Journal of the Korean Geographical Society, Vol.37, No.5, 2002(511~521)

Detection of Changes in Coastal Sand Dunes Using GIS Technique and Field Monitoring

Kyeong Park* and Eunmi Chang**

GIS 기술과 현지 모니터링을 이용한 해안사구 변화 탐지

박 경* · 장은미**

Abstract : Coastal sand dunes in West coast of Korea are under stress. Due to the newly constructed Seohaean(West Coast) Highways, the number of visitors and the anthropogenic pressures will keep rising in near future. Sea level rise due to the global warming may cause a lot of damage to the natural resources and residents of coastal area. Therefore, many countries including United States are doing nationwide coastline survey using highly sophisticated methodology. In this study, high resolution IKONOS satellite images along with aerial photographs taken since 1960's have been sequentially analyzed using GIS software (Erdas Imagine 8.3). On-site monitoring has been performed at the 31 measuring points in 10 beaches since the May of 2001 in order to measure the sand budget. Post-construction monitoring after installation of sand fences is also being done on sites regularly. Restoration works seem to be effective at this moment.

Key Words : GIS, Satellite Image, Sand dune, change detection, monitoring

요약 : 해안사구는 지속적으로 변화하고 있다. 최근에는 지구온난화에 따른 해수면 상승 등의 이유로 재해대책의 차원에서 해수면 변화를 연구하는 것이 범세계적인 추세이다. 최근의 서해안 고속도로의 개통으로 서해안 사구 지역을 포함한 해수욕장을 찾는 사람은 계속 증가할 것으로 판단된다. 하지만 해수면 상승에 따른 해안선 후퇴와 이에 따른 해안지역의 환경변화에 대한 국내의 관심은 매우 부족한 현실이다. 이 연구에서는 태안해안국립공원과 인근 지역의 사구에 대하여 1960년대부터 촬영된 항공사진과 최근의 헬기를 이용한 항공촬영 결과 및 고해상도 IKONOS 위성영상을 GIS 프로그램을 이용하여 시계열적으로 분석하여 사구 지역의 변화를 분석하였다. 특히 현지에서 1년 이상 지속적으로 31개 지점에서 모니터링한 자료를 분석하여 사구복원을 위해 설치된 모래울타리 및 보호 목책과 같은 시설물 및 식생복원의 효과를 분석하였다. 적극적인 복원대책의 효과가 긍정적으로 나타나고 있는 것으로 판단된다.

주요어 : GIS, 위성영상, 해안사구, 변화탐지, 모니터링

1. Introduction

The nation's beaches are under constant pressure. To protect against coastal erosion, sea walls and jetties have been constructed without consideration of ecologically harmful impacts. Also, demands on coastal sand for industrial use are still high and lead to the extensive sand mining within the sand dunes and tidal flats around the coastal national parks. Sand mining eventually leads to degradation of coastal environments and destruction of habitats. The sand dunes that lend beauty to the coastal landscape also serve an invaluable purpose. By absorbing the force of storm surge, high

* Senior Scientist, Korean National Parks Authority(kpark97@npa.or.kr)
** Director, 3GCore Institute(emchang@3gcore.com)

waves and wind, sand dunes help to prevent inland property loss.

Since 1999 when sand mining completely was prohibited within the boundary of Taean National Park, sand bars are forming near the coastlines without any human control. Sequential air photos taken from the 1960s and IKONOS satellite image taken in 2001 clearly demonstrate the positive effects of ban of commercial sand mining. Sea wall constructed in 1990s to protect the coastline does not seem to be functioning as was planned. Sands are eroded from the beaches; this can be clearly shown by the air photos and satellite image. Black pine trees (Pinus thunbergii), which people believe to be very old, are actually very young and planted by human during the 1970s. Bagsajang (whose name means white sand) is actually now without sand.

Both beach nourishment and dune restoration are viable engineering alternative for shore protection and habitat restoration. Its application is suitable for some locations such as Bagsajang where severe erosion is occurring. At this moment, efforts are concentrated upon the restoration of beach-dune system, which can be regarded as corridors to connect the marine to terrestrial habitats. The human settlements, roads, and ports, however, separate coastal dunes from each other. Therefore, some species that prefers to migrate above land or above sea are not protected properly. Heavy recreational use over the fragile ecosystem during the short vacation season also accelerates the erosion of foredunes and the loss of vegetation cover over the sand dune.

2. Data Acquisition Methods

Aerial photographs were borrowed from National Geographic Institute and IKONOS pen-sharpened data were bought from e-HD.com (ID: SIA001PSMS-GD CD3510 1/2) extending from Bagsajang beach through Sambong beach and Gijipo beach to Baramarae sand bar. Aerial photographs were scanned by a high quality scanner and saved as TIFF file. All the images were rectified to less than 1 pixel root-mean-square error (RMS) using a first order polynomial and were resampled to 1 meter pixels using the nearest neighbor method with Image Analyst (Intergraph USA) and Imagine 8.3 (Erdas, USA). Ground control points were selected from images and 1:25,000 and 1:5,000 digital maps. Coastal areas were classified as partly waterlogged zone, pure sand zone and sand dune zone by head-up digitizing method.

National Wetlands Inventory is a US Fish and Wildlife Service mapping program that delineates detailed wetland classes using manual interpretation of aerial photographs (Lewis et al. 1998). Head up digitizing includes subjective judges however, mutiple date images have been shown additional benefits in mountaineous areas, but great benef have on the coastal plains and simpler topograph (Wayman et al. 2001). Quantitative analysis using objected oriented classification may be applied later. In USA, laser mapping system has shown its effectiveness of change monitoring in coastal area. Beach and cliff changes are quantitatively shown by comparing cross-shore profiles consisting of individual laser spot elevations (USGS,1998). Recent classification efforts using Landsat TM and similar sensors have applied improved and innovative techniques in order to increase stratification accuracies (Vogelmann et al. 1998). Such efforts have resulted in varying degrees of success, depending on the level of categorical specificity. Ancillary data such as digital elevation models, digital topographic map, soil map and prior information about the landscape have proved to be useful in some studies (White et al. 1995). Here ancillary data was not integrated into classification of sand beach and dune because of the lack of appropriate data; therefore the systematic expert system was not attempted.

Plants are identified and classified at the field by the experts. Previous study results are also doublechecked after the field trips.

Data sets on sand budget and coastline changes are also being collected twice a month in the field. This data collection will continue until year 2003. During the summer vacation season, data collection has been stopped due to the human impacts on sites. Measurement poles with a marking were installed at 31 sites in 10 beaches. Profile changes will be measured to calculate sand budget changes. Sand fences were constructed to restore the stable dune morphology. Around the sand fences, the effects of sand fence are measured twice a month also. Most of sand fences are built with sliced bamboo sticks, however to compare the efficiency, fishing nets are also used for comparison's sake.

3. Theoretical Backgrounds of Sand Dunes

1) Growth

A natural beach will often have a dune on the landward side of the beach berm. Dunes are formed by the action of onshore winds. Sand deposited on the beach by surf zone processes is carried inland by the wind. Topographic features and vegetation interfere with wind transport and cause deposition in the lee of obstacles. In this way an incipient dune or embryo dune is initiated. The shielding effects of this dune promote further deposition and so the incipient dune grows in size. As the dune grows, a slip face on the leeside develops and the ability of the wind to transport sand up and over the dune is progressively reduced. In time, a dune system will be created, consisting of an incipient dune, a foredune and hind dunes. The size and character of sand dunes are governed by the shape and size of the beach embayment, its orientation to the prevailing wind and wave climates, the grain size and amount of sand available or supplied to the beach, and the type and state of dune vegetation.

2) Vegetation

Dune vegetation is the primary factor determining the stability of a sand dune. A graduation of primary to secondary to tertiary species occurs from the incipient dune to hind dune areas. The vegetation canopy provides aerodynamic protection to underlying species from salt laden winds.

In many instances, natural dune vegetation is quite fragile. Significant damage can lead to total degradation and loss of the protective vegetation cover. This in turn leads to dune blowout in dune area. The revegetation of exposed dune and beach areas is hindered by sand drift. Difficulties can also arise if exposed areas are first, remote from a source of nutrient supply (normally the hinddune and strandline areas), second, remote from the source of recolonizing seedlings, and finally, exposed to a microclimate considerably harsher than that of hind-dune areas.

The interactions between coastal processes and dune vegetation are, in natural circumstances, very positive. The principal species are well suited to stabilizing dune sands and initiating beach recovery following severe storms. During storms, sand is removed from the beach to form an offshore bar, and during intense storms, a demand for dune sand is created which involves reserves held by primary species.

Beach vegetation, such as Elymus mollis and Carex kobomugi, provides some resistance to the removal of sand during the storm, but its principal role is to quickly stabilize the sand which returns within a few weeks of the return of fine weather. With loss of vigor of primary species, sand is free to move inland, where it impacts vegetation which does not have the capacity to tolerate burial and further dieback results.

Coastal dunes have been and are used for a variety of purposes including mining, water extraction, waste water disposal, housing, agriculture, aquaculture, recreation, and roads. Problems that have arisen from some of these uses include sand drift, shoreline recession, soil over-nutrification, loss of species and reduced recreational amenity. Past experience indicates that coastal dune vegetation has limited capacity to recover from some of these uses. Much of the coast has already sustained some loss of intrinsic value which may be costly and difficult to rehabilitate.

If remaining intact coastal dunes are to retain their natural plant and animal communities, a limited number of compatible land use options are possible. Existing vegetated dunes can be utilized for recreation, education, research, and conservation with little permanent damage if such use is properly managed. Other uses such as sand mining, property building and waste disposal are more disruptive and permanent loss of vegetation is unavoidable.

3) Management Considerations specific to Taean Coastal National Park

Dunes are held together by plants and damage to these by vehicle and people can cause total destruction of dunes. Therefore public access paths need to be carefully sited and controlled. Rotation of access points can be helpful. Pedestrian access should be via properly constructed walkways if traffic is moderately high. Elevated wooden walkways are regarded as perhaps the best and most aesthetically pleasing solution as they can be built above the vegetation. Vehicles traveling on the beach between high and low water marks have little impact on the sedimentary beach system. However vehicles can readily damage or destroy vegetation on coastal sand dunes. Plants growing on newly forming dunes are particularly sensitive to vehicle impact. Even the closure of beaches to vehicles during periods of high tides, which would force drivers to run up the face of dunes or through bird nesting sites and embryo dunes, should be strongly enforced.

4. Monitoring Results

Aerial photos are compared with the high-resolution IKONOS images taken in 2001. It is necessary to be careful to compare the areas of sand beaches and dunes, since internal and external orientation are not processed, but rectified with digital maps. We could not make perfect orthophotos, partly because the flight reports on the camera angles, yaw, roll, pitch rate, partly because stereo pairs of the one spot are not available for all the images. It is also difficult to control the time of taking photos in order to avoid the effect of tide and ebb. Then it is not meaningful to make quantitative comparison for the sand dune areas; however the general tendency of the changes in beaches and dunes. The overlaid vector data were made in 1983, therefore the red lines showing roads

Figure 1. Vehicles can damage or destroy vegetation on coastal sand dunes as can be seen in Sambong beach.

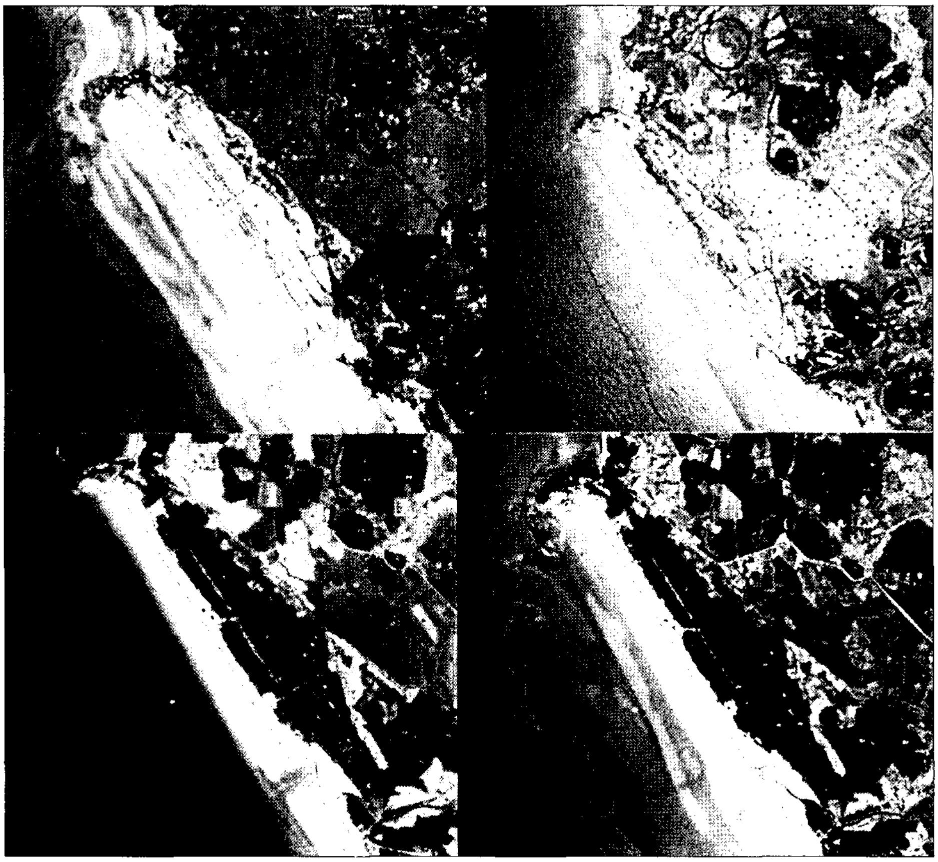

Figure 2. Sambong beach in 1967, 1981, 1998, 2001.

are not corresponding to raster data in 1967. Waterlogged beaches vary in areas due to tide. Inner sand dunes have decreased since 1977, finally could not see inner naked sand dune is not observed in 2001 images in case of Bagsajang beach. It is impossible for us to find inner naked dunes after 1991 at Sambong beaches. Gijipo did not show any inner naked dunes due to rocky and terrain with steep slope in the early photo. Before the planting of pine trees along the fore dunes, sand dunes shows very high reflection rates, which means almost all the dune areas are vegetation free in 1965. Pine trees and

Table 1. Areas of sand beaches and dunes measured from multi-temporal images.

(unit: m^2)

Beach	Class	1967	1977	1991	1998	2001
Bagsajang	Naked beach/dune	49357	73944	104461	133138	105590
	Partly waterlogged	473036	45834	154530	98627	46093
	Naked Inner dune	128061	110344	11616	10948	-
Sambong	Naked Beach/dune	77484	96632	63173	52851	65477
	Partly waterlogged	284684	104620	45177	65327	391593
	Naked Inner dune	38632	39163	-	-	-
Gijipo	Naked Beach/dune	236222	253883	152261	77291	107847
	Partly waterlogged	361184	19029	47181	82355	533383

shrubs were planted over the beaches and dunes between 1981 and 1998. Stabilization rate of sand dunes are not great from 1998 to 2001.

Dune management is the combination of activities that aim to sustain the role and value of beach dunes. Management for a stable dune system involves the control of windblown sand when it encounters the foredune. The elevated foredune interacting with vegetation is recognized as one of the basic requirements for coastal stability.

The basic principle in dune management is to maintain a satisfactory vegetative cover on the foredune. This prevents sand blowing inland where it is lost from the coastal system. Management of coastal dunes involves the application of land capability principles, organization of recreational activity and rehabilitation of disturbed dunes.

1) Dune Reconstruction by Installation of Sand Fence

Any restoration program implemented on coastal dunes requires a suitable landform for the planting of grasses, shrubs and trees. Preparing such landforms generally involves the reforming of dunes.

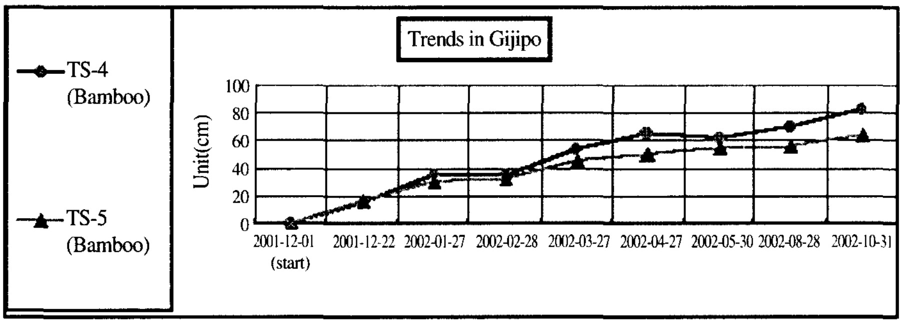

Figure 3. Depositional trends in Gijipo beach after installation of sand fence.

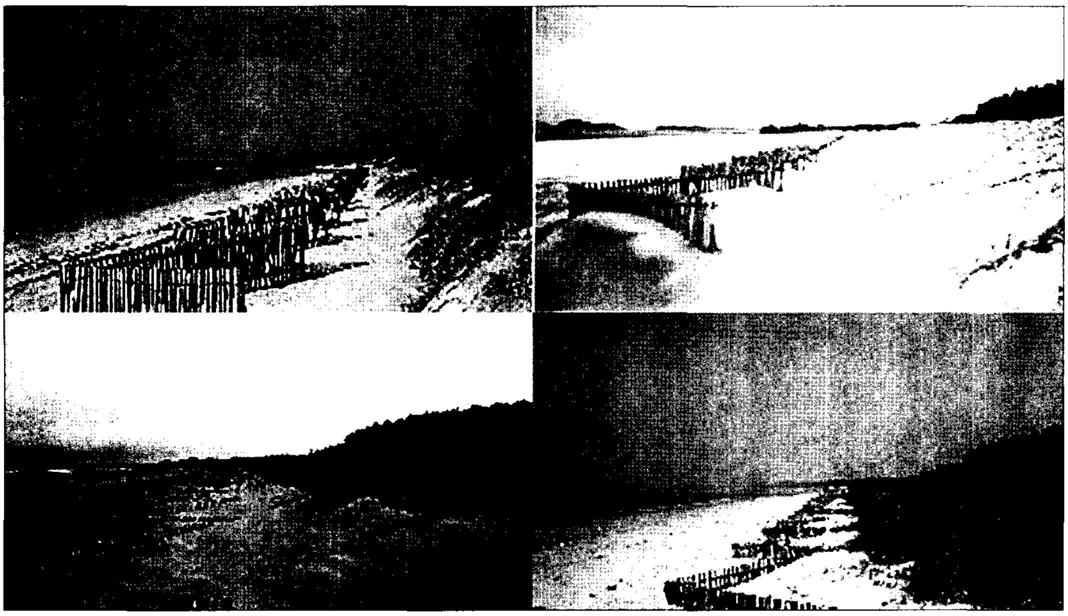

Figure 4. Sequential pictures taken in Dec. 2001, Jan. 2002, May 2002, and Oct. 2002 (from upper left, clockwise).

This may involve filling of small blowouts, or on a larger scale, the reconstruction of hundreds of meters of dune. In Taean Coastal National Park, sand fences are installed to help restore the foredunes in December 2001. Foredunes in this area are being lost due to the malpractices around the beaches such as driving vehicles across the dunes or sand sliding around the slip face.

Sand fences have been made of half-sliced bamboo sticks and fishing nets rather than traditional wood fences due to the practical reasons. Fishing nets will not be used any more because they are not easily decomposed.They are either 100cm or 70 cm above the ground and buried 20 cm under the ground. Spacing between the sticks is either 5 or 8 cm. Various types of sand fences have been constructed to compare the efficiency of the different types of sand fences.

2) Dune Revegetation

The major objective of any dune restoration program should be to provide sufficient plant cover to protect against wind erosion. Species native to the coastal dune system have adapted to survive the hostile environment of drifting sand, strong winds, salt spray and infertile soils, and provide long term stability to the system.

A successful revegetation program will also provide other benefits to the coastal system including increased protection for landward areas and amenities, improved habitat for native fauna, particularly birds, and enhanced beach amenity.

The provision of dune protection is necessary where land use pressures will, in the absence of protection measures, cause damage to the dune landform or vegetation. A combination of dune fencing, formalized access ways and signposting is normally used to protect the dune system.

Fences were built during the fall of 2002 in Taean National Park. Fences are effective to preserve naturally vegetated areas by protecting them from uncontrolled pedestrian and vehicle traffic. Formalized access ways allow pedestrians and vehicles access to dunes in a manner which protects both the dune and adjoining vegetation; they are fenced to direct and confine the movement of the people and vehicle; and the dune surface is generally protected by materials such as board walks to prevent sand blowing from the access ways.

3) Protective Works

In general, protective works tend to be expensive involving extensive construction works as in Figure 1. Even though they often provide the only socially and economically acceptable means of reducing hazards to existing properties at risk. Unless carefully designed and constructed, structural works, by reason of their location within the active beach zone, may have a number of unforeseen detrimental effects on shoreline ecosystem (Texas GLO, 1999).

A properly designed and constructed seawall will protect properties and areas of the foreshore from the impacts of beach erosion and coastline recession hazards. However, the recreational use and scenic appeal of the beach are reduced significantly by seawalls, especially if their presence facilitates the loss of sand in front of the wall as is frequently pointed out by the television media such as KBS.

Beach nourishment is known to provide coastal protection and increases beach amenity by building a wider beach. However, unlike groins, nourishment

Figure 5. Seawall, Bagsajang, Taean

does not promote erosion in downdrift locations of the beach. In fact, beach nourishment programs have few if any detrimental effects provided that an adequate supply of suitable sand is available and that it can be obtained without undesirable side effects. One potential drawback of beach nourishment is that further nourishments may be needed in the future as in most beaches in Atlantic coast (Nordstrom et al., 1986). In Bagsajang beach, small-scale beach nourishment has been performed in year 2001 and 2002. In 2001, sands were removed instantly after the storm. During the year 2002, experimental groin was built in front of the Bagsajang beach and sands filled in 2002 seem to remain downdrift side of the groin. Further study is necessary to draw any conclusions on the effects of groin at this moment.

4) Dune Vegetation

The understanding of coastal dune vegetation, in particular knowledge of the species which are present on the dunes of Taean Coastal National Parks, their distribution both along the coast and in different dune environments, and of the characteristic associations in which they are found, is critical to the effective restoration of dunes and their role in coastal processes.

Vegetation is the key factor in dune stability and it is the vulnerability of dune vegetation that makes the dunes sensitive to impact (USACE, 1995). Examples of human activities that can damage dunes are: stock grazing; road building; stockpiling building materials; earthworks in general; construction; housing; garbage dumping; most recreational activities; pedestrian and vehicular traffic. Information required to properly manage dune vegetation includes knowledge of species present, the locations of species, and processes by which species persist. Table 1 shows the list of the vascular plants commonly found in sand dunes in Taean Coastal National Park.

For the purposes of coastal dune management, it is convenient to divide dune vegetation into three groups based on performance, growth habit and zone of colonization. These groups are primary colonizing species, (grasses and vines); secondary shrubs and transient species; and tertiary species (enduring trees such as pine tree) (KNPA, 2001).

Dune vegetation is highly adapted to the salt laden winds of the coast, and maintains the foredunes by holding the sand already in the dune, trapping sand blown up from the beach, and aiding in the repair of damage inflicted on the dune either by natural phenomena or by human impact. The com-

Table 2. Common vascular plants in Taean Coastal National Park listed during the field survey by the first author.

No	Family Name	Korean name	Scientific Name
1	Poaceae	갯그령	*Elymus mollis* TRIN
2	Poaceae	갯쇠보리	*Ischaemum anthephoroides* (STEUD)MIQ.
3	Poaceae	갯잔디	*Zoysia sinica* HANCE.
4	Cyperaceae	좀보리사초	*Carex pumila* THUNB.
5	Cyperaceae	통보리사초	*Carex kobomugi* OHWI.
6	Verbenaceae	순비기나무	*Vitex rotundifolia* L. fil.
7	Fabaceae	갯완두	*Lathyrus japonica* WILLD
8	Roaceae	해당화	*Rosa rugosa* THUNB
9	Convolvulaceae	갯메꽃	*Calystegia soldanella* ROEM. et SECULT.
10	Borraginaceae	모래지치	*Messerschmidia sibirica* L.
11	Chenopodiaceae	명아주	*Chenopodium album var. centrorubrum* MAKINO
12	Chenopodiaceae	갯능쟁이	*Atriplex subcordata* KITAGAWA
13	Pinaceae	곰솔	*Pinus thunbergii* PARL

bination of dune height, dune shape and intact vegetation creates a protective system which directs salt-laden winds upwards and over the dune crest. As a result, salt sensitive vegetation communities can establish in close proximity to the beach. The sequence of herbaceous forms followed by shrub and tree forms is true in the general sense (Seo, 2001).

Dune vegetation not only stabilizes the dune, but also has habitat, educational and recreational values. The beach and the foredune are used extensively for recreation purposes and vegetation contributes to recreational and aesthetic values. Indirectly, the stabilizing ability of vegetation limits the amount of wind blown sand in the beach environment and thus enhances its recreational utility.

Beyond the foredune, taller pine forests afford protection from onshore winds and protect rice paddies behind. Vegetation plays an important role in the stabilization and formation of coastal dunes. Foreshore vegetation impacts on several of the sand transport pathways, and therefore influences the rate of shoreline recession and dune rebuilding.

The beach vegetation is generally temporary, being removed during storm events. Nevertheless these pioneer plants trap and hold windblown sand so that it does not damage plants on the relatively more stable foredune. The beach vegetation is mainly dominated by the grasses, Elymus mollis and Ischaemum anthephoroides, which aid in the creation of beach mounds and ridges, (incipient foredunes), under prograding conditions (Seo, 2001).

The foredune vegetation proper is usually composed of semi-permanent populations of herbs, shrubs and trees which stabilize the foredune sand mass. Sand trapped in the foredune acts as a reservoir of sand for the beach during periods of wave erosion and to a certain extent, by the development of soil concretions and a dense root web, the foredune vegetation also buffers the effects of storm erosion.

Figure 6. Manripo Beach before the development (1967). Sands used to be blown over the hills.

5) Windborne Sediment Transport

The major causes of coastal erosion are the waves and elevated water levels associated with storms. Wind also promotes coastal erosion in the form of windborne sediment transport. Although such erosion is slower and less dramatic than the effects of storm waves, the inexorable inland march of migrating or transgressive sand dunes can smother coastal developments. Blowouts on coastal dunes can result in vegetation loss, potential dune migration, reduced amenity and the loss of sand from the beach system.

There are three distinct modes whereby the wind can transport non-cohesive sediments or "sand" in a downwind direction. These are suspension, saltation and traction. Saltation is the most significant form of transport for beach sand. The particles most readily moved by wind have diameters of 0.1 to 0.2mm (fine sand). A threshold wind velocity is necessary to initiate sand movement. Typically this is of the order of 20 km/h. Above this threshold velocity, transport varies as the cube of wind velocity. According to Yu's study of Shindu dune fields (2001), the mean amount of aeolian sand transport is upto 30 kg/m/day. He indicates that actual movement of sand is larger than his calculation.

References

Arens, S. M., 1990, Aeolian Processes in the Dutch Foredunes. Universiteit van Amsterdam Ph. D. Dissertation 150p.

Bernd-Cohen T. and Gordon, M., 1998, *State Coastal Management Effectiveness in Protecting Beaches, Dunes, Bluffs, Rock Shores: A National Overview*. 68p.

Carter, R. W. G., Curtis, T. G. E., and Sheehy-Skeffington, M. J., 1992, *Coastal Dunes - Geomorphology, Ecology, and Management for Conservation*. A. A. Balkema 533p.

Charlier, R. H. and De Meyer C. P., 1997, *Coastal Erosion - Response and Management*. Springer, 343p.

Choi, J. K., 2002, Estimation of ground subsidence rate in reclaimed land by L-band SAR. Yonsei Univ. MS Thesis. 80p.

Demek, J. and Embleton, C., 1978, Guide to Medium - Scale Geomorphological Mapping. IGU Commission on Geomorphological Survey and Mapping. E. Schweizerbartsche verlags-buchhandlung Stuttgart. 348p.

Department of Commerce, *NOAA Coastal Change Analysis Program (C-CAP): Guidance for Regional Implementation*, NOAA Technical Report NMFS 123

Gray, D. H. and Sotir, R. B., 1996, *Biotechnical and Soil Bioengineering Slope Stabilization - A Practical Guide for Erosion Control*, John Wiley & Sons, Inc. 378p.

Kahng, T. G., 2002, The transformation of coastal sanddunes in the south Choongchung Province. Korea Univ. Ph. D. Dissertation, 142p.

Kim, M. H., 2002, The Measurement of coastal sand dune's height with digital terrestrial photographs, Seoul National Univ., MA Thesis, 64p

Komar, P. D., 1983, CRC *Handbook of Coastal Processes and Erosion*, CRC Press Inc. 305p.

Korean National Parks Authority, 2001, First year report on " Reconstruction of sand dunes by the nature-friendly methods".

Lewis A.T., Kempa R. G and Spell R. E, 1998, Wetlands mapping and monitoring in California, *Natural Resources Management Using Remote Sensing and GIS*, 139-145

Nordstrom, K. F., 2000, *Beaches and Dunes of Developed Coasts*, Cambridge University Press.

Nordstrom, K. F., Gares, P. A., Psuty N. P., Pilkey, O. H. Jr., Neal W. J., and Pilkey O. H. Sr., 1986, *Living with the New Jersey Shore*, Duke University Press 191p.

Pethick, J., 1984, *An Introduction to Coastal Geomorphology*. Edward Arnold 260p.

Seo, J. C., 2001, Morphological changes and sediment budget of coastal dunefields in Shinduri, Korea, Seoul National Univ., Ph. D. Dissertation 86p.

Silvester, R. and Hsu, J. R. C., 1993, *Coastal Stabilization - Innovative Concepts*. Prentice Hall, Inc. 578p.

Texas General Land Office, 1999, *Dune Protection and Improvement Manual for the Texas Gulf Coast*.

U. S. Army Corps of Engineers, 1989, *Environmental Engineering for Coastal Shore Protection*. Engineer Manual 1110-2-1204.

U. S. Army Corps of Engineers, 1995, *Design of Beach Fills*. Engineer Manual 1110-2-3301.

U. S. Army Corps of Engineers, 1995, *Coastal Geology*. Engineer Manual 1110-2-1810.

USGS. 1998. Coastal Erosion along the U.S. West Coast During the 1997-98 El Nino: Expectations and Observations. American Geophysical Union Proceedings of fall 1998.

Vogelmann J. E., Sohl, T., Campbell P.V and Shaw,

D. M., 1998, Regional Characterization of land cover using multi sources of data, *Photogrammetric Engineering and Remote Sensing*, 64(1), 45-57.

Wayman J.P. Wynne, R. H., Scrivani, J. A. and Reams, G. A., 2001, Landsat TM-based Forest area estimation using iterative guided spectral class rejection, *Photogrammetric Engineering and Remote Sensing*, 67(10):1155-1166.

White J. D., Kroh G.G. and J.E. Pinder III, 1995, Forest Mapping at Lassen Volcanic National Park, California, using Landsat TM data and a geographical information system, *Photogrammetric Engineering and Remote Sensing*, 61(3), 299-305

Yu, H. S., 2001, Aeolian sand transport during the winter and morphological change of coastal foredune in Shindu dunefields, Korea, Seoul National Univ., MA thesis.

(*Received* November 20, 2002)