period of time, it is difficult for children to observe and participate throughout an entire vegetation succession cycle even if they do field work. Thus, as a step toward effective environmental education for a sustainable society, we developed a learning support system for children to better understand vegetation successions. This learning support system enables simulated forest management over a period of hundreds of years, providing users the opportunity to observe and learn which factors encourage and hinder plant growth in forests. The system simulates a period of approximately 300 years, and regularly scores the skills of the user according to the state of the forest. The changing score encourages the user to optimize forest management. As a first step of system evaluation, college students were asked to participate as users. Consequently, the participants suggested that this system can enhance understanding of, and problem-solving skills regarding, vegetation successions.

1 INTRODUCTION

In recent years, global environmental problems have become increasingly more severe. Under these circumstances, it is important to realize a sustainable society. Thus, it is necessary to study the history of the natural environment and its patterns of change as the foundation of mankind from experience. However, one of the difficulties of environmental education is that it is not easy for learners to apply knowledge learned via teachers and textbooks to the real world. For example, it can be explained in SATOYAMA, which is a virtual ecosystem that is drawing attention as a powerful educational tool to promote environmental education. The complicated mechanism of vegetation succession and the actual state of succession in SATOYAMA have not been experienced learning outside though learning by textbooks and images is done.

Figure 1: Vegetation succession.

Kawaguchi, S., Mizoguchi, H., Egusa, R., Takeda, Y., Yamaguchi, E., Inagaki, S., Kusunoki, F., Funaoi, H. and Sugimoto, M.
A Forestry Management Game as a Learning Support System for Increased Understanding of Vegetation Succession.
DOI: 10.5220/0006767303220327
In *Proceedings of the 10th International Conference on Computer Supported Education (CSEDU 2018)*, pages 322-327
ISBN: 978-989-758-291-2

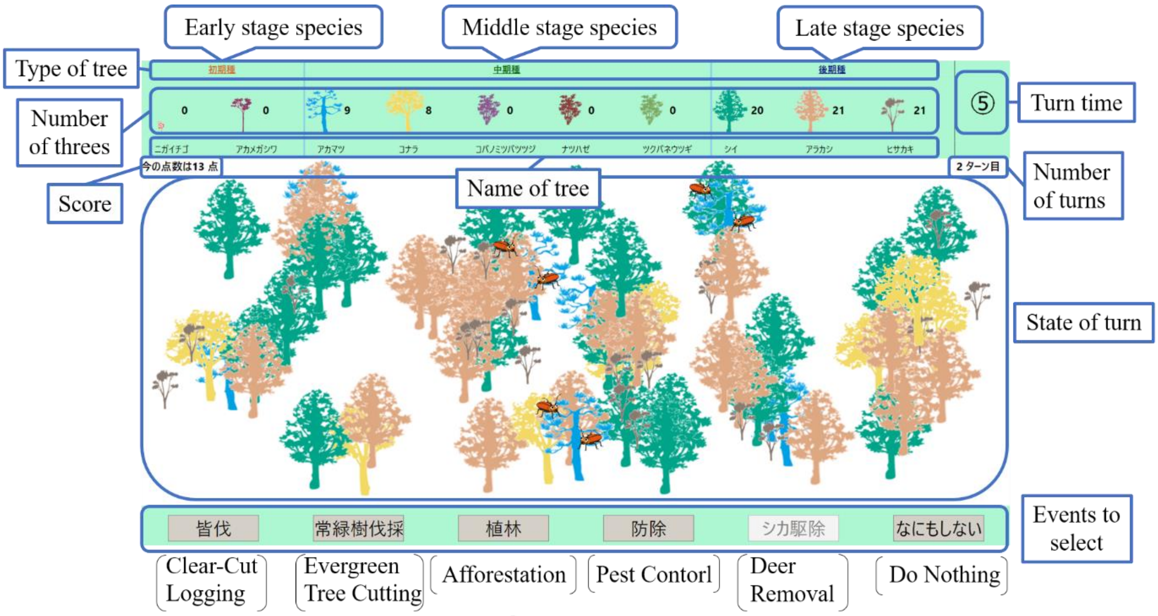

Figure 2: Screenshot of game.

Moreover, even if practical experiential learning is carried out, an actual vegetation succession occurs over a period of several decades to hundreds of years; thus, via SATOYAMA, it remains difficult to obtain a realistic experience of a vegetation succession cycle. Figure 1 illustrates the basic concept of vegetation succession. In order to overcome these problems, development of a learning support system is required to obtain a deeper understanding of vegetation succession that is not influenced by the relatively extended cycle duration.

Thus, a vegetation succession SUGOROKU game based on SATOYAMA preservation has been developed to familiarize users with current environmental problems. In this game, the change in dominance of indicator plants in response to environmental disturbance factors (logging, landslides, precipitation, etc.) was expressed in a SUGOROKU format. Additionally, we have used animation to visualize changes throughout a vegetation succession cycle of SATOYAMA (Deguchi, et al., 2010, Deguchi, et al., 2012). Consequently, we were able to demonstrate that the developed game contributes to increased motivation to learn, enhances understanding of the complexities of vegetation succession, and fosters problem-solving skills related to vegetation succession (Adachi, et al., 2013, Nakayama, et al., 2014, Yoshida, et al., 2015). However, it should be noted that the game developed in this study has focused on the specific area of "Rokko Mountain." In addition, the use of a large-scale ultrasonic sensor enables the user to immerse themselves in the virtual forest and travel along a predetermined path as an indicator plant. Furthermore, a wide variety of plants corresponding to major vegetation in various locations throughout Japan, utilization of a mobile platform to enable portability, and infrared sensor-based immersion were implemented in this study to promote better understanding of SATOYAMA vegetation succession and enhanced problem-solving skills related to forest management. In addition, we aimed to diversify the simulation contents as according to the attributes of each user, and devised a plan to develop new games in which each student could participate.

Therefore, a SATOYAMA management-based game, which can be customized to address the environmental problems to which each user is familiar, was developed (Kawaguchi, et al., 2017). The vegetation succession occurring in SATOYAMA changes in response to human intervention, such as afforestation, deforestation, pesticide use, and deer relocation, in addition to the influence of animal feeding habits and competition between plants. After studying materials that would enable visualization of these changes, last year, we designed a SATOYAMA management game and carried out trial version development and a preliminary evaluation experiment with 40 elementary school students. Based on the results of the evaluation analysis of the demonstration experiment, the following problems related to content, game, and system were observed:

- There was insufficient time for the user to observe a change in vegetation succession during game play and consider the corresponding cause.
- It was difficult for the user to observe the ideal conditions of vegetation in SATOYAMA.
- Management methods were insufficient to cope with various vegetation conditions.
- It was a system that could not sufficiently create a sense of immersion in a virtual world.

Therefore, to build upon the previous research, the following goals were chosen for the current research:

- The user will be able to observe a change in vegetation succession during game play and understand the corresponding cause.
- The user will be able to observe the effects of a forest management decision on SATOYAMA and compare the current state to the ideal state at any time.
- Develop an improved management method for more realistic SATOYAMA management.
- Increase the number of species at the succession stage corresponding to major vegetation found throughout Japan, as this will facilitate a sense of immersion.

Subsequent sections of this paper describe the current form of the game and the preliminary experiments performed by university students, as this experiment will later be conducted by primary school students.

2 CURRENT GAME IMPLEMENTATION

2.1 Game Purpose

The game introduced in this chapter is titled the SATOYAMA Management Game. SATOYAMA is a mountain that humans manage and use, and is located between a town where humans live and surrounding nature. It is regarded as a forest necessary for agriculture such as firewood charcoal production, compost and wood ash production, and timber production. In this game, users can simulate SATOYAMA environmental management. Figure 2 shows the game screen, which also presents the following management method events:

- Clear-Cut Logging
- Evergreen Tree Cutting
- Afforestation
- Pest Control
- Deer Removal
- Do Nothing

The user selects one of the above actions to initiate over a certain period of time; consequently, the vegetation in SATOYAMA changes according to the selected action. Of these management methods, there are two types of deforestation: clear-cut logging and evergreen tree logging. The game begins with SATOYAMA in a poor state in which many late-stage species are vegetated; the initial and ideal states are presented in Figure 3. The user is given 20 opportunities to implement one of the six management methods and achieve the ideal state of SATOYAMA in which many middle-stage species are vegetated. As was previously mentioned, the current state of SATOYAMA is consistently compared to the ideal state to provide the user with a score. This score is displayed on the game screen such that the user can check it as desired. This facilitates understanding of the complex mechanism behind vegetation succession.

The following ten species in the three successional stages (Figure 4) are implemented in this game:

- Early-stage species: *Rubus microphyllus, Mallotus japonicas*
- Middle-stage species: *Pinus densiflora, Quercus serrata, Rhododendron reticulatum, Vaccinium oldhamii, Abelia spathulata*
- Late-stage species: *Castanopsis* spp., *Quercus glauca, Eurya japonica*

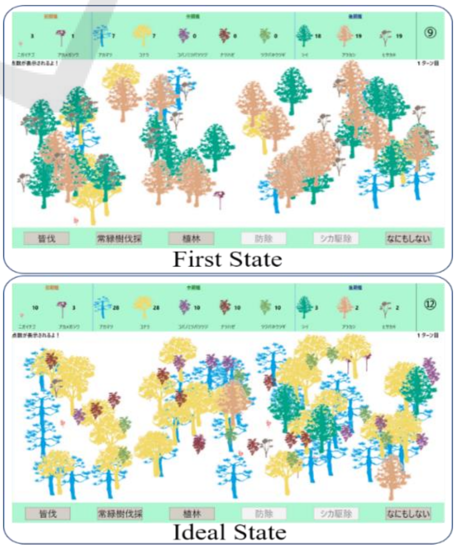

Figure 3: Initial and ideal states of SATOYAMA.

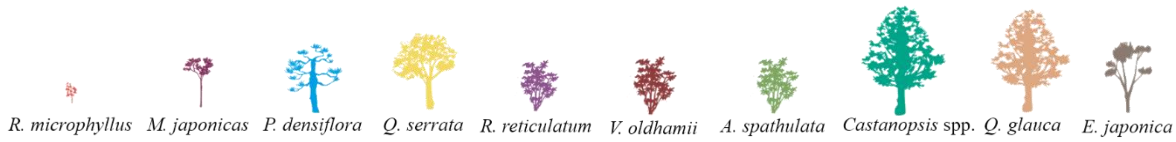

Figure 4: Types of plants.

Table 1: Plant-event relationship matrix.

Plants / Events								
Clear-Cut Logging	+5	+5	→0	→0	→0	→0	→0	→0
Evergreen Tree Logging			+5	+4	+4	→0	→0	→0
Afforestation			+4	+3	+3			
Pest Control	+5	+4	+6					
Deer Removal	+3	+3	+3	+3	+3	+1	+1	+1
Do Nothing	-3	-3	-2	-2	-2			

These plants have different growth rates and terminal sizes. The early-stage species of *Rubus microphyllus* is a intolerant shrub and *Mallotus japonicas* is a intolerant middle tree, whereas middle-stage species *Pinus densiflora* and *Quercus serrata* are a intolerant tall trees. Contrastively, middle-stage species *Rhododendron reticulatum*, *Vaccinium oldhamii* and *Abelia spathulata* are intolerant shrubs Late-stage species *Castanopsis* spp and *Quercus glauca* are tolerant tall trees and late-stage species *Eurya japonica* is a tolerant shrub.

As was previously mentioned, human intervention, animal feeding habits, and competition among plants cause the numbers of these plants to fluctuate. In SATOYAMA, this human intervention refers to the six management methods implemented in the game. Alternatively, the vegetation in this virtual ecosystem is influenced by the plants eaten by pine longicorn and deer. Furthermore, when two or more plants grow in the same place, competition between plants exists. For example, when tall trees and shrubs are planted in the same high-density forest area, the tall trees can receive the sunlight needed to grow, but also prevent sunlight from reaching the shrubs. Consequently, the number of shrubs in the area will decrease. As many late-stage species are present in the initial state of SATOYAMA, if humans do not manage the ecosystem, the number of taller trees will increase, thereby leading to suppression of shorter shrubs growth and their eventual extinction.

2.2 System Configuration

The entire system comprises a screen, a short focus projector, a personal computer (PC), and a mouse. When the user selects an event on the screen by using the mouse, the corresponding change is applied to the virtual ecosystem, which also permits the user to change the number of each plant as desired. These operations and controls were implemented using a C# program developed via Visual Studio 2013.

The plant-event relationship matrix is shown in Table 1. It should be noted that the relative relationships between each plant reflect the state of vegetation succession. When learners select clear-cut logging, all plants are cut down. However, since the tall trees are gone, only the early-growing early-stage species will become vegetated. Additionally, if evergreen tree logging is chosen, the number of late-stage species will decrease, whereas early-stage species and middle-stage species will increase. Alternatively, choosing afforestation will increase the number of middle-stage species, thereby causing the number of early-stage species to decrease. As an example, when the number of *P. densiflora* increases to a minimum of six, pine longicorn appear. Conversely, when the number of *R. microphyllus* increases to at least three, deer appear. Although the occurrence is randomly determined, the effects on plants by two animals are dependent on the characteristics of the plants. Middle-stage species shrubs, *Rhododendron reticulatum*, *Vaccinium oldhamii*, *Abelia spathulata* are vegetated when the numbers of *Pinus densiflora* and *Quercus serrata* in the middle tuber exceed 50%, and disappear when the numbers are 50% or less.

3 EXPERIMENT

3.1 Method

Students from Tokyo University of Science in Chiba prefecture in Japan participated in the experiment, which was carried out from November 12th to 15th, 2017. The participants were eight fourth-year undergraduates, four first-year master's degree students, and three second-year master's degree students. Also, always on the time. Each participant was asked to consider a management strategy before the commencement of each game, and to carefully observe the SATOYAMA environment while playing. Figure 5 presents a photograph of the experimental environment.

3.2 Results

We evaluated the final score of each participant, and averaged their scores for each of three trial games. In order to investigate whether a significant difference exists between the average scores of each trial game, the average scores were analyzed via the multiple-comparison Tukey method.

Table 2 presents the average and dispersion of scores, and Table 3 presents the results of the Tukey method. At a confidence level of 5% and 1%, no significant difference was observed between the second and third average scores. However, the differences between the first and second and first and third trial averages were found to be significant at confidence levels of 5% and 1%.

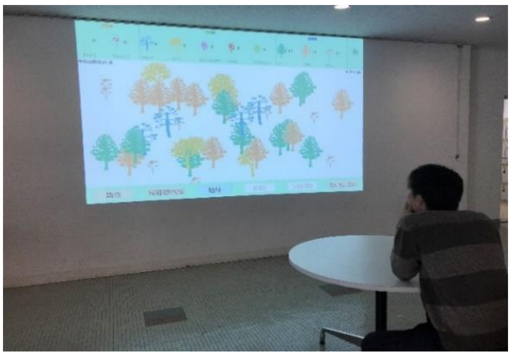

Figure 5: Experimental environment.

4 CONCLUSIONS

In this study, we aimed to promote deeper understanding of vegetation succession and improved problem-solving skills via immersion in a virtual ecosystem that allowed the user to visualize the effects of various significantly influential factors. The users were tasked to manage SATOYAMA such that the ideal environment could be realized.

In the experiment conducted to evaluate this game, the difference between the first and second and first and third trial average scores of 15 participants was found to be significant. These results indicate that participants were able to develop a deeper understanding of vegetation succession and improved problem-solving skills by playing this game, as the increasing scores indicate increasingly effective management strategies.

By playing the game, users can learn about vegetation successions via implementation of a management method that is more realistic than previously available SATOYAMA management methods. Furthermore, this game allows the user to visualize and better understand the consequences of human intervention, in addition to how animal population and plant competition affect the state of vegetation succession.

Table 2: Trial average and dispersion scores.

	First	Second	Third
Average	40.8	66.7	73.7
Dispersion	380	92.6	11.0

Table 3: Tukey results.

	First-second	Second-third	First-third
Calculation result	7.91	2.12	10.0
α=0.05 (3.67 or more)	○	×	○
α=0.01 (4.84 or more)	○	×	○

However, the effectiveness of this game can be increased by incorporating video analysis of the participants playing the game, as this would facilitate the study of vegetation successions and provide an additional means to qualitatively assess the effectiveness of the game as a tool to learn forest management support. In addition, the game was preliminarily evaluated via undergraduate and graduate students to facilitate optimization prior to presenting the game to elementary school students.

ACKNOWLEDGEMENTS

This work was supported by JSPS KAKENHI Grant numbers JP26282061, JP26560129, JP15H02936, JP16H03059, and JP16H01814.

REFERENCES

Deguchi, A., Inagaki, S., Kusunoki, F., Yamaguchi, E., Takeda, Y. & Sugimoto, M. (2010) 'Vegetation Interaction Game: Digital SUGOROKU of Vegetation Succession for Children', In *Proceedings of the 9th International Conference on Entertainment Computing (ICEC2010)*, September, pp. 493-495.

Deguchi, A., Takeda, Y., Kusunoki, F., Tanaka, M., Inagaki, S., Yamaguchi, E. & Sugimoto M. (2012) 'Development and evaluation of a digital environmental learning game for children', In *E-Book Proceedings of the ESERA 2011 Conference: Science learning and Citizenship*, pp. 26-32.

Adachi, T., Goseki, M., Muratsu, K., Mizoguchi, H., Namatame, M., Sugimoto, M., Kusunoki, F., Yamaguchi, E., Inagaki, S. & Takeda, Y. (2013) 'Human SUGOROKU: full-body interaction system for children to learn vegetation succession', In *Proceedings of the 12th International Conference on Interaction Design and Children(IDC2013)*, June, pp. 364-367.

Nakayama, T., Adachi, T., Muratsu, K., Mizoguchi, H., Namatame, M., Sugimoto, M., Kusunoki, F., Yamaguchi, E., Inagaki, S. & Takeda, Y. (2014) 'Human SUGOROKU: learning support system of vegetation succession with full-body interaction interface', In *Proceedings of CHI EA'14- CHI'14 Extended Abstracts on Human Factors in Computing Systems (CHI2014)*, April, pp. 2227-2232.

Yoshida, R., Adachi, T., Muratsu, K., Mizoguchi, H., Kusunoki, F., Namatame, M., Sugimoto, M., Yamaguchi, E., Inagaki, S. & Takeda, Y. (2015) 'Life-size board game "HUMAN SUGOROKU" to teach children about vegetation succession', In *Proceedings of the 7th International Conference on Computer Supported Education (CSEDU2015)*, vol. 2, April, pp. 295-300.

Kawaguchi, S., Sakai, T., Tamaki, H., Mizoguchi, H., Egusa, R., Takeda, Y., Yamaguchi, E., Inagaki, S., Kusunoki, F., Funaoi, H. and Masanori, S. SATOYAMA: Time-limited Decision Game for Students to Learn Hundreds Years Forestry Management, *proceedings of the 9th International Conference on Computer Supported Education (CSEDU 2017)* , vol. 1, April, pp. 481-486.