Research article

Survey on the Slope Protection Method for Sloped Farmland Aimed at Conservation of Regional Unique Landscape

SHOKO NISHIWAKI*
Graduate School of Frontier Sciences, The University of Tokyo, Tokyo, Japan
Email: 7063598150@edu.k.u-tokyo.ac.jp

KENJI OKAJIMA
Graduate School & Faculty of Bioresources, Mie University, Mie, Japan

EIJI YAMAJI
Graduate School of Frontier Sciences, The University of Tokyo, Tokyo, Japan

Received 13 January 2018 Accepted 20 October 2018 (*Corresponding Author)

Abstract Japan's National land has many steep mountains and few flat lands. We performed slant ground use for a long time to secure farmland, in Japan. In slope protection methods of the sloping farmland, there are fundamental two types of “slope tamping” and “stone wall”. The slope protection methods of the sloping farmland are one of the elements characterizing a scene including sloping farmland as a thing peculiar to area. In this paper, we analyzed the type of the slope protection method of sloping farmland in the point of “one hundred selection of Japanese sloping farmlands” and the representative sloping farmland in Japan using a subsurface geological map drawn on a scale of 1 to 200000. The geology in each point of target area was classified into three main groups as volcanic rock, sedimentary rock and metamorphic rock. Three main groups were further classified by rock types or geological timescale. We formed clear that rock types or geological timescale of the subsurface geology in the point was related to the choice of the slope protection method of sloping farmland. We conducted a field survey based on this classification. As a result, in region where two or more subsurface geologies are adjacent, the rock of the subsurface geology next to each other in domains from the subsurface geological feature border to around 200m is used as materials of the protection method of sloping farmland.

Keywords sloping farmland, rice terrace, terraced field, stone wall, slope protection method

INTRODUCTION

Japan's National land has many steep mountains and few flat lands. We performed slant ground use for a long time to secure farmland, in Japan. In Japan, farm village landscapes with rice terrace or terraced fields are cultural landscape. The slope protection methods of the sloping farmland are one of the elements characterizing a scene including sloping farmland as a thing peculiar to area. Typical ones in the slope protection method of rice terraces and Terraced fields are stone walls and slope tamping.

In slope protection methods of the sloping farmland, there are fundamental two types of “slope tamping” and “stone wall”. Some research suggested that the type of the slope protection method of sloping farmland depended on the presence or absence of unearthed rocks at the time of the paddy field reclamation; however, these are not describe detailed the kind of stones. When the slope protection methods are broken for some reason or to deteriorate over time, we may not choose appropriate slope protection method or materials. It shows the possibility that a traditional landscapes fails.

METHODOLOGY

We performed documents investigation and a field survey. In this paper, we will express Rice terrace and terraced field with sloping farmland.

Documents Investigation

In this paper, we focused on relationship between the rock types of the subsurface geology and the slope protection method and revealed tendency in choosing slope protection method. We basically used subsurface geological map drawn on a scale of 1 to 200000 published by AIST Geological Survey of Japan. In this map, the discontinuous boundaries between neighboring quadrangles were resolved using a unified legend.

We chose 464 areas registered in a prefecture or country of Japan as the sloping farmland which represented an area. Fig.1 shows the locations of the 464 areas. In the analysis, we used information on registered sloping farmland. The black dots in Fig. 1 are the target area. The rock classification and geologic time classification of the subsurface geology we used are shown in Fig. 2 (Arai et al., 2005; Itoh, 1982; Itoh and Nishiki, 1985).

Fig. 1 Distribution of Documents investigation target area

Cenozoic Era			Mesozoic Era	Paleozoic Era	
Quaternary Period	Neogene period	Paleogene period			
present-day	2.6 million years ago	23 million years ago	65.5 million years ago	251 million years ago	542 million years ago

Pliocene/Miocene

Holocene/Pleistocene

Fig. 2 Rock classification and geological time classification of subsurface geology

Field Survey

We did a field survey to more quantitatively show the relationship between the subsurface geology and the choice tendency of the slope protection method. The purpose of the survey is to clarify what kind of stone were used for stone wall of slope protection method. We grasped the subsurface geology of the target area by subsurface geological map, and we investigated how far the geological boundary of the subsurface geology affects the stone used in stone wall.

The boundary between Arita City and Yuasa Town in Wakayama Prefecture of Japan was selected as a target area where surface geology is changing within the region. We investigated the outcrop of the geological indicator as an indicator of the survey site. And the survey point was decided by changing the distance from the outcrop. The distance between the survey points was set within 100 m. We gathered the following data at each survey point. Location data by GPS (GARMIN OREGON 300), stone used for material of stone wall types classified by reference to subsurface geological map, and photographic data as material of stone wall. From these information, the relationship between distance from outcrop or geological boundary, or elevation difference and stone used in stone wall was considered.

RESULTS AND DISCUSSION

Documents Investigation

Among the sloping farmlands in 464 areas, 293 areas selected stone wall as slope protection method, 171 areas selected slope tamping as slope protection method. In the rock classification, 157 areas have volcanic rocks, 45 areas have plutonic rocks, 115 areas have sedimentary rocks, 80 areas have accretionary prism, and 54 areas have metamorphic rocks as subsurface geology.

Fig.3 (a) shows the proportion of rock classification and geologic time classification in the study area. The rock classification and geological time classification of 464 areas and the distribution area ratio of rocks in Japan have the same tendency. Fig.3 (b) shows distribution area ratio of rocks in Japan.

Fig.4 shows the relationship between the rock classification and the slope protection method the sloping farmlands of the survey target area.

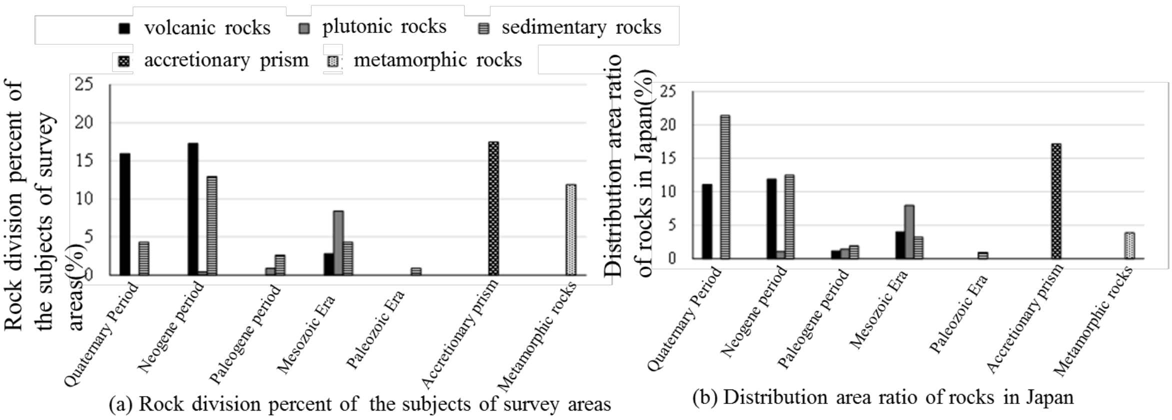

Fig. 3 Rock classification and geological age classification of survey target area and Distribution area ratio of rocks in Japan

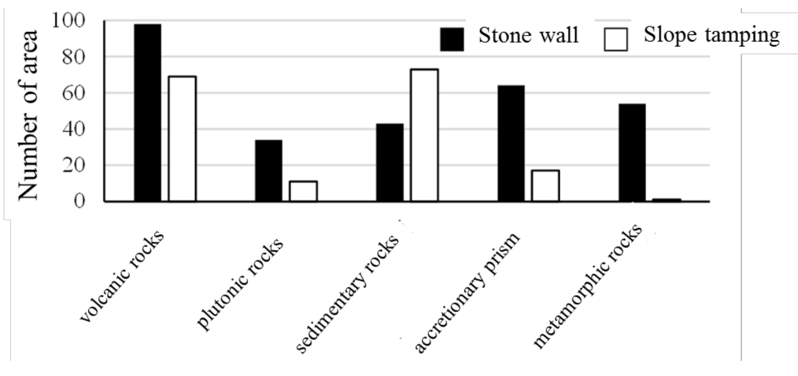

Fig. 4 Relationship between rock classification of surveyed area and slope protection method of sloping farmland

Field Survey

Table 1 shows the types of stone used at each survey points. In Table 1, ① to ④ and No.1 to No.29 correspond to numbers in Fig. 5. Fig. 5 shows the subsurface geological map around the surveyed area. In the Fig. 5, the same type of subsurface geology exists in places where the same numbers are applied. In Fig. 5, It is believed that sedimentary rocks that were made into the Holocene existed in ①. Likewise, it is supposed that ② in Fig. 5 has the accretionary prism that were made into Mesozoic Era, ③ the metamorphic rocks of about 230 million to 160 million years ago, and ④ the Mesozoic sandstone and conglomerate. Specifically, the rocks present in ② are cherts. It must be sedimentary rock in ①, but because it is somewhat unstable at the geological boundary of the surface geological map, it is the reason why the outcrop of chert exists in ①. In this survey, we considered the chert (②) as the subsurface geology at the survey points near the outcrop of the chert. The survey points were set up to traverse three subsurface geologies such as accretionary prism, metamorphic rock, sandstone and conglomerate.

Table 1 Results of each survey point

	No.	North latitude	East longitude	Limestone	Crystalline schist	Chert	Sandstone	Conglomerate	Mudstone	Total
①	No.1	34°4′ 00.71″	135°10′ 40.56″	0	0	100	0	0	0	100
	No.2	34°03′ 57.5″	135°10′ 39.5″	0	0	97	3	0	0	100
	No.3	34°03′ 54.6″	135°10′ 39.6″	0	0	97	3	0	0	100
	No.4	34°03′ 50.6″	135°10′ 39.7″	1	1	92	6	0	0	100
②	No.5	34°3′ 46.7″	135°10′ 40.6″	0	2	97	1	0	0	100
	No.6	34°03′ 43.6″	135°10′ 38.6″	0	0	98	2	0	0	100
	No.7	34°03′ 41.9″	135°10′ 40.4″	0	0	100	0	0	0	100
	No.8	34°03′ 38.5″	135°10′ 45.8″	5	0	92	3	0	0	100
	No.9	34°03′ 35.9″	135°10′ 45.6″	0	0	95	5	0	0	100
	No.10-1	34°03′ 34.7″	135°10′ 47.7″	0	0	100	0	0	0	100
	No.10-2	34°03′ 34.0″	135°10′ 48.6″	47	0	53	0	0	0	100
	No.11	34°03′ 33.6″	135°10′ 46.7″	0	0	100	0	0	0	100
	No.12	34°03′ 32.7″	135°10′ 47.5″	0	0	100	0	0	0	100
	No.13	34°03′ 28.8″	135°10′ 47.9″	0	0	71	16	0	0	87
	No.14	34°03′ 27.2″	135°10′ 46.6″	0	0	98	2	0	0	100
	No.15	34°03′ 24.4″	135°10′ 46.5″	0	0	34	3	2	0	39
	No.16	34°03′ 23.9″	135°10′ 49.0″	0	0	98	2	0	0	100
	No.17	34°03′ 23.6″	135°10′ 49.0″	0	0	100	0	0	0	100
	No.18	34°03′ 19.6″	135°10′ 53.0″	0	0	100	0	0	0	100
③	No.19	34°03′ 18.3″	135°10′ 55.1″	0	0	100	0	0	0	100
	No.20	34°03′ 16.2″	135°10′ 56.8″	0	0	0	100	0	0	100
	No.21	34°03′ 14.3″	135°10′ 57.0″	0	0	55	35	1	0	91
	No.22	34°03′ 14.4″	135°10′ 59.3″	0	0	81	11	8	0	100
④	No.23	34°03′ 12.3″	135°11′ 00.4″	0	0	1	99	0	0	100
	No.24	34°03′ 9.6″	135°10′ 59.7″	0	0	0	100	0	0	100
	No.25	34°03′ 5.2″	135°11′ 00.9″	0	0	0	100	0	0	100
	No.26	34°03′ 00.9″	135°11′ 01.6″	0	0	5	88	7	0	100
	No.27	34°02′ 54.7″	135°11′ 04.0″	0	0	1	99	0	0	100
	No.28	34°02′ 49.7″	135°11′ 03.9″	0	0	0	40	16	2	58
	No.29	34°02′ 45.7″	135°11′ 02.3″	0	0	0	80	20	0	100

In Fig. 5, it is considered that the time of sedimentation is new and it is thought that ① is not sufficiently consolidated as rocks, but the rocks of ②, ③, ④ is considered to be used as the material of stone wall. Through on the field survey, the outcrops of the chert at the subsurface geology of ① and ② was confirmed (triangle dots in Fig. 5), ③ and ④ confirmed sandstone outcrops (white triangle dots in Fig. 5). It must be sedimentary rock in ①, but because it is somewhat unstable at the geological boundary of the surface geological map, it is the reason why the outcrop of chert exists in ①. In this survey, we considered the chert (②) as the subsurface geology at the survey points near the outcrop of the chert.

At the 20 survey points in ① and ②, the chert was used as material of stone wall at a rate of 53 to 100%. Also, at all the survey points in ④, over 90% of the material rocks of stone wall were sandstone and conglomerate. In addition, both stone materials were used at the three survey points of the survey spot (within ③) within 200 m from the geological boundary of ② and ④.

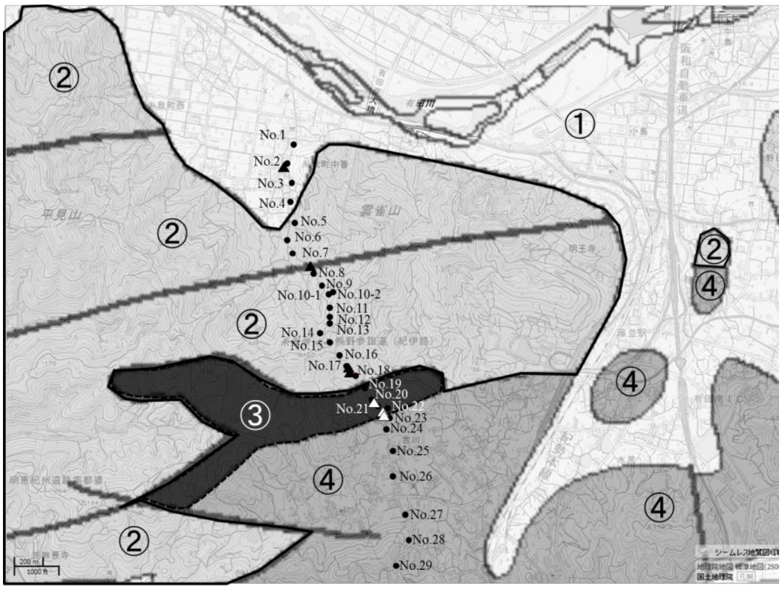

Fig. 5 Subsurface geological map around survey area and survey spot

CONCLUSION

From the above results, the following can be considered. As a result of documents investigation, when the subsurface geology is plutonic rocks, accretionary prism, or metamorphic rocks, the stone wall is strongly selected as slope protection methods. On the other hand, when the subsurface geology is volcanic rocks, slope tamping were selected in nearly half of the sloping farmland and in the case of sedimentary rocks the stone walls are selected in nearly 30% of the sloping farmland. In addition, the area where the subsurface geology is pyroclastic flow deposit among volcanic rocks selects slope tamping as slope protection methods.

Among districts where the subsurface geology is a pyroclastic flow deposit, there is a tendency to select slope tamping when the pyroclastic flow is formed in the Holocene or Neogene period. Sloping farmlands where older pyroclastic flows are located in the subsurface geology tend to select stone walls. Moreover, in the area that consolidated volcanic rocks are there to the subsurface geology, the area where the former geologic formations of the Miocene volcanic rocks where the Green Tuff is formed will tend to select the slope tamping as slope protection methods for Regardless of its composition. Among mafic volcanic rocks, there is a tendency to select slope tamping as slope protection method if the subsurface geological districts were made in the Quaternary Period, otherwise it seems to choose stone walls.

When the subsurface geology is plutonic rocks, we found out the following. When the plutonic rocks of the subsurface geology were felsic, stone walls were chosen in general, although the slope tamping was selected with 27% of the slope farm depending on the weathering degree of rocks.

Districts where sedimentary rocks in the Quaternary or New Tertiary are located in the subsurface geology select the slope tamping, but in the area with rocks consolidated where the altitude in higher than the sloping farmland, there possibility to choose stone walls. It was found from the field survey in the other area that there is a possibility of choosing stone wall as a slope protection method even if consolidated rocks located in a place where the altitude is high and sloping farmland are separated by a horizontal distance of 500 m or more.

When the surface geology is an accretionary prism, the slope tamping concentrate in the subsurface geological areas formed in the middle or late Jurassic centers called the Mino - Tanba -

Ashio Belt. In the sloping farmland where the subsurface geology is an accretionary prism and exists outside the Mino - Tanba - Ashio Belt, there is a tendency to choose stone wall as a slope protection method.

In sloping farmland whose subsurface geology is metamorphic rocks, it turned out that in most cases would choose stone wall.

In the field survey, basically we could actually confirm that stones of subsurface geology are used on the ground. Furthermore, within about 200 m of the geological boundary of the subsurface geology, it is possible that adjacent rocks will be used as materials for stone walls. In other words, in sloping farmland where several subsurface geologies are located nearby, not only the rocks of the just below subsurface geological structure but also the rocks of adjacent subsurface geology are used.

REFERENCES

Arai, T., Futatsugi, S. and Imamura, R. 2005. 2 The formation of Japanese ground. In Geology Learned by Case, The Japanese Geotechnical Society, 17-61. (in Japanese).

Geological Survey of Japan. Seamless Digital Geological Map of Japan (1:200,000). 2015. https://gbank.gsj.jp/seamless/index.html?lang=ja&

Itoh, S. 1982. Surface geological classification and its application to agricultural land conservation. Jour. of JSIDRE, 50 (6), 505-510. (in Japanese).

Itoh, S. and Nishiki, T. 1985. Surface geological map and its application to development and conservation of farmland. Jour. of JSIDRE, 53 (10), 877-884. (in Japanese).

Kamata, Y. 1977. Subsurface geology. In Nagasaki Prefecture Southern Region Integrated Development Area Land Classification Basic Survey, Land Management Office of Nagasaki Prefecture, 18-23. (in Japanese).

Kondo, Y., Kishimoto, S. and Kakuta, S. 1997. Stone. In New Edition Civil Engineering Materials Science, Corona Publishing Co., 48-89. (in Japanese).

Matsuo, K. 1953. Studies on the sloping farm-land. Journal of the Agricultural Engineering Society, 21 (4), 36-43. (in Japanese).

Mekata, M. 1973. Kitakami, Subsurface geology. In Mountains Development Area Land Classification Basic Survey, Iwate Prefecture, 18-22. (in Japanese).

Murata, Y. and Kano, K. 1995. The areas of the geologic units comparing the Japanese Islands, calculated by using Geological Map of Japan 1:1,000,000. The 3rd Edition CD-ROM Version.

Nakagawa, C. and Kanamaru, F. 1969. The factor of landslide in Shikoku. Journal of the Japan Landslide Society, 41-1, 25-33. (in Japanese).

Nakashima, M. 2002. Distribution and characteristics of rice terraces. Jour. of JSIDRE, 70 (3), 195-198. (in Japanese).

Okajima, K., Kaburagi, R. and Iida, T. 2012. Analysis of disaster factors in stone wall of paddy fields and actual situation of restoration based on the field survey. Journal of Rice Terrace Research Association, 13, 57-71. (in Japanese).

Sasaki, N. 1973. Kitakami, Soil. In Mountains Development Area Land Classification Basic Survey. Iwate Prefecture, 1973. 23-27. (in Japanese).

Sato, T., Ishimaru, T., Sugihara, K. and Shimizu, K. 1992. Data collection by literature survey on rock physical properties in Japan. Power Reactor and Nuclear Fuel Development Corporation, PNC TN7410 92-018, 1-37. (in Japanese).

The National Institute of Advanced Industrial Science and Technology. 2015. GeomapNavi. Geological map display system of Geological Survey of Japan, https://gbank.gsj.jp/geonavi/