CHAPTER 14

LANDSCAPE RESTORATION

A case practice of Kushiro Mire, Hokkaido

F. NAKAMURA, Y.S. AHN

Department of Forest Science, Hokkaido University, Sapporo, Japan

Abstract. Kushiro Mire, a marsh located near the mouth of the Kushiro River, is suffering from the cumulative effects of pollution caused by land-use development in the watershed. A high wash load is of particular concern and accounts for approximately 95% of the total suspended sediment load that flows into the marsh. Researches have found that turbid water floods the margins of the marsh; this is due to riverbed aggregation in a channelized stream reach that provides agricultural drainage. An analysis of Cs-137 concentrations determined that the rate of fine sediment deposition was approximately three to eight times higher in the channelized reach than in a reach of the natural river. This rapid sediment deposition has lowered groundwater levels and enriched the nutrient content of the marsh soil. Consequently, woody species are rapidly invading the margins of the marsh, causing concern about a vegetation shift from reed-dominated marsh to woodland. To address the physical and biological changes that are taking place in Kushiro Mire, various restoration projects have been planned and are being implemented under the Kushiro Mire Conservation Plan. Three examples of projects in the Kushiro Mire Conservation Plan are a restoration of the straightened river channel to meandering course, a forest restoration near Takkobu Lake, and a wetland restoration of a crane habitat. To develop pasture fields the natural meandering rivers in the Kushiro Mire have been channelized from the marginal areas of the marsh. The channelization projects lost pristine river-floodplain landscapes and inhibiting wildlife species. In the Kayanuma area, a river section extending about 2 km of Kushiro River is planned to restore from a straightened channel to a original meandering stream and floodplains. Monitoring and scientific evaluation will be conducted before and after the project and compared with downstream reference reaches. Fine sediments and nutrients have been accumulating in Takkobu Lake because of agricultural development and soil erosion in the uplands. The number of aquatic species in the lake has also been decreasing. An environmental assessment was undertaken in collaboration with "Trust Sarun", a non-profit organization, and sites were selected for conservation and restoration work. A larch forest was purchased to prevent it from being clear-cut and thus increasing sediment loading in the lake. The forest will be restored to its natural state. In addition, the Ministry of Environment in the Hirosato District acquired a wetland restoration site that was originally designated as an "ordinary area," i.e., the least regulated area of a national park. The restoration site is an abandoned agricultural field with an old drainage system developed in the 1960s; it is an important breeding habitat for red-crowed cranes (*Grus japonesis*). Based on a preliminary investigation, and under careful supervision to avoid disturbing the cranes, soil excavation and seeding experiments were undertaken and biogeochemical processes have been monitored.

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1. INTRODUCTION

Many of ongoing and planned restoration projects in Japan have addressed disturbed rivers, wetlands, and lakes. The degradation of these aquatic ecosystems often involves multiple causes occurring at larger spatial scales than the restoration sites, which may limit the ability or effectiveness of local habitat improvement. Watershed perspective is then assumed for such ecosystem restoration. The extensively managed landscape of Japan is however complex in ecological and institutional structures. With a lack of coordination among regulatory agencies typical in the Japanese government, it is practically impossible to apply a comprehensive approach at a whole watershed scale. Although this institutional limitation constrains specific restoration actions to be localized at sites, important is to plan and design the actions within the watershed's context.

When addressing watershed degradation, a key issue is material cycling based upon the knowledge of watershed hydrology and geomorphology. This is because much of the ecological degradation in aquatic systems is the result of altered hydrology and material cycling. The Kushiro Mire is the largest wetland complex in Japan, spanning an area of 190 km^2. The wetland's watershed encompasses 2,500 km^2, 23 times as large as the wetland area.

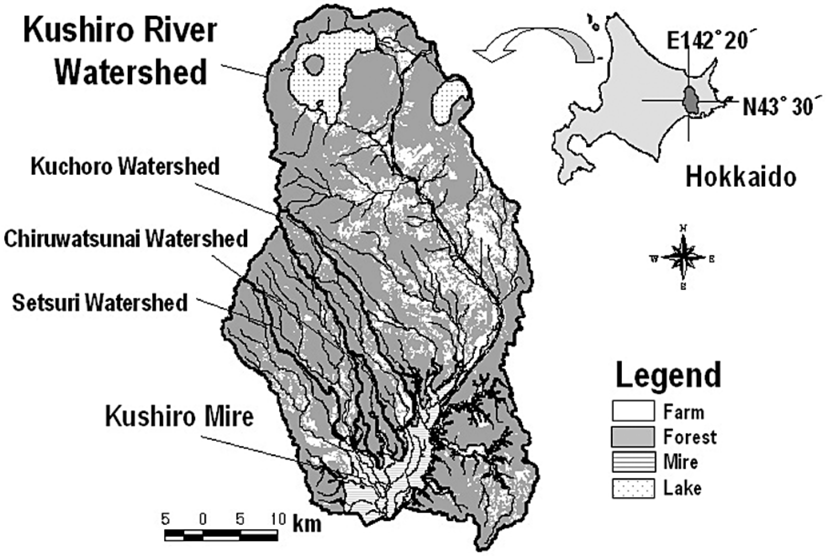

Figure 1. The location of the Kushiro Mire and land use of the Kushiro River Watershed.

The wetland has drawn further attention since 1980, when it was registered under "the Convention on Wetlands of International Importance Especially as Waterfowl Habitat", commonly referred to as the Ramsar Convention. Located in the downstream end of the watershed, the Kushiro Mire has been subject to cumulative influences of upstream landuse (Figure 1). In this paper, we introduce the ecological status of the Kushiro Mire and its related watershed-scale degradation, describing our conceptual approaches to ecological restoration.

Before specifically discussing restoration activities in Kushiro, one should have a clear view of what is 'restoration'. Literally, it is a process of returning. Scientifically, it is defined as the act of returning an ecosystem that has physical, biological, and chemical characteristics in its pre-disturbance conditions (Lake, 2001; Jungwirth et al., 2002). In this definition restoration may imply the reestablishment of disturbance regimes native to the restoration site in which biological and physical processes can promote heterogeneous landscape and species diversity. However, where overwhelming human perturbations have caused irreversible degradation, 'rehabilitation' can be applied by improving structural and functional attributes to facilitate an occurrence of self-sustainable ecosystem (Wissmar and Beschta, 1998).

In both cases, we emphasize that a highest priority is 'passive restoration' (Wissmar and Beschta, 1998). Passive restoration attempts removing human impacts preventing natural recovery of a damaged ecosystem and then let nature develop its own self-sustainable system. This is 'passive' because restoration practitioners must wait for a sufficient period of time to allow for the natural recovery processes. Most common misunderstanding is that active manipulations using construction equipments constitute restoration projects. This approach is referred to as 'active restoration', which should represent a last restoration alternative with a lowest priority. Passive restoration, on the contrary, eliminates limiting factors, such as bank revetments, drainage ditches, and fertilizer application, initiating natural recovery towards most stable ecosystems of rivers and wetlands. Humans only assist nature in returning to its pre-disturbance conditions. After implementing passive restoration, monitoring and observation of the natural recovery process should be conducted. If recovery trends are not ascertained in a self-sustaining manner, further actions including active restoration may be necessary. Thus, the principle underlying any restoration project should be 'passive', working based on the careful observation of ecosystem responses. Restoration should not be the creation of a new ecosystem that previously did not exist, and otherwise the restoration may exacerbate the extent of current degradation.

In Europe a river restoration project aiming for "Space for rivers" has been implemented. Dykes and revetments were removed to restore its historical floodplain. This is an example of passive restoration, assuming that the river will regain its pre-disturbance conditions in natural patterns of hydrological and geomorphic processes across the floodplain. In addition, this restoration also addresses the effects of restoration on flood control and water resource management (Hansen, 2003; Geilen, 2003). As with in Europe, river restoration always involves the issues of flood control and water resource management in Japan. It is necessary to balance between restoration and public interests in these issues.

2. THE HISTORICAL CHANGES OF THE KUSHIRO MIRE

In the Kushiro Mire, wetland habitats have been degraded or lost by various human activities. This section summarizes the existing reports to describe watershed-scale landuse impacts on the wetland habitats.

2.1 Alterations of the Kushiro Mire associated with cumulative watershed-scale impacts

A Landsat satellite image, taken on May 11th in 1992, is shown in Figure 2. Three black areas are lakes (Shirarutoro, Touro, and Takkobu). There are similar dark spots along the Kuchoro and Setsuri River, tributary to the Kushiro River. These dark color areas indicate a condition of high water tables (e.g., a floodplain), clearly shown during a snowmelt flooding. The area of inundation along the Kuchoro River is particularly large and dark in color.

In extreme rainfall events, many of the Kushiro River tributaries become turbid in dark brown color. In the Kuchoro River, suspended sediment delivery in one flood event (from September 27th to October 1st in 1995; roughly 35 mm rainfall/hour) was estimated to be 1,120 tons (Nakamura et al., 2004a). The annual production of suspended sediment was 7,400 tons, and 95% of the yield was fine suspended sediment of which diameter was less than 0.1 mm. This type of fine suspended sediment load is called washload, which is naturally produced at mountain slopes and in floodplains and partly delivered into the ocean. In a meandering river, washload deposits on point-bars to form natural levees along the river course. It may however cause a serious problem in a channelized river that has high gradients. At the point where the straightened channel intersects with a downstream meandering reach, flood power is greatly reduced, causing fine sediment deposition there to cause riverbed aggradation (Emerson, 1971; Brookes, 1988). In the Kuchoro River, riverbed aggradation exceeding by about 2 m its original riverbed occurred at an entry point of the straightened channel into the wetland. This aggradation decreased the cross section of the river by half, when compared to that immediately after channelization. Overbank flooding with fine suspended sediment has likely occurred at the entry point in high flow events (Nakamura et al., 1997).

Thus, the dark color areas in Figure 2 have been confirmed as flooding of turbid water with washload. An algorithm to estimate the degree of turbidity in the wetland was developed using water turbidity index (WTI) determined on Landsat satellite images and field verification of WTI (Kameyama et al., 2001). Using this algorithm, wetland alterations associated with washload were evaluated on a spatial and temporal scale; the area of turbid water has been expanding since 1980. The locations of turbid water flooding have also been changing in these years (Nakamura et al., 2004a).

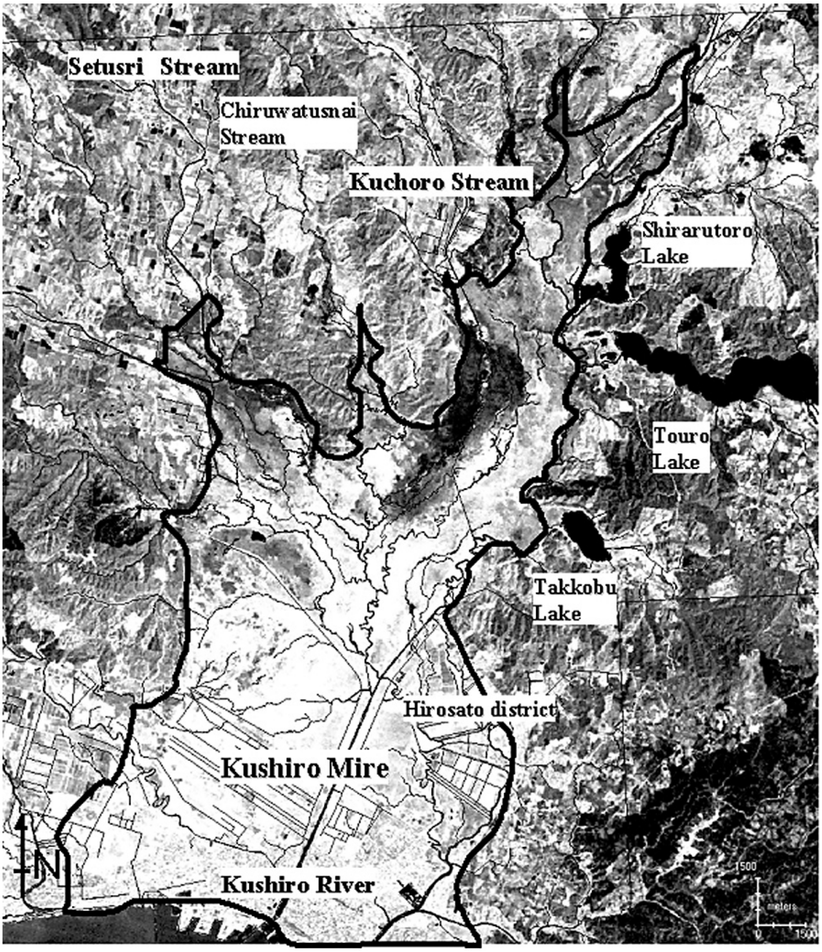

Figure 2. A Landsat Thematic Mapper image of the Kushiro Mire, taken on May 11th, 1992. A solid line declineates the Kushiro Mire. Areas in dark gray or black color represent lakes and the wetlands of which water tables are near their surface.

To examine a relationship between watershed landuse and sedimentation rates in the wetland, radioactive fallout (Cesium-137) has been used (Mizugaki and Nakamura, 1999). Cesium-137 was released into the atmosphere during the period of frequent nuclear tests. The peak fallout in Japan occurred in 1963, roughly coinciding with the onset of growing agricultural landuse development. Cesium-137 is insoluble in water and tends to be adsorbed particularly onto fine sediment. Thus, by determining the depth of Cesium-137 peak fallout in wetland sediment, sedimentation rate during the agricultural development can effectively be estimated. Analyses of sediment core samples indicated that fine suspended sediment has deposited about 200 cm near the Kuchoro River channel. The deposition was 160 and 100 cm at the distances of approximately 30 and 50 m from the channel, respectively. Contrastingly, sediment deposition was 40cm near the Chiruwatsunai River channel, of which upstream regions are relatively undeveloped. During the agricultural development, fine sediment deposition in the Kuchoro River has progressed at the rates of three to eight times as great as those in the Chiruwatsunai River and other regions (DeLaune et al., 1978; Johnston et al., 1984). This abnormal sedimentation rate in the Kuchoro River supports the overbank flooding containing washload detected in the satellite image analyses. Thus, upstream agricultural development in the last half-century and stream channelization have likely changed the sedimentation in the wetland.

Plant responses to sediment deposition differ in species and at different life stages including germination, seedling establishment and growth (Jurik et al., 1994; Wang et al., 1994; Smith et al., 1995). In the Kushiro Mire hydrological alteration and nutrient-rich turbid water in the wetland due to watershed agricultural development may have resulted in vegetation change. Nakamura et al. (2002) examined forest stands and wetland soils in 15 to 17 quadrats, comparing between two streams with developed watersheds (the Kuchoro River and Setsuri River) and a stream with its undeveloped watershed (the Chiruwatsunai River). The result of a canonical correspondence analysis (CCA) indicated that water table variation, mean particle size, and electric conductivity were greater in the disturbed watersheds than undisturbed one. Water tables also tended to be lower in disturbed watersheds with *Salix* spp. as a dominant tree species. In contrast, soil moisture and organic material contents and water tables were greater in the undisturbed watershed (Chiruwatsunai). A dominant tree species was the Japanese alder (*Alnus japonica* Steud).

Decreased reach length in a straightened stream channel usually results in magnified flood peaks with short rising rims, thereby increasing water table variations in riparian wetlands (Nakamura et al., 2002). In the Kushiro Mire increased flood power and turbid water flooding further enhanced coarse sediment deposition in the wetland, lowering ground water tables there and recharging ion rich ground water. Terrestrialization and nutrient enrichment favor the growth of *Salix* stands which rarely occurred in the wetland. Contrastingly, wetland soils with slow decomposition rates are distributed extensively in the Chiruwatsunai River because of its higher water levels. In these soils with excessive moisture contents, alder trees appear to grow in the place of *Salix*.

In downstream portions of the Kushiro Mire, alder forest expansion has also been recognized in native fens dominated by a reed-sedge community. A recent field experiment found that wetland hydrology was an important parameter to explain this alder expansion (Nakamura, 2003). High water tables manipulated by a revetment appear to have affected the survival of alder trees. A detailed investigation implicated that alder trees were killed at where water table reached 80 cm from the bottom of peat accumulation. However, this threshold water table might be deeper if the peat mats were floating (Figure 3).

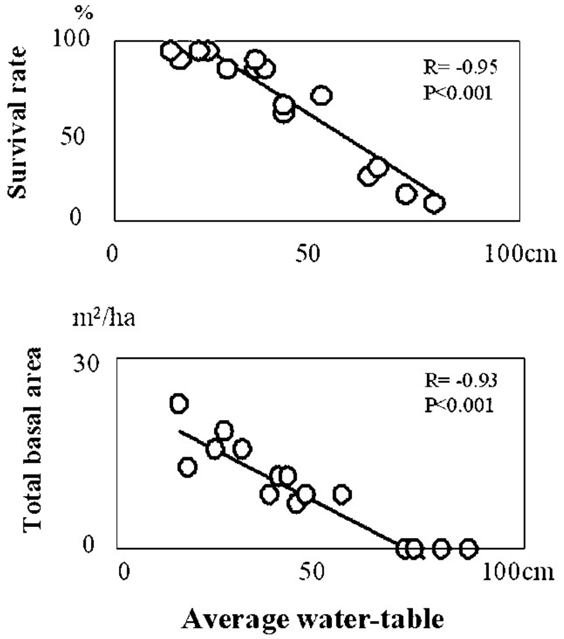

Figure 3. Survival and the total basal area of Japanese alders in relation to increasing water tables. Water tables above the bottom of peat layers were averaged for the period between September and November in 1998. Survival rates were quantified based on the numbers of trees that have no winter buds on their stems (after Nakamura et al., 2003).

In flood events, stream water accompanying washload can be delivered to backwater swamps behind natural levees. Yachidamo (*Fraxinus mandshurica* var. *japonica* Maxim.) and Japanese elm (*Ulmus davidiana* var. *japonica* Nakai) often grow on the levees, and alders are common in the backwater swamps. However, as with the Kuchoro River and Setsuri River, wetlands in a developed watershed receive a large amount of sediment loading through extensive flooding of turbid water. Fine sediment deposition beyond natural processes can occur. Habitat conditions in such wetlands are likely to be altered, causing vegetation changes there. In the Kushiro Mire, alder forests have invaded into reed-sedge communities even in interior parts of the wetland. Where rapid sedimentation accelerates terrestrialization, the end-point of vegetation shift might be a *Salix* dominant forest.

Figure 4 presents tree distribution in the Kushiro Mire, which was constructed in the development of an environmental information map described later in this paper.

In the construction, distortion in about 200 aerial photographs was first removed. Using a computer data processing with stereovision, trees with canopies greater than 1m diameters were extracted and shown against a Landsat image. Forest expansion is clearly visible along the edges of the wetlands, particularly at downstream ends of the Kuchoro River and Setsuri River.

Rare species including the Japanese crane (*Grus japonensis*) and Siberian salamander (*Salamandrella keyserlingii*) often nest or lay eggs in reed-sedge dominated marshes. It has been concerned that the rapid forest expansion due to human disturbances reduces their breeding habitats.

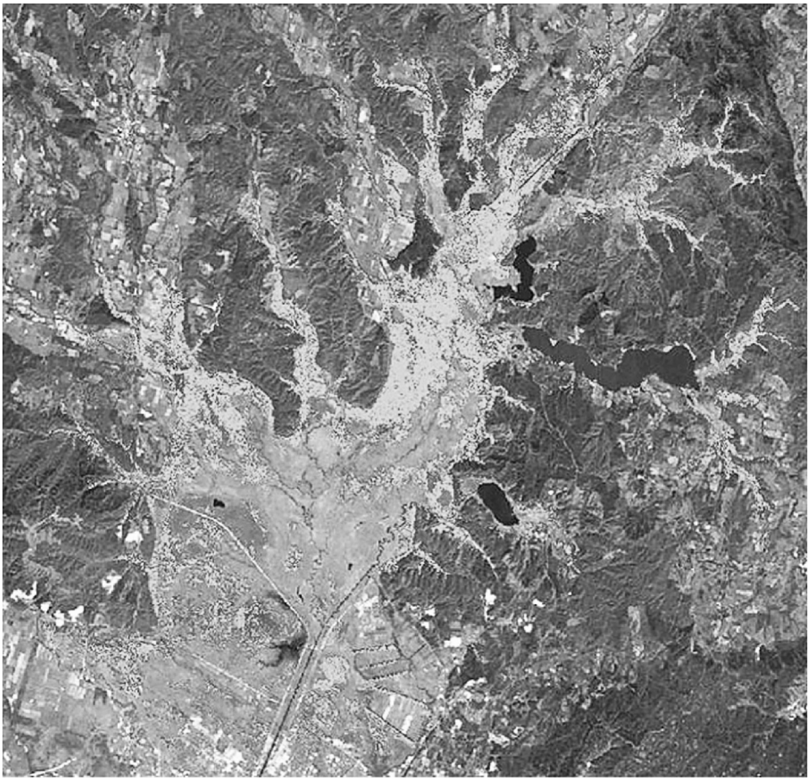

Figure 4. The distribution of tree stands in and around the Kushiro Mire. After removing distortion in about 200 photographs, computer data processing and verification using stereovision extracted trees with canopies greater than 1m diameters. The data is shown against a Landsat image.

2.2 The historical changes of lake environment

Eastern three lakes (the Takkobu Lake, Sirarutoro Lake, and Touro Lake) are a small lake into the Kushiro River, located in the eastern margin of the Kushiro Mire

(Figure 2). It was formed about 3,000 years ago, when the sea level descended because of sea regression. The main stream flows into three lakes, whereas the Kushiro River drains into three lakes under high flow condition because the elevation of the three lakes and the Kushiro River is almost equal. Therefore, when the water level of the Kushiro River rises, a part of water discharge of the Kushiro River flows into the three lakes (Hayashibara et al., 2003; Hokkaido Institute of Environmental Sciences, 2005). Thus three lakes are influenced by inflows from both its catchments and the Kushiro River drainage.

Recent and current studies have consistently indicated that water quality and plant community structures in the three lakes are rapidly being altered. These three lakes tend to be in eutrophic conditions; lake phosphorous concentrations are elevating in all lakes. In the Takkobu Lake and Touro Lake, high total nitrogen concentrations (around 1.2 mg/L) and algae bloom in a summer have been observed (Takamura et al. 2003). Furthermore, chlorophyll *a* concentrations are increasing while species numbers of aquatic macrophytes (floating-attached, submersed, and floating-unattached plants) are clearly declining (Kadono et al., 1992). In addition, abundance of lake balls (*Aegagropila linnaei* Kutzing) and species numbers of aquatic insects has declined (Kimura and Ubukata, unpublished data).

To compare the effects of watershed landuse on water quality, we plotted relationships of total nitrogen, total phosphorus and population for the three lakes (Takamura et al., 2003) against data produced by the International Lake Environmental Committee (2001) (Figure 5). The larger populations, the higher nutrient concentrations. However, nutrient concentrations in the three lakes have relatively higher value despite of the small population size.

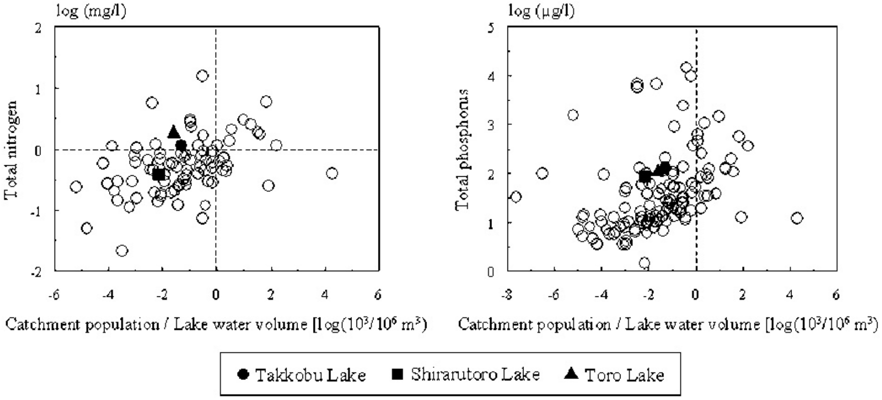

Figure 5. Relationships between population and total nitrogen, total phosphorus in catchments. The nutrient concentrations of the three lakes published by Takamura et al. (2003) were added to the relationships derived from the International Lake Environmental Committee (2001).

It has already been suspected that wastewater from a campground and households were the sources of water quality degradation. Elevated concentrations of fine suspended sediment and nutrients may have reduced water transparency, causing the declining numbers of aquatic plant species. Not only these point sources, but also watershed-scale degradation of hydrology and water quality may be another factors that cause the alteration of lake ecosystems.

In the Takkobu area, various ecosystems including wetlands, lakes, rivers, and upslope, occur together in a small watershed. Human influence started with deforestation in the Takkobu area began in the 1880s and intensified after 1898. Moreover, agricultural development, construction of drainage networks and roads were undertaken after 1940s.

The sedimentation associated with flood event and landuse development is reflected in changes in the physical characters of lake sediment. For example, agricultural activity, deforestation, and road construction can lead to an increase in inorganic sediment (Gurtz et al., 1980; Kreutzweiser and Capell, 2001) and coarse sediment inflow (Walling et al., 1998; Owens et al., 1999), and these can be identified from changes in the physical characters in lake core sediment samples (Kim and Rejmánková, 2002). The changes in the physical characters were defined as a “signal”, which is a valuable time marker (Page et al., 1994; Walling et al., 2003). Lake Takkobu core samples contained two tephra layers and the signal of canal construction in 1898 (Ahn et al., in press). From the refractive indices of dehydrated glasses, the lower tephra layer was identified as Ko-c2 (1694) and the upper tephra layer as Ta-a (1739). A clear peak in the Cesium-137 concentration was detected at all the sampling points. The sediment yield averaged over the last 300 years for Takkobu Lake was reconstructed for four periods using the signal, tephra, and Cesium-137 as marker layers (Figure 6).

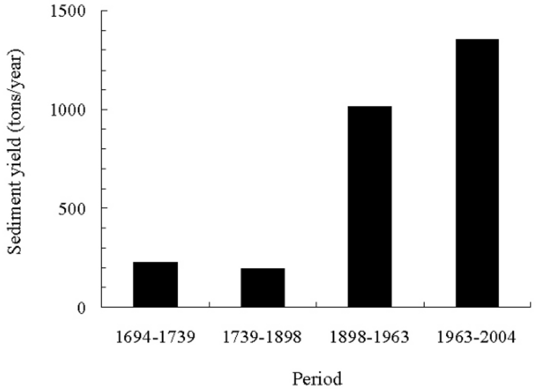

Figure 6. The average sediment yields reconstructed over the last 300 years for Takkobu Lake, using the signal, tephra, and Cesium-137 as marker layers.

The sedimentation rates from 1694–1739 and 1739–1898 reflect the natural sedimentation rates, and those from 1898–1963 and 1963–2004 indicate the rates after land use development. The period of 1898–1963 is characterized by deforestation and canal construction as well as initial agricultural development, and during the period after 1963 deforestation, ditch and road construction, and intensified agricultural development have continued. The average sediment yield under natural erosion condition for the first two periods was 226 tons/year in 1694–1739 and 196 tons/year in 1739–1898. The development of the Takkobu watershed started in 1880s with partial deforestation and channelization, leading to an increased sedimentation yield 1,016 tons/year in 1898–1963. Continuous deforestation, channelization works, road construction, as well as agricultural development caused a further increase up to 1,354 tons/year in 1963–2004. Compared to the average natural sedimentation yield of 206 tons/year until 1898, initial watershed development accelerated lake sedimentation, indicated by the 5-fold sediment yield. With increasing agricultural development since 1960s, sedimentation yields were highest for 1963–2004, 7-fold compared to natural conditions (Ahn et al., in press).

Progressive development, timber harvesting, including agricultural conversion of wetlands and stream channelization, has directly influenced the wetlands. Concerning this watershed degradation in the Takkobu area, a local environmental conservation group and non-governmental organization, NPO Trust Sarun Kushiro, have been working on land acquisition in upland forests for restoration of native deciduous forests and ultimate protection of the lake ecosystem.

2.3 Declines of wetland habitat due to landuse development (particularly, in southern areas of the Kushiro Mire)

In August 1920 a massive flood caused a great deal of damage on the Kushiro City. This experience initiated a sequence of stream channel manipulation for flood control followed by agricultural development. The Akan River, which formerly drained into the Kushiro River, was disconnected, and in 1921 the Kushiro River was partly channelized. Peat lands along the Kushiro River, which were previously covered by reed (*Phragmites communis* Trin.) and alders, were drained by agricultural conversion.

After establishing the Hokkaido Regional Development Bureau (HRDB) in 1951, the government began agricultural development in the Kushiro Mire as “The 1st five-year program for Hokkaido Integrated Development”. HRDB reported that 52 km^2 of the Kushiro Mire was converted for various purposes including agriculture and housing until 1996. This landuse conversion concentrated in southern portions of the wetland, where the Kushiro City was located. Many of the farmlands were later abandoned.

The portion of the Kushiro Mire in Hirosato (260 ha) consists of previously abandoned farmlands, in which the Ministry of the Environment (MOE) has been conducting wetland restoration since 2002 as described later in this paper. Drainage ditches are still present in the old farmlands developed in late 1960s. As shown in Figure 4, alder forests have been invading into the wetland. Although we know this forest expansion is not associated with fine sediment loading, it is still unknown whether the expansion is anthropogenic (revetment construction and agricultural land use) or natural succession. There are many unknown factors regarding to the recruitment habitat of the Japanese alder. Propagation by means of seedling establishment has not been observed in field survey; most of the trees continue vegetative growth by sprouting. In addition, because the wetland in Hirosato has no inflows from nearby streams, disconnected by revetments, sediment loading from upstream is unlikely to occur.

3. CONSERVATION MEASURES AND THE DEVELOPMENT OF INFORMATION DISSEMINATION STRATEGY

To address these wetland and watershed degradation, HRDB established "The Committee for Conservation of the River Environment in Kushiro Mire (hereinafter, referred to as the Committee)" in 1999, and proposed 12 measures to conserve the river and wetland ecosystems in the Kushiro Mire in March 2001. The details are available in the Proposal for Conservation of the River Environment in Kushiro Mire. Subsequently, MOE has developed a restoration project, the Kushiro Ecosystem Restoration Project (hereinafter, the Project).

Before implementing any restoration, it is important to evaluate current conditions of existing ecosystems (Figure 7). This preliminary assessment identifies degraded ecosystems to be restored and remaining intact ones to be preserved, providing a clear criterion in site selection. Intact ecosystems serve as a reference for understanding the processes and relationships between biotic and physical factors of naturally self-sustaining ecosystems. This understanding is essential for determining causes of the degradation and restoration strategies to allow for natural recovery to occur. For spatial analyses, geographic information systems (GIS) are effective to integrate a variety of data based on aerial photographs, topographic maps, satellite images, and land use information. Existing governmental reports and literature also provide valuable sources for the assessment.

If any symptoms that indicate the deterioration of objective ecosystems could be found through the above screening process, we should examine more intensively to identify the controlling or regulating variables in the fields (Figure 7). Once we clarify these key variables deteriorating the ecosystems, we may proceed to set the target of the restoration project. The target ecosystem should be set with an agreement of local public and be feasible to be accomplished by restoration project, considering economical and social constraints. Reference site (intact site) or pictures prior to human disturbance will be instructive information to set the target. So-called 'adaptive management', that is using the experiment as management strategy, will be important in this stage, because we cannot predict perfectly the response of restored ecosystems (Figure 7). This process is not just a trial-and-error procedure; rather it should be the validation procedure with a clear hypothesis. If the hypothesis is validated by the experimental results, we can extend the techniques over a broad restoration area.

A preliminary assessment in the Project identified ecosystems for potential preservation and restoration in the Kushiro Mire: 1) a largest fen in Japan; 2) raised bogs bisected by the Kushiro River revetment; 3) meandering reaches in which a largest freshwater fish species, the Sakhalin taimen (*Hucho perryi*), survives; 4) wetland habitats for the Siberian salamander and Japanese crane; 5) spring habitats at the breaks of slopes for the Japanese crayfish (*Cambaroides japonicus*); 6) the eastern three lakes supporting lake ball populations; 7) native forests remained in the upstream watersheds.

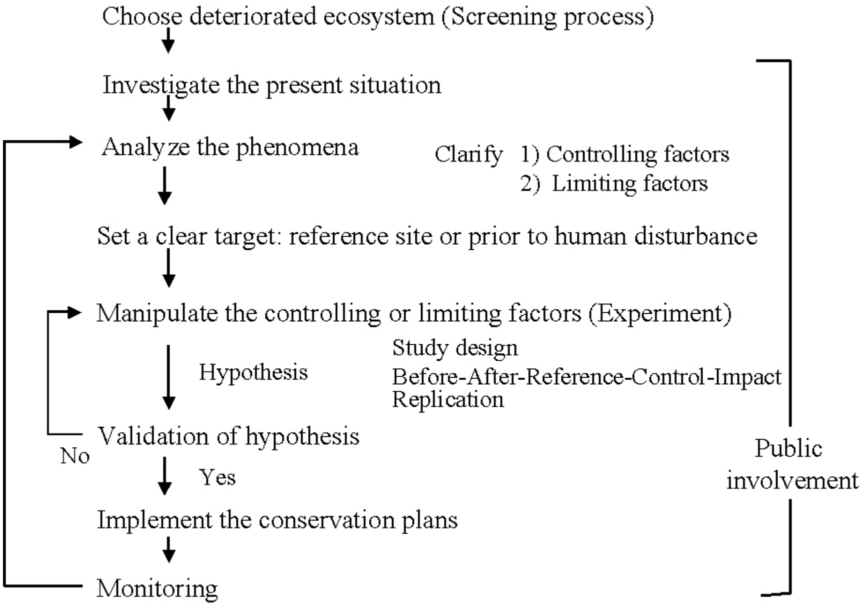

Figure 7. General flow of restoration projects in Kushiro Mire.

Currently, although various scientists and agencies study the Kushiro Mire, much of their data and results are independently documented and not open to public. The Project has started a GIS database project for information dissemination, integrating this isolated information as an environmental information map. This map is temporarily available through the Internet (Ministry of the Environment, 2005). The goal of this GIS database project is to construct an environmental information map (hereinafter, the Map) such that 1) integrates spatial-scale information including topography, vegetation, and wildlife distribution, which allows to simultaneously identify these spatial attributes for a location of one's interest; 2) enables temporal-scale analyses by which digitizing existing topographic maps and aerial photographs and identifying land use activities and vegetation; 3) is available to the public after excluding confidential data, such as the locations of rare species habitats or personal information. The Map also promotes information sharing through an interactive function between the web site and public; users can manipulate and analyse GIS data on the web and both download and upload GIS data files. The Map is so to speak an information infrastructure to support the Project based upon public consensus and scientific data.

4. THE PRINCIPLES OF PRESERVATION AND RESTORATION AND SPECIFIC MEASURES

4.1 Ameliorating watershed-scale human impacts

Watershed-scale pollution management in Hokkaido is normally conducted by the HRDB Flood Control Division. Reporting its specific strategies and measures, Nakamura (2003) has discussed the principles of construction engineering, sediment hydraulics, and geomorphology, including two-dimensional flood simulation. This section of the present paper provides only a brief summary of these principles, which are related to the issues in the Kushiro Mire.

It is noteworthy that the Committee developed numerical objectives for watershed pollution control, and presented specific measures to achieve these objectives. The long-term goal is to recover the conditions of the Kushiro Mire ecosystem that existed at the time of the Ramsar registration in 1980, when its watershed remained relatively undisturbed before extensive land use development (Nakamura et al., 2003). Furthermore, a more specific goal for the next 20 to 30 years is the reduction of watershed pollution loadings to the levels of 20 years ago, in order to protect wetland conditions existed in 2000 from further degradation. To achieve these goals, pollution loads were estimated using existing data and simulation models. For example, annual sediment load was 800 m^3 in 1980 and is currently 1,400 m^3. A specific objective for controlling sediment load was then determined as the reduction of the current sediment yield by 40 %. Likewise, 20 % reduction is the target value for a total nitrogen yield.

Some of the committee members asserted that agricultural development already advanced in 1980, arguing to set the target values at those in older years (e.g., 1970). However, considering the feasibility of restoration goals, all committee members agreed with the above goals and target values.

Proposed strategies to achieve the target values for watershed pollution controls include the provision of filtration grounds and ponds along stream channels and at the ends of drainages, and forest restoration in water source regions. The Committee is currently discussing specific locations and methods.

4.2 Restoration of the straightened river channel to meandering course

The natural meandering rivers in the Kushiro Mire has been altered into the straighten channel from the marginal areas of the marsh. The main objectives of the channelization project were to develop pasture fields both side of the river channels and to convey floods safely. Although those objectives could be achieved, we have lost pristine river-floodplain landscapes and inhabiting wildlife species. A largest freshwater fish species, the Sakhalin taimen, is now in danger of extinction because of the channelization projects.

As a pilot plan, a river section extending about 2 km of the Kushiro River in the Kayanuma area is planned to restore from a straightened channel to a meandering stream and floodplains (Figure 8). The artificial dike built at the right-side bank (left side of the figure) will be removed to allow flooding over the floodplains. The abandoned meandering section created by channelization project will be re-connected with the main channel and the straightened channel will be partially buried with the dike sediment. The restoration project will be monitored and evaluated based upon the scientific research results before and after the project and comparison with reference section existing downstream reaches.

Figure 8. The restoration project of meandering river. River flows from up to bottom of the picture. The meandering section (right side) will be connected to the main channel.

4.3 Restoration programs to improve lake ecosystems

Of the three eastern lakes, the Touro Lake and Takkobu Lake are of greater concerns (Takamura et al., 2003) because of algae blooms since 2000 and the rapid decline of aquatic plant diversity. The degree of eutrophication still remains low in the Takkobu Lake (Takamura et al., 2003), assuming greater possibility to prevent further degradation.

Criticism against the Project included: restoration constitutes traditional public engineering works just for feeding money to construction industries; restoration is contradictory to the development activities destroying healthy ecosystems in elsewhere. To deal with these arguments, the MOE Committee developed a system of rule-based site selection to maintain the independency of site selection from political and institutional constrains. This rule-based process ensures the objectivity of site selection and establishes a clear rationale of restoration activities, which is subject to public evaluation. To develop this site selection rule for the lake restoration in Takkobu, the scope of the restoration was first determined as the lake's watershed. Sites for preservation and restoration were then identified on the watershed-scale GIS database. Although we consider applying this approach to the entire Kushiro River Basin including the Kushiro Mire, it is a challenging task. Unfortunately, GIS data inventory spanning 2,500 km^2 of the basin is incomplete, and searching and compiling existing data and reports have been time consuming.

Restoration activities in the Takkobu Lake and its watershed are at the stage of experiment (Nakamura et al., 2003). Based on the GIS analyses, three types of potential preservation or restoration sites were extracted in the Takkobu Lake Watershed with its area of about 42 km^2: Type (1) delineates forest with species compositions that are resembled to historical stands and wetlands. Type (2) represents non-native forests that are close to the wetlands, including non-native forests, sparsely grown young forests, and secondary grassy fields. Type (3) includes unvegetated areas, such as bare grounds, roads, and clear-cut sites. Young silvicultural stands, farmlands, and secondary grassy fields adjacent to the unvegetated areas are also included to this type, if the site has steep slopes and close to the wetlands.

The results of this extraction process are shown in Figure 9 (Nakamura et al., 2003). The total area of type (1) was 1,809 ha, accounting 43.0 % for the Takkobu Lake Watershed. These areas are not remaining pristine ecosystems but should be maintained their current conditions. With considering social and economic conditions, these areas will be protected from further alterations as much as possible. Type (2) sites occupied 13.1 % with 550 ha. A potential restoration measure for non-native forests in type (2) is the restoration of native forests, and those for secondary fields and abandoned farmlands are tree planting and wetland restoration. Type (3) sites consisted 269 ha of the watershed, making up 6.4 %. The provision of forest buffer zones has been considered to control soil erosion.

At present there are many issues to be discussed in evaluation and the accuracy of extraction process. This rule-based site selection should be further improved through findings in literature and field survey.

4.3.1 An approach to the restoration of native forests

We consider that controlling pollution loadings impacting wetland ecosystems and restoring indigenous forests warrant the first priority in the Takkobu restoration. For selecting a reference site, GIS data and historical reports were used to examine the composition and structure of native forests, because few pristine forests currently exist in the field. This analysis indicated that deciduous forests dominated by the Japanese oak (*Quercus crispula* Blume) occurred on volcanic ash deposits, consisting mostly of the Takkobu Lake Watershed (Nakamura et al., 2003). On its adjacent mudstone layer in the south, coniferous-deciduous mixed forests were established. Existing forest stands that are closely resembled to these historical forests were then examined in the field. It was further revealed that Japanese oak dominant stands and Japanese elm stands (other co-dominant species include alders and Yachidamo) still exist on hillslopes and along stream channels, respectively. In addition, relatively large size trees of these species occur sparsely across the Takkobu Lake watershed.

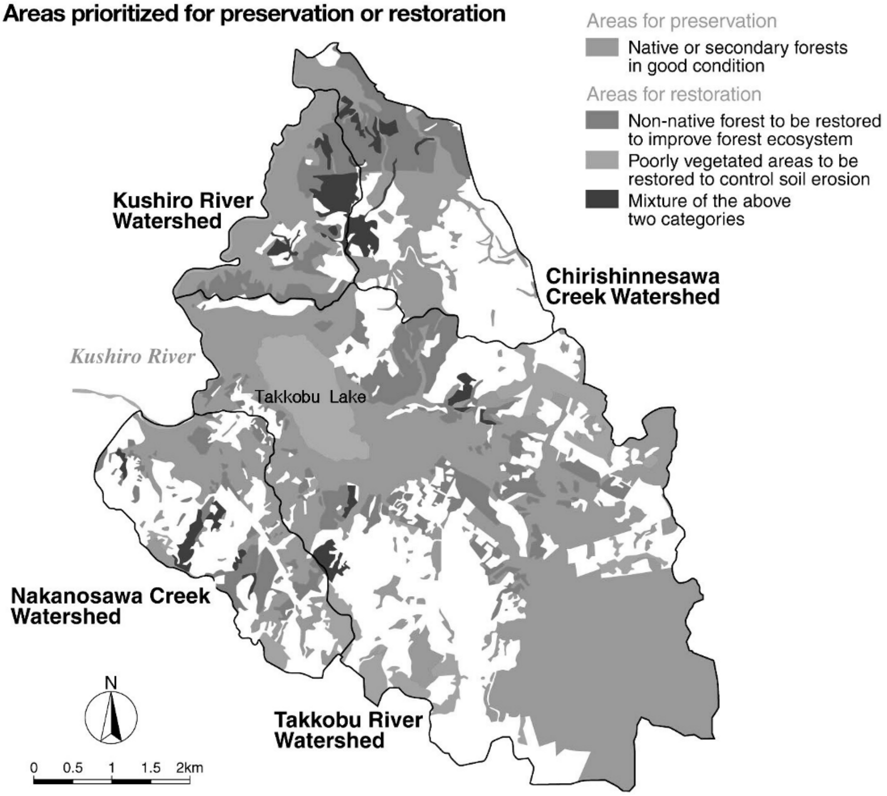

Figure 9. Areas prioritized for preservation or restoration in the Takkobu and adjacent watersheds, which were extracted based on vegetation, forest structure, and topography. Areas that do not satisfy any criterion were determined as "restoration sites of a lowest priority" (shown as blanks in the map; 1,647 ha, accounting 40 % for the classified area) (after Ministry of the Environment, 2005).

These remnants of native forests adjacent to the restoration sites serve as reference sites to be achieved by the restoration. To evaluate a recovery process after implementing restoration, indicative parameters include forest species composition, tree size, rates of sprouting, the volume of dead trees, seedling and sapling density, and the species composition and density of forest-dependent animals.

Emphasizing passive restoration, factors preventing a natural recovery will be removed before implementing tree planting. The limiting factors in the Takkobu restoration include the infestation of Sasa species suppressing the germination and growth of young trees, deer (*Cervus Nippon yesoensis*) grazing on tree saplings, and desiccation. To prescribe site-specific restoration actions, we will further identify 1) those forests that can likely recover by protecting them from future landuse activities, 2) those forests that can maintain natural regeneration by fallowing or excavating surface soils to disturb Sasa covers, 3) those that can recover by controlling deer grazing and desiccation, 4) those sites that can establish forests by tree planting, and 5) those sites that can only recover forest stands by active manipulation including weed control and construction of engineering structures. To avoid disturbing genetic resources, the MOE Committee developed a nursery program, which collects seeds nearby areas of the restoration sites and prepares seedlings for tee planting.

4.3.2 Collaboration with citizens

To establish collaboration with a local environmental group, the NPO Trust Sarun Kushiro, MOE entrusted Trust Sarun with field survey in the Takkobu restoration. One of the criticisms against restoration by the governments is that the authority takes a primary leadership while "public participation" is superficial. Participation by the public has been effective in the Takkobu restoration at various stages of the restoration planning, extending from attending seminars and committee meetings to conducting field survey. In general, NGOs do not have political or institutional boundaries as the government and authorized agencies do. Therefore, the NGO's participation in the Takkobu restoration enabled the planning at the watershed scale, irrespective of the artificial boundaries. Furthermore, ecological restoration requires a long-term planning for years to decades, which is hardly managed solely under an authority's leadership but can be done with the collaboration with NGOs. Thus, social and political infrastructure is also important for ecological restoration.

It is not all advantages in restoration under public leadership. Especially with limited resource information and restoration techniques, restoration planning may not be an easy task for private entities. In any restoration projects, it is important for both citizens and the governments to recognize their limited ability and to complement their limitation each other in developing effective restoration strategies to achieve the desired goals.

4.4 Hirosato Wetland Restoration

The MOE Committee members all agreed that the goal of a wetland restoration project in Hirosato is the recovery of wetland landscape that existed before the agricultural development in the late 1960s. The conditions to meet for implementing the wetland restoration are to 1) restore a sustainable wetland ecosystem, 2) minimize the adverse impacts of restoration activities on adjacent wetland ecosystems and farmlands, 3) ensure the protection of local residents from flooding, soil erosion, and water quality degradation, and 4) avoid disturbing nesting Japanese cranes.

In most years a pair of cranes has nested and succeeded breeding in the wetland in Hirosato. It was concerned that the restoration would disrupt their nesting activities. This issue was debated among a conservation group, the Akan International Crane Center, the Committee members, and MOE. Lastly, all worked out an agreement that a great deal of careful attention must be made in any field survey and restoration actions; from the top of a crane truck with its height of 25 m, the conservation group oversees both surveyors and birds and determines their distance. Depending on the distance, surveyors on the ground need to change the locations and times of work.

4.4.1 Summary of a preliminary survey and its findings

Six transects were established in a wetland restoration site, which has vegetation typical in Hirosato. At more than 100 plots over transects, vegetation (species and coverage) and physical and chemical parameters (ground water tables, concentrations of dissolved materials in soil) were inventoried. Using CCA, the relationships between vegetation and environmental gradients were examined (Nakamura, 2003).

Dominant plant communities changed over the space from a relatively natural portion of the wetland, an abandoned farmland, and a transitional area between them. Representatives were the community of alder - slender sedge (*Carex lasiocarpa*), bluejoint reedgrass (*Calamagrostis langsdorffii*) and starwort (*Stellaria radians*), respectively. This vegetation shift in space was also correlated with the gradients of groundwater tables and nutrient concentrations in wet soils (positive correlations) and variation in groundwater tables (negative correlation). Particularly, the differences in groundwater tables was prominent among the natural area, old field, and transition between these; the plant communities in old field had extremely low in water tables and high in its variation (Figure 10). Hydrological characteristics at a larger scale than the project area were further examined. The cross sectional profile of groundwater table showed a bell curve, with a highest water table in the center of the wetland. Water table decreased rapidly towards the agricultural drainage and an old channel of the Setsuri River that has been disconnected from its main channel (Figure 11).

In addition, water tables in the natural portions of the wetland ranged between zero and –0.4 m whereas those in the old field ranged from –0.3 to –2.0 m with its lowest value near the old channel. The wetland seems to be fed only by precipitation and has no inflows from nearby stream channels. Thus, wetland water can be drained by the agricultural drainage and old Setsuri River channel that has considerably low water tables due to disconnection from its main channel. The old farmland seems to be progressively desiccated (Yamada et al., 2004). Because sufficient amount of water usually can maintain wetland conditions (Wheeler and Shaw, 1995), the drier conditions of the Hirosato wetland definitely suppress the growth of wetland plants. The considerable vegetation change from the natural wetland portion to the old agricultural field reflects the change in the groundwater table, that is, desiccation. Therefore, the Hirosato wetland restoration focuses on this old farmland.

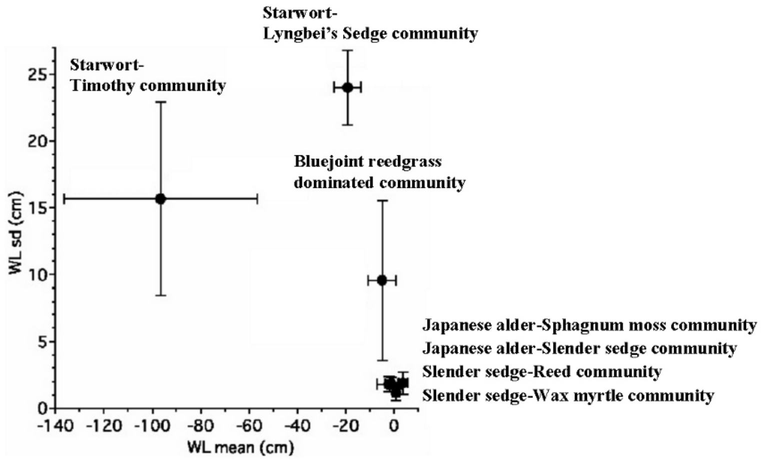

Figure 10. Biplot of mean water table (WL mean) and water table variation (WL sd), as well as its variation in dominant plant communities in the Hirosato wetland. Vertical and horizontal bars show the standard deviation of each mean. (after Nakamura et al., 2003)

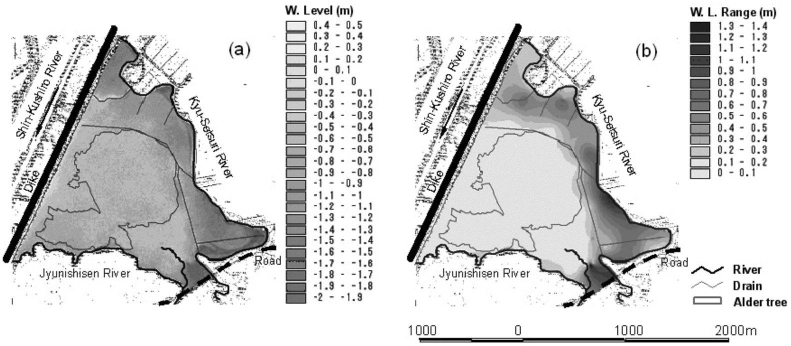

Figure 11. Spatial distributions of (a) groundwater tables at an instance of measurement in June and (b) variation in groundwater tables during the period of measurement. (after Nakamura et al., 2003)

4.4.2 Approaches to restoration, the experimental design and implementation

To ascertain a cause of wetland degradation in Hirosato, an experimental restoration has been conducted. The experiment constitutes analyses on both temporal and spatial scales; data will be compared between before and after treatment, and between reference (intact sites), control (restoration sites without treatment), and impact (restoration sites with treatment). In addition, replications to allow statistical tests are established (Nakamura, 2003). Using this design, called BARCI (Before-After-Reference-Control-Impact), restoration actions and their effectiveness to lead the wetland restoration toward its goal can be evaluated in a scientific framework.

In searching a reference site for the old farmland, an aerial photographic interpretation determined that slender sedge - reed community was dominant prior to farming. Therefore, existing slender sedge - reed community that has not been affected directly by human activities was chosen in the Hirosato wetland as a reference site.

An effective restoration action in the old farmland might be a recovery of wetland hydrology. The aforementioned preliminary analyses indicated that increasing groundwater tables was required for ameliorating the wetland desiccation to recover native wetland communities. Restoration alternatives for the wetland restoration include: water diversion from the Kushiro River to the the Setsuri River old channel; revetment construction at the agricultural drainage and the Setsuri River old channel to prevent draining wetland water; soil excavation in the old farmland to raise the groundwater levels. Considering water rights and impacts on adjacent existing farmlands, a presently possible action is soil excavation, which can also remove the filled materials in the agricultural conversion. Other restoration alternatives would be considered when some conditions, such as land acquisition and consensus among irrigators, are met. An experimental site for soil excavation was established in the old farmland. Within the experimental area, the effects of excavation on water quality, water table variation, and vegetation recovery should be assessed because it can cause strong disturbance in the nearby natural wetland. Concurrently, the MOE Committee has been discussing social and technical feasibility of water diversion from the Kushiro River because this is a most passive approach, requiring a minimal manipulation of the wetland. Resolution in the issues of water rights and flood control are being discussed. When concluding that the stream water diversion is not practical, the MOE Committee will pursuit revetment construction along the Setsuri River old channel and soil excavation.

To examine the presence of viable seeds under the soil layer to be excavated, a seed bank test was performed using seedling emergence technique in soils at the three depths down to 1 m. No slender sedges and reeds but small numbers of other species and seedlings emerged (Nakamura et al., 2004b). Only a few seedlings of a wetland species, Harikougaizekishou (*Juncus wallichianus*), germinated in the soil at the depth between 25 and 35 cm. Thus, vegetation recovery after excavation will likely to be limited without seeding. Another study of the effectiveness of vegetation recovery with and without seeding will be necessary.

The soil excavation experiment was begun in 2002. The depth of excavation was determined so that the water table could be equivalent to that in the reference site. This excavation test was designed to evaluate various alternatives in order to find a most appropriate method for vegetation recovery (Figure 12). For example, one experiment plot was excavated with a slope to test seedling emergence at various soil depths, and another was seeded with reeds. To minimize adverse impacts of excavation on the natural wetland, it was carried out in a winter when soil was frozen. For an access to the experimental site, a 1.5 km-long bridge was manually made by from ice in the winter, which melted away in the following spring.

Figure 12. An experimental excavation site in the Hirosato wetland.

4.4.3 Controversial alder forest control

As previously mentioned, regeneration mechanisms of alder forests are largely unknown. In the Hirosato restoration site, it is important to determine the direct cause of forest expansion by revealing habitat conditions optimal for alder growth. However, as shown in Figure 10, Japanese alders and slender sedges co-occur as a dominant community in the interior parts of the wetland, sharing similar hydrologic conditions. Currently available data cannot explain habitat conditions supporting alder forest expansion.

Evapotranspiration by alder trees is greater than that of reed dominant communities. Expansion of alder forest may increase evapotranspiration in the Hirosato wetland, contributing to further wetland desiccation.

Controlling alder forest expansion may also be necessary for protecting one important native wetland species, the sphagnum moss (*Sphagnum imbricatum*) because the species is sensitive to a change in light and hydrologic conditions. MOE has been studying the effects of alder control, including cutting trees and sprouts, on vegetation under the trees, evapotranspiration and groundwater tables. We are aware of that cutting trees and sprouts can be a short-term solution but not be a causal treatment. It is also inappropriate to extend the area of alder control at present, before its regeneration dynamics and optimum habitat conditions have been clearly understood.

Even if the cause of alder forest expansion in Hirosato is human related (e.g., the disruption of water inflow by the revetment and drainage impact), the removal of revetment would be impossible because of the needs of flood control in existing agricultural land use. Given water diversion from the Kushiro River is a potential alternative action, the role of wetland hydrology in the alder forest expansion should be clarified at first.

5. IMPLICATIONS FOR FUTURE RESTORATION

To be widely accepted by the public for restoration projects, it is necessary to establish consistent national policies in land conservation, agriculture, and natural resource conservation. The ecological meaning of restoration projects should be established in these policies in the past and future. With erroneously perceiving the purpose of ecological restoration, the government should not pursuit a large-scale engineering construction, which in the past often adversely impacted natural resources. However, the history of development at the expense of degradation or loss of pristine ecosystems should not be ignored. This experience could be helpful for evaluating the need of ecological restoration.

The restoration actions should also be undertaken under public understanding and consensus. We emphasize the priority of extraction of remaining intact ecosystems and their preservation. Adjacent degraded ecosystems should be restored as much as possible, to protect a healthy sustainable ecosystem over a large area. Thus, in parallel to promoting restoration projects, greater areas of the nation's pristine ecosystems should definitely be preserved.

Information dissemination is essential to eliminate persistent public distrust of the government activities and to gain public understanding of restoration projects. The entire restoration process, including the development of goals, field experiments, and monitoring, should be open to the public, as the restoration progresses.

Information sharing is essential in consensus building with local communities. A restoration goal can be developed only by understanding people's values and needs in the local communities; for example, whether the public wants to recover a self-sustainable ecosystem, or favour a secondary ecosystem that is maintained by active management. A variety of desired endpoints are possible in restoration, which should be actively discussed by the public in the district.

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