Journal of Environmental Assessment Policy and Management
Vol. 16, No. 3 (September 2014) 1450023 (16 pages)

DOI: 10.1142/S1464333214500239

Imperial College Press
www.icpress.co.uk

THE EIA SYSTEM AND HAZARD MANAGEMENT OF SEDIMENT-RELATED DISASTER IN JAPAN — A CASE STUDY IN WIND FARM PROJECTS

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Received 10 June 2013
Revised 19 January 2014
Accepted 20 February 2014
Published 24 September 2014

Japan suffers many sediment-related disasters due to intense rainfall and other geographical and meteorological features. This paper aims to clarify the potential role and challenges of Environmental Impact Assessment (EIA) as a hazard management tool of sediment-related disaster, through surveys of the regulatory framework and analyses of case studies of wind farm projects. Based on the analysis, this paper mainly obtains the following conclusions:

(1) One of the important roles of the EIA is to identify potential hazards of sediment-related disaster, because a large proportion of the projects involve potential hazards in terms of the siting, nevertheless, few of EIAs evaluate the hazards;
(2) Long-term monitoring is a needed and essential role for EIA because, while re-vegetation would be carried out as a hazard mitigation on average for half the area with land change, in some cases re-vegetation has not been successful in 5 years since the implementation;
(3) Improvements in the EIA system are required in order to be able to integrate the various features of hazardous information, including non-legally binding hazardous areas and local knowledge, into a common consideration for robust hazard management.

Keywords: EIA; hazard management; sediment-related disaster; wind farm project.

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Introduction

In recent years, susceptibility to sediment-related disasters has been increasing on a global scale due to unusual meteorological phenomena that might be caused by climate change. Japan is a typical country with high susceptibility to sediment-related disasters because of its geographical and meteorological features. Japan has a total land area of 370,000 km^2, of which 70% is mountainous; it receives almost double the global average of annual precipitation and a large number of typhoons (Yoshimatsu and Abe, 2006). As a consequence, approximately 1,200 sediment-related disasters occur in Japan each year, with approximately 30 fatalities (MLIT: Ministry of Land, Infrastructure, Transport and Tourism, 2013).

A large number of studies have been carried out in the field of hazard assessment, which estimates an area's susceptibility to sediment-related disasters based on key geographical and meteorological factors (e.g. Wang and Sassa, 2005; Yoshimatsu and Abe, 2006; Uchida *et al.*, 2009; Mouri *et al.*, 2013). Furthermore, Japan has accumulated an enormous wealth of experience of dealing with sediment-related disasters thus far. For instance, the National Research Institute for Earth Science and Disaster Prevention (NIED) has surveyed 186 dominant sediment-related disasters across Japan since 1586. However, in terms of implementation of hazard management of sediment-related disasters, as described in MLIT (1999), control of individual developments and actions in the hazardous areas has not been carried out adequately under the existing relevant laws and regulations, and major improvements are still needed.

In the field of environmental assessment, while some publications such as Canadian Development Bank *et al.* (2004), Benson (2007) and Bilateral Joint Research Seminars JSPS, Japan and ESRC, UK (2013) identify the benefits of natural hazard management in environmental assessment for new development projects, the number of related case studies is quite limited, for instance, earthquake (Phantumvanit and Nandhabiwat, 1989), landslides and avalanches (Geneletti, 2008) and floods (Jeremy *et al.*, 2009). And to our knowledge there is no study of policy integration between EIA and hazard management of sediment-related disasters so far.

This paper aims to clarify the potential role and challenges of the EIA as a hazard management tool for sediment-related disaster. We accomplish this through surveys of the regulatory framework and analyses of case studies of wind farm projects, as a typical project type, which involves a relatively high potential risk of sediment-related disaster.

The second section introduces the study's framework based on the overall framework of the laws for sediment-related disaster management and the EIA system in Japan. In the third section, we look at positional relations between the locations of wind farm projects and designated hazardous areas, in order to analyze the potential role of hazard management within the EIA on a national scale. We also consider specific details through case studies, mainly based on the EISs. The last section contains our conclusions.

The Study's Framework

Legal measures for sediment-related disaster management

Figure 1 presents the framework of Japanese acts for sediment-related disaster management. Sediment-related disasters can be classified as debris flow, landslide or slope failure, based on the differences in damage features, investigation methods and prevention countermeasures. For each type of disaster, the Erosion Control Act (1897), the Landslide Prevention Act (1958) and the Act on Prevention of Steep Slope Collapse Disasters (1969) were established. These acts have prescribed structural measures, such as mudslide-control dams, to prevent sediment movements, which trigger sediment-related disasters. In addition, the acts prescribe the capability to designate legally binding hazardous zones where specific developments, which could increase a degree of hazard of sediment-related disaster occurrence, shall be controlled and restricted (hereinafter called "legal hazard zones"). However, in practice, since the designations have been premised on where the construction of structural measures were scheduled, the number and

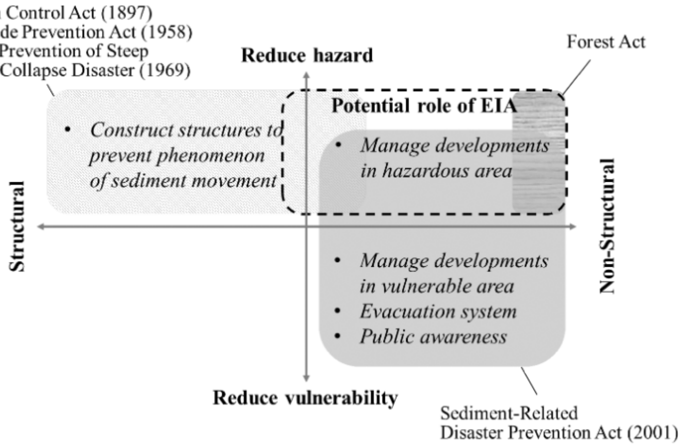

Fig. 1. The framework of Japanese laws for sediment-related disaster prevention and the EIA in this paper.

coverage of legal hazard zones has been quite limited, and a large part of potentially hazardous areas of sediment-related disaster occurrence have remained an undesignated area under the acts (MLIT, 1999).

Because of the establishment of the Sediment-Related Disaster Prevention Act in 2000, non-structural measures such as making the local population aware of vulnerable areas, establishment of evacuation systems, restriction of certain developments, and regulation of the structures in designated vulnerable zones have taken place to reduce vulnerability. Additionally, in response to the limited coverage of legal hazard zones, a large part of other potentially hazardous areas have been designated as "non-legal hazard zones," based on the basic investigations carried out by each prefectural authority, which were originally intended to designate vulnerable areas under the Sediment-Related Disaster Prevention Act. In addition to the above acts, protection forests have also been legally designated under the Forest Act, some of which aim to prevent sediment movement that might trigger sediment-related disasters.

As mentioned above, the three types of laws correspond to hazard management for specific developments, mainly by controlling and/or restricting the developments in each of the designated hazardous areas, as shown in the upper-right quadrant of Fig. 1. Although the coverage of each area is insufficient, the areas overlap a great deal with each other, because sediment-related disasters involve other hazards. Furthermore, although it is relatively easy to draw up hazardous areas without any strong legal basis, such as non-legal hazard zones, such areas do not have strong links to decision making. In light of this, we suggest a tool to integrate the various hazards of each designated area under one umbrella, in order to implement robust hazard management. EIA, which is the focus of this paper, can be defined as such a tool, corresponding to the upper-right quadrant of Fig. 1. In addition, the EIA is able to secure implementation of certain structural measures, such as mitigation measures, therefore, it partially covers the upper-left quadrant of Fig. 1 as well as non-structural measures.

The capability for hazard management of sediment-related disaster in the Japanese EIA systems

The Japanese EIA Act does not prescribe any environmental items directly focused on sediment-related disasters. However, the technical review report issued by the MOE recommended that "slope stability" related to hazard management of sediment-related disasters should be taken into account as a sub-environmental item, in case of developments involving deforestation, land development and change of vegetation and drainage, especially in mountainous areas (MOE, 2002).

Particularly in areas where any sediment-related disasters have occurred, the report requests a detailed survey for the prediction and evaluation of EIA.

In addition to the EIA Act, all of the prefectures and specially designated cities have established an assessment system by ordinances (hereinafter called "prefectural EIA"). Compared with the EIA Act, the systems of prefectural EIAs tend to focus more on slope stability, because prefectural EIAs have a wider range of environmental items to take into account the local context, and some prefectural EIAs prescribe slope stability as a major environmental item.

Features of wind farm projects and hazard management of sediment-related disasters

This paper focuses on wind farm projects, as typical projects, which involve a relatively high hazard of sediment-related disasters due to the following three specific features.

First, a large proportion of wind farm projects have been located in mountainous areas in Japan, especially in recent years. Although the percentage of mountainous wind farms was 35% of the total before 2003, it grew to 56% after 2004 (MOE, 2011a). In mountainous areas, wind farms tend to be located along ridges because of good wind conditions. Such areas are sensitive to natural drainage systems. In addition, areas of land affected by development is over 5 ha in 61% of all projects whose total generation capacity is 10 MW or more, and some projects involved over 30 ha land use change (MOE, 2011a).

Second, accelerated developments of wind farm projects have been predicted in many countries, as one of the main countermeasures to tackling climate change. Particularly in Japan, in response to the enormous momentum towards shifting to renewable energy after the Fukushima Dai-ichi nuclear accident in March 2011, wind energy has been expected to play a key role in the shift to renewables, because of its high installation potential (MOE, 2011b).

Third, wind farm projects have been controversial with respect to local environmental conservation in many countries. In Japan sediment-related hazards and water contamination potentially triggered by land development have been the dominant concerns of local residents. Based on our survey, data of thousands of newspaper articles from across Japan, at least 17 projects faced such opposition. Moreover, according to Kobe-Shinbun (2011), a landslide occurred on the developed site of one operating wind farm, due to a torrential rain caused by the typhoon in September 2011 (Awaji wind farm, see Fig. 2). After the disaster, local residents strongly demanded prevention countermeasures from the developers and

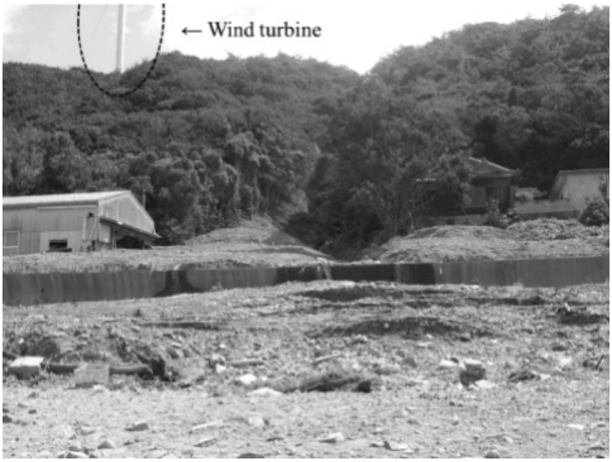

Fig. 2. Landslide occurred around the land developed for an operating wind farm.

local authorities. These facts suggest that more efforts to promote communication between developers and local residents are needed during the planning stages.

In light of the above, this paper focuses on wind farm projects to discuss the EIA system and hazard management of sediment-related disasters. EIA for wind farms has been discussed in the professional literature from various systems (see e.g. Phylip-Jones and Fischer, 2013).

Study method

As described in the first section, although a large number of previous studies have been carried out on hazard assessment of sediment-related disasters, to our knowledge this is the first study of policy integration between the EIA and hazard management of sediment-related disasters. This study takes both a macroscopic and microscopic approach, in order to clarify the potential role and challenges of the EIA as a hazard management tool of sediment-related disaster.

With regards to the macroscopic approach, we survey overall potential hazards of sediment-related disasters on wind farm projects across Japan in terms of the siting, and discusses a potential role of EIA as a hazard management tool based on the results. For this, we select 109 wind farms, which are all large-scale wind farm projects (7.5 MW or more) that began operating prior to April 2012 (New Energy and Industrial Technology Development Organization: NEDO, 2012). The total installed capacity of selected projects accounts for 86% of the total capacity in Japan (2.56 GW, 13rd in the world). We analyze positional relations between the turbine locations of each project and the designated hazardous areas mentioned in the section "Legal measures for sediment-related disaster management", as well as other topological features (forests and "landslide distribution areas" disclosed by the NIED). A geographical information system (GIS) database of the turbine locations is developed mainly via a 1:25,000 topographic map issued by the Geospatial Information Authority of Japan and available environmental impact statements (EISs); supplemental satellite images are used as well. Other GIS data are collected from the National Land Numerical Information download service developed by MLIT and the NIED website.[1] And the analysis is carried out by GIS software, ArcGIS ver. 10.1.

For case studies this paper surveys: (1) specific positional relations between the project locations and designated hazardous areas; (2) mitigation measures for hazard management as a result of EIA; (3) result of scoping in response to authoritys' advice and public comments, based on EIS descriptions and the supplementary documents, such as a summary of authority's advice and public comments. The cases are first selected based on the availability of EISs, due to the difficulty of comprehensive data collection of EISs in Japan. Most of the EIAs for wind farm projects (except for prefectural EIAs) had been conducted voluntarily by the developers under the NEDO EIA guideline (without mandatory information disclosure), until the recent amendment of the EIA Act in 2012, which required EIA with mandatory information disclosure. Among the available EISs, this paper excludes the cases not located in mountainous areas. Following this selection, 4 cases under the NEDO EIA guideline, 7 cases under prefectural EIA ordinances and 10 cases under the EIA Act were analyzed as the case studies.[2]

Results and Discussion

Positional relation of the nationwide wind farm projects using GIS

According to the NEDO statistic, 109 large-scale projects (1,396 wind turbines, 2.19 GW) have started the operation as of April 2012 (NEDO, 2012). Figure 3 shows project locations and the number of projects in each prefecture. While the projects are widely distributed from northern to southern Japan, they tend to be located in mountainous areas relatively near the shoreline because of good

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[1] Due to a lack of availability of comprehensive data, legal hazard zones are excluded from the GIS analysis.

[2] At least 120 EIAs have been carried out under the NEDO EIA guideline (MOE, 2009). On the other hand, 15 are prefectural EIA ordinances (as of 2012), and 18 are EIA Act cases (12 of which are in mountainous areas as of 2013). This number includes EIAs that were still being processed.

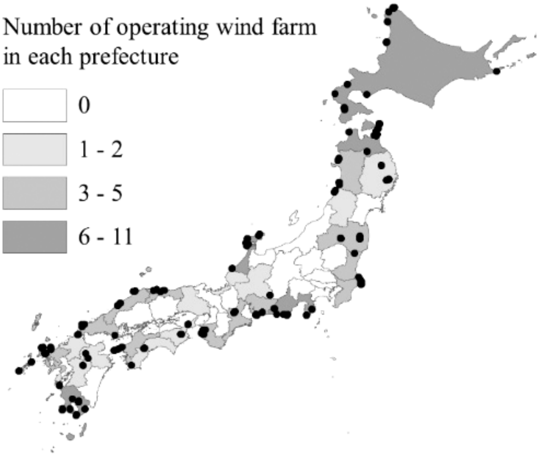

Fig. 3. Locations of the operating large-scale wind farm projects in Japan.

accessibility to roads and ports to transfer the turbines, as well as good wind conditions.

The analysis of positional relations between project locations and hazardous areas is presented in Table 1. The results show that more than half of the operating projects are located in non-legal hazard zones and approximately 30% are in landslide distribution areas. In addition, 25 projects are located in both areas. These figures indicate that a large proportion of the projects have potential hazards of sediment-related disasters. On the other hand, the fraction of wind turbines located in each area is less than half. Therefore in most projects, the project sites are partially situated in the two areas, and especially in landslide distribution areas, the potential hazards could be avoided with some layout modifications.

The results also show that over 90% of the projects and 75% of the wind turbines are located in forest areas, meaning that almost all the projects involved deforestation to some extent. Additionally 42% of the projects involved deforestation of protection forests.

Table 1. Positional relation of the project and turbine locations.

	Non-legal hazard zones	Landslide distribution areas	Protection forest	Forest area	Total
No. of projects	57 (52%)	32 (29%)	46 (42%)	102 (94%)	109 (100%)
No. of wind turbine	343 (25%)	90 (6%)	325 (23%)	1050 (75%)	1396 (100%)

The above result merely shows potential hazards of sediment-related disasters related to siting. However, since over half of the projects are located in hazardous areas and most of the projects involve some deforestation, there is a clear need for hazard management of sediment-related disasters in EIA. This would serve to integrate the various features of hazard information to carry out robust hazard management.

Case studies based on EISs

The positional relation between project locations and designated hazardous areas

Table 2 presents the selected case studies and the project features. In non-legal hazard zones and landslide distribution areas, the GIS is used to survey positional relations, because only 2 EISs describe the positional relation with non-legal hazard zones. Since all EISs describe the positional relations of legal hazard zones, our analysis is based on EIS descriptions.

The overall tendency of the positional relation is that, while a relatively small part of the cases are located in legal hazard zones, more than half of the cases are in non-legal hazard zones and landslide distribution areas. While developers tend to disregard the non-legal binding areas, the potential hazard of sediment-related disaster exist here as well, as is shown in the section “Positional relation of the nation-wide wind farm projects using GIS”. To this end, we have carried out a more detailed case study of the Minenohara wind farm project, to indicate the potential hazards, especially in the non-legal hazard zones more clearly.

In the Minenohara case shown in Table 2, after the publication of the scoping document based on the NEDO EIA guidelines in 2006, the developer was forced to cancel the project in 2009, due to huge opposition by local residents and environmental protection groups. Therefore, the EIA procedure was not completed. A key feature of the case was that local residents had experienced a large-scale debris flow in 1981, which killed 10. Thus the additional hazard, potentially triggered by the development, became one of the dominant issues of concern of the opposition, because the project site was located just next to the point of past debris flow (see Fig. 4).

According to the disaster analysis report of past debris flows, the disaster in 1981 was influenced by a change of water catchment conditions triggered by a land development of golf courses in the 1970s (NIED, 1981). In particular, originally, catchment water flowed along with the slope (see gray arrow in Fig. 4), but the flow was dammed by the land development, and large amounts of the water flowed to the occurrence point (see black arrow in Fig. 4). In light of this

Table 2. Cases selected for surveys and the project features (21 cases).

	Project physical features								Legal hazard zones[b]			Scoping result	
EIA system	Project name	Planning stage	Reference document	Project scale [MW]	No. of turbine	Area of land change [ha]	Non-legal hazard zones[a]	Landslide distribution area[a]	Erosion control act	Landslide prevention act	Act on prevention of steep slope collapse disaster	Was slope stability selected as candidate env. item?	Was slope stability selected as env. item finally?
Prefectural EIA 7 cases	Hatoriko	EIA	scoping	101	44	11.5	—	OO	—	—	—	Yes	No
	Takine	operating	final EIS	46	23	19.9	O	O	—	—	—	Yes	Yes[c]
	Nigorigo	canceled	scoping	20	10	6.9	—	—	—	—	—	Yes	No
	Yahagi	operating	final EIS	10	16	3.6	—	—	—	—	—	Yes	No
	Kasatori	operating	final EIS	38	19	35.0	OO	O	O	—	—	Yes	No
	Aoyama	permitting	final EIS	80	40	55.8	OO	—	O	—	—	Yes	No
	Watarai	EIA	scoping	50	20	55.9	O	OO	—	—	—	Yes	No
EIA Act 10 cases	Kitahiyama	EIA	scoping	120	60	104.0	OO	O	—	—	O	No	No
	Ogawara	EIA	scoping	36	12	6.0	O	—	—	—	—	No	No
	Takamori	EIA	scoping	25	11	47.0	—	—	—	—	—	No	No
	Sumida	EIA	scoping	165	55	72.0	OO	—	—	—	—	No	No
	Ishinomaki	EIA	scoping	20	8	NA	OO	—	O	NA	—	No	No
	Echizen	EIA	scoping	21	9	5.2	OO	O	O	—	—	No	No
	Chuki	EIA	scoping	90	30	29.8	OO	—	—	—	—	No	No
	Makigawa	EIA	scoping	25	10	10.7	—	—	—	—	—	No	No
	Uku	EIA	scoping	100	50	12.6	—	O	—	—	O	No	No
	Hirado	EIA	scoping	38	19	5.5	—	OO	—	—	—	No	No
NEDO EIA 4 cases	Awaji	operating	final EIS	38	15	9.7	O	O	O	—	—	No	No
	Hyogo	canceled	draft EIS	30	12	12.5	—	O	—	—	—	No	No
	Nyugasa	canceled	scoping	30	30	10.0	OO	OO	—	—	—	No	No
	Minenohara	canceled	scoping	27	16	6.0	OO	—	—	—	—	No	Yes[c]

[a] Evaluated by using GIS software; "OO" means the project is located in the designated areas (over 5 turbines), "O" in the area (1-5 turbines), "-" outside the area.

[b] Evaluated by the EIA document: "O" means the project is located in the designated area; "-" outside the area.

[c] Slope stability was selected in response to public comments or administrative advice.

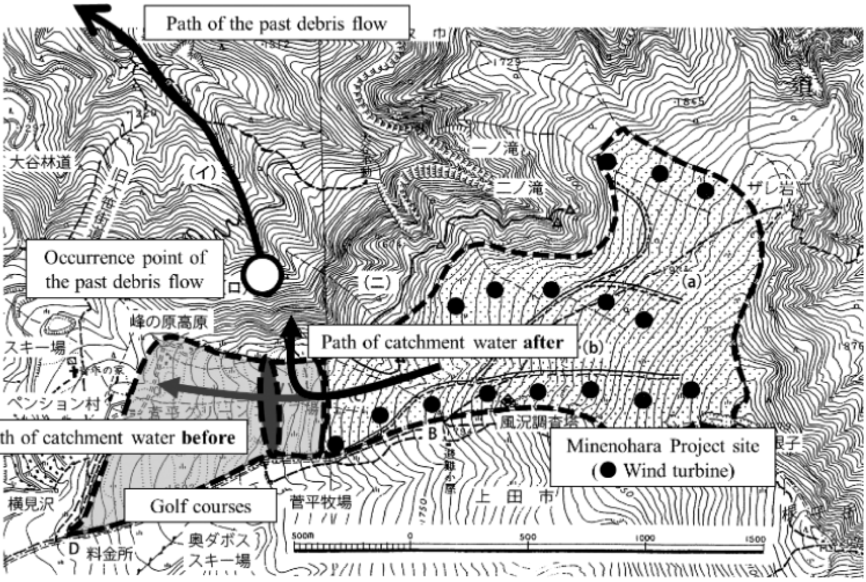

Fig. 4. Map of the Minenohara wind farm project site and surrounding area (Yamaguchi, 2008).

experience, local residents expressed the concern that the land development on top of the slope would increase the hazard of sediment-related disaster. Although the project site seemed to have potential hazard of sediment-related disaster, the site was not in any legal hazard zones, due to reasons mentioned in the section "Legal measures for sediment-related disaster management". On the other hand, the project site was located in a non-legal hazard zone, especially designated as "a river or mountainous stream recognized as a place where debris flow might occurs" (see Fig. 5). Moreover, in the Awaji wind farm project mentioned in the section "Features of wind farm projects and hazard management of sediment-related disasters", the occurrence of the past landslide inside the developed land, did not correspond to a legal hazard zone, but did correspond to non-legal hazard zones, as in the Minenohara case.

The above plot indicates the potential hazards in non-legal hazard zones. It is important to have adequate hazard management of sediment-related disasters and sufficient communication among stakeholders, especially with the local population. The EIA could be a useful tool for both hazard management and communication. However, in practice, most developers tend to underplay negative information about non-legally binding designated areas and past disaster history, therefore, most EISs have not included significant information about hazard management of sediment-related disasters.

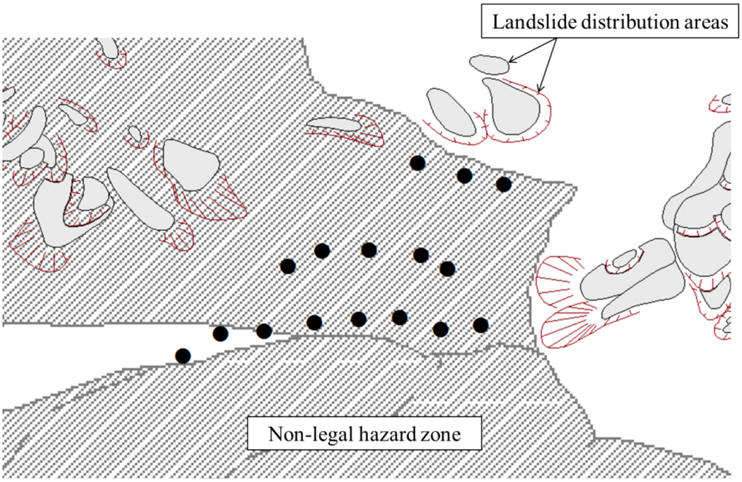

Fig. 5. The relation between the location of the turbines and non-regulatory designated areas.

Mitigation measures for hazard management as a result of the EIA

Table 2 shows the area of land change of the examined cases as an indicator of impact on slope stability. The maximum is 104 ha and the average is 26 ha, which is far larger than the area of an average thermal power plant (3.3ha, 150 MW-class) or geothermal power plant (9ha) (MOE, 2011a). Furthermore, the area of land use change has a statistically-significant correlation with the project scale and number of turbines.[3]

Based on the descriptions of the EISs, re-vegetation programs would be implemented in half of the area of land change after each development, as a mitigation measure for slope stabilization. Re-vegetation is commonly used in hazard management for projects other than wind farms as well, because of the attractiveness as a low-cost alternative (Schwab, 1994). While many studies, such as Sidle *et al.* (1985) and Merifield (1992), mentioned effectiveness in terms of slope stabilization as well as aesthetic benefits, re-vegetation is often difficult and its outcome uncertain. In the Kasatori wind farm project shown in Table 2, re-vegetation has not been successful in the 5 years since the program was implemented, and some of the developed land collapsed due to torrential rains. Moreover, in the Awaji wind farm project shown in Fig. 2 and Table 2, a landslide disaster occurred from the developed land 5 years after the start of operations. These facts suggest that long-term monitoring should be one of the roles of EIA, in

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[3] Project scale and area of land change ($r = 0.65$, $p = 0.0018$), No. of turbine and area of land change ($r = 0.63$, $p = 0.0028$).

order to establish actual slope stabilization by the re-vegetation program. Although prefectural EIA ordinances and the EIA Act oblige developers to carry out monitoring after construction, monitoring of slope stability would not be carried out if slope stability was not selected as a result of the scoping.

In addition to the uncertainty above, as Bell *et al.* (1989) pointed out, re-vegetation is not very effective in addressing slope stability in some unstable sites. For such unstable site, more focus needs to be placed on surface or subsurface drainage to remove excess water form critical portions of the site, and structural control measures are needed to ensure slope stability (Sidle and Brown, 1992). In other types of projects, construction of reservoirs or retaining walls have been implemented as mitigation measures in the EIA processes, in addition to re-vegetation programs. Such measures should also be considered in wind power developments.

The results of scoping and advice of authorities and municipal heads on scoping

In the scoping process of the Japanese EIA system, once developers select environmental items and publish them in scoping documents with accompanying explanations, authorities and the public can give their advice and opinions. Based on official and public comments, the developers determine the final environmental items to be considered. In accordance with the process, Table 2 presents (1) whether slope stability was selected as a candidate item or not, and (2) whether slope stability was selected for final consideration.

The table shows that whether slope stability was selected as a candidate item is simply based on the type of the EIA system, regardless of the positional relation with the hazardous areas for sediment-related disasters. We also note that there were only two cases that added slope stability as an environmental item in response to the advice and comments, although in 6 of 10 cases for which the detailed contents of the feedback were available, the developers were asked for additional consideration of slope stability. According to the description of the EISs, the reason for why developers did not add slope stability in the 4 cases was that the potential impact on slope stability could be mitigated adequately by carrying out mitigation measures, such as a re-vegetation program. However, re-vegetation involves difficulty and uncertainty, as mentioned in the section "Mitigation measures for hazard management as a result of the EIA".

One of the two cases with added slope stability was the Minenohara wind farm project, which faced huge opposition by local residents and environmental groups. In another case, the developer conceded that slope collapse might be triggered by the construction of a power transmission facility. However, the former project was canceled due to the opposition before the survey was carried out, and the latter avoided the potential risk fundamentally by modifying the route of the transmission line. Therefore, impact assessment for hazard management was not implemented in either case.

It follows that even if a project has the potential hazard of sediment-related disaster in terms of the siting, in practice, slope stability is rarely selected as a scoping result. Partly this is because slope stability has not been prescribed as a major environmental item in most Japanese EIA systems. Furthermore, due to a lack of accumulated experiences and practices of hazard management in EIA, it seems that developers tended not to take it into consideration.

Conclusions

This paper clarifies the potential role and challenges of EIA as a hazard management tool for sediment-related disaster. Through surveys of the regulatory framework and analyses of case studies of wind farm projects, we obtain the following conclusions.

One of the important roles of the EIA is to identify potential hazards of sediment-related disasters that might be triggered by new development, because among 109 operating wind farm projects nationwide, over half are located in non-legal binding hazardous areas, and 94% are located in forests. Clearly, a large number of the projects involve sediment-related disaster hazards. Nevertheless, few cases have evaluated this hazard in the EIA processes thus far.

As for the area of land use change, which could be an impact indicator for hazard management, the average area of land change caused by the developments is 26 ha, which is greater than the area of an average thermal power plant (3.3 ha, 15 MW-class). Although on average re-vegetation would be carried out in half of the area, there have been cases in which the re-vegetation had not been successful in 5 years after the implementation. Consequently, long-term monitoring is needed to secure actual re-vegetation, as one of the roles of the EIA. Moreover, research is needed into methods to select an adequate type of the mitigation measures.

Since projects that have experienced sediment-related disasters in the past are located in non-legally binding hazardous areas for sediment-related disasters, this suggests a need to improve the EIA system to be able to integrate the various types of hazard information, including non-legally binding hazardous areas and local knowledge, in order to carry out robust hazard management.

In the future, geographic information relating to the hazards should be incorporated into early decision making. For instance, utilization of such information in the SEA process would help avoid wind power developments in areas potentially subject to sediment-related disaster. Moreover, the integrated approach of hazard management through EIA/SEA could make hazard evaluation more transparent for local residents.

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