Several Landscape Ecological Concepts on the Aral Sea Crisis Revealed by Remote Sensing

Yukihiro Morimoto (*), Atsuo Morimura (**) and Natalia Ogar (***)

* Laboratory of Landscape Architecture and Conservation,
Faculty of Agriculture, Osaka Prefecture University
1-1, Gakuen-cho, Sakai, Osaka, 593 Japan
Fax: +81-722-52-0341
Email: yuki@center.osakafu-u.ac.jp

** Division of Agriculture, Osaka Prefecture University Graduate School
1-1, Gakuen-cho, Sakai, Osaka, 593 Japan
Fax: +81-722-52-0341
Email: morimura@envi.osakafu-u.ac.jp

***Institute of Botany and Phytointroduction, National Academy of Sciences
Alma-Ata, Kazakhstan
Fax: +7-3272-617938
Email: envirc@kazmail.asdc.kz

Abstract

Characteristics and problems of the Aral Sea desertification caused by an irrigation policy was discussed from the view point of landscape ecology. (1) General concepts of vegetation distribution including geobotanical zoning, (2) landscape mosaics in delta vegetation, (3) relationship between traditional and modern land use and natural condition, and (4) vegetation changes caused by massive irrigation in the arid areas of Middle Asia. A time sequential animation of GVI, vegetation maps made from NOAA LAC and SPOT HRV data sets were very powerful for the study.

Key words: the Aral Sea, desertification, arid areas, landscape ecology, vegetation change, remote sensing, sustainable land use, vegetation monitoring.

1.Introduction

An exploitative irrigation policy of the former Soviet Union, which supports cotton and rice production in Middle Asia has led to the drastic contraction of the Aral Sea. In addition to this sensational fact, the large amount of irrigated lands are going to reduce productivity because of salinization. This phenomenon is called the Aral Sea desertification. We must

distinguish the terms desertification and desert. A desert is a natural ecosystem found in arid areas in which ecological conditions continue to change on a daily, seasonally, and yearly basis in a natural way. Desertification, on the other hand, means a drastic decline of biological productivity or a decrease in biological diversity. It is necessary, therefore, to know what the natural fluctuations are, in order to distinguish them and assess the human impact on them.

It goes without saying that irrigation agriculture was not planned for the purpose of destroying nature. Managing to create an enormous income from irrigated agriculture was a brilliant success. However, the contraction of the Aral Sea and some other consequences brought by irrigation had been treated as trifling matters by the authorities until the 1970s. The development seems to have been planned mainly from the view point of rapid construction. Careful consideration to sustainability was not given to the extensive project. Rice production in crop rotation, however, seems to have been planned for leaching salinized soils. Rice is a main crop producted in the irrigation system of Kazakhstan, but the production is maintained by an enormous amount of water, more than 3,000 mm/y (Watanabe et. al. 1996).

After 1980, cotton production in Uzbekistan began, as did rice production in Kazakhstan because of salinization. This demonstrate that large scale agriculture need to be based on landscape ecology in order to achieve sustainability.

We are going to present a natural structure of the vegetation distribution in this area and show the types of changes that are now taking place by means of remote sensing and ground truth.

2.General recognition using GVI animation

The irrigated areas in Middle Asia stretches along rivers and big canals. Syr-Dar`ya and Am-Dar`ya rivers of Aral Sea basin and Ili river for Balkhas lake are the main sources for irrigation.

As the precipitation is around 100 mm/yr., biological productivity in the arid area of the Middle Asia in natural conditions is very low. In addition, nomadism had been the main land utilization until the 1950's when this large scale irrigation project started. We notice , however, that desert does not mean simple and uniformly low productivity. Due to the abundant solar radiation, the potential for the productivity of plants through irrigation is greater in the Aral Sea region than in Japan (Otsuki et. al. 1996). Even in a natural ecosystem, great mountain ranges capture precipitation, and big rivers flow down from the mountains to the desert area. I believe that large *Phragmites* communities at the deltas of these rivers and lakes may have contributed to the motive for the irrigation agriculture.

An animation of weekly Global Vegetation Index (GVI) data set could show the characteristics of the seasonal change of the vegetation activity. Two completely different and contrastive type of vegetation exist in the arid area. One is spring-type vegetation which depends on on-the-spot precipitation. *Artemisia terrae-albae* is the most common small shrub species in such environment. The height of the plant is determined by quantity of spring rainfall, and it turns brown and is dormant in summer. It is the climatic climax community. The other is summer-type vegetation which depends on underground water and river water. This is the wetlands vegetation which consists of a series along ground water level; Phragmites australis communities in the most wet environment, riverside forest called Tugai, grassland of Calamagrostis epigeios , Tamarix spp. et. al. including medicinal plant, Glyceyrriza . These trees and plants had been supporting the life of nomads including their tent house called a 'Yulta'.

3. GVI assisted geobotanical zoning

Vegetation types and their distribution have been studied in depth by N. Ogar and others, however remote sensing data can assist the study in various aspects. only by field expeditions. Weekly GVI images can offer important informations on the determination of the geobotanical zoning. Vegetation types are affected by geology, topography and regions, and satellite images of low spatial resolution are expected to show comprehensive landscapes of the region.

The principal component image created from NDVI of weekly GVI for four seasons, temperature and a near infrared channel could effectively assist in the geobotanical zoning. And the reliability of the result was verified by reclassification of sampled pixels in each zone using the maximum likelihood method. Factor analysis for the species composition of each zone showed the importance of ground water condition and surface geology.

Thus we are able to create a large scale landscape ecological zoning map of the arid areas of Middle Asia. This map shows that conditions in the desert become more severe from Balkhas lake through the Aral Sea to the Caspian Sea.

4. Mosaics of delta vegetation shown by SPOT HRV

In springtime, flooding occurs in the delta area due to snow melting on the mountain. This is essential seasonal dynamics for the vegetation of the deltas; submergence, leaching salinity and flushing silty soil down to the lake. Dynamic processes such as the destruction of vegetation, the scattering of seeds and the regeneration of the plant community occur naturally. SPOT HRV images of the Ili delta show us mosaics of the patch regeneration of

the plant communities. That means the natural vegetation in a delta consists of disturbance dependent plant species, and a difficulty with the ground truth in high resolution images taken some years before.

Reservoir dam construction in the Balkhas Lake basin has caused a kind of desertification of the Ili delta. This is not only due to the use of water for irrigation, but to flooding regulations.

5. Extensive irrigation agriculture and traditional land use

Traditional land use in the past had close ties to natural conditions. The environment of the Silk Road and colonies including famous trading cities such as Samalkand and Tashkent offers suitable conditions for oasis agriculture. That is, the environment is neither a mountainous zone nor a desert lowland. As in Uzbekistan, oasis agriculture at the foot of a mountain range can capture rainfall. Thus, traditional cotton and silk worm production had been sustainable in Uzbekistan. In Kazakhstan, however, nomadism had been the most suitable and sustainable land use in arid areas because of the lack of such an environment.

On the other hand, wetland were chosen for large scale irrigation agriculture where an appropriate drainage system, the most important countermeasure against salinization, is difficult to construct. Even under natural conditions with flooding, some parts of a delta are covered with Solonchak and Takyr soils where biomass is very limited. These condition are clarified with a color synthesis image of NOAA LAC which consists of visible range (blue), infrared (green) and thermal range (red, reverse). We can distinguish salinized soils from clouds which are almost inevitable for large areas.

6. Saksawool and barbecue

The riverside forest has a large standing mass per unit area, but only occupies a limited lowland in the vast desert region. Here we must mention Saksawool, which depends on little precipitation and comparatively deep underground water. It is a drought tolerant, C4, and large shrub which has the largest biomass in the area. There are two species, namely *Haloxylon persicum* and *H. aphyllum*, the former preferring sandy condition. The height and density of the Saksawool woodlands are mainly determined by the ground water level. They form sparse communities of less than 1 m in height under dry conditions. However, closed stands around the irrigated farms sometimes reach 6 m in height.

We can clearly see the examples around the Bereke farm near the Bakanas in the Balkhas basin by means of a false color composite image of SPOT HRV. Along the drainage line,

which is a geologically old river flow, on activated Saksawool community can be recognized. This is thought to be a temporal stage in a change to a Tsugai forest.

On the other hand, a main dinner entree of the nomads is barbecue of mutton called Shashrik. The charcoal of Saksawool is the best fuel for cooking, and its usage and regeneration were considered to be in a balance before the 1950s. But it has been on a remarkable decrease. One of the reasons for this is the shortage and the rise in price of oil and coal after the dissolution of the Soviet Union. Saksawool woodlands, once distributed widely in the former Aral Sea shore region, have mostly been cut down already. We can see some experiments with afforestation in the Saksawool woodland, but they have not been a sufficient success.

7. Invasion by plants on the exsiccated sea bed of Aral

It has been said by journalist that the exsiccated sea beds are covered with only salty sand and silty clay. However, through the use of SPOT HRV images and careful ground truth, information about the exsiccated sea beds proved this statement to be an exaggeration. Moving sand dunes, which were caused by overpasturing, are in existence only around villages.

On the exsiccated sea bed of the Aral Sea, invasion and plant succession are now occurring on a very dynamic basic. Pioneer plants here are the annual hyper halophytes: *Atriplex fominii*, *Salicornia europaea*, *Suaeda arcuata*. Sometimes, a very large plant community on a salt swamp is established during the initial decade, but then it declines as the environment changes. The invasion of *Tamarix* spp. occurs in the early stage and endures for a comparatively long time. As a results, we can clearly notice belts of vegetation in the classified Satellite image using three channels and an NDVI channel of SPOT HRV. Plant succession along the process from a salt swamp to a dry land occurs according to the soil properties and other conditions. There are three main directions ; namely halophyte, meadow and psammophyte directions (Ogar 1995).

It is an astonishing fact that we can see vegetation even on the exsiccated sea bed in this extremely dry region. We must add, however, that we could not find any Saksawool which is the most important species for the environment.

8. Trade off relationship

Some ecologists do not recommend rice production in such arid areas. It is true in one sense, however, that rice requires almost the same habitat as *Phragmites* and rice production may be a natural land utilization. This means that rice paddies are in a trade off relationship

with natural wetlands. The NDVI images in summer from NOAA LAC show large irrigated farms and natural wetlands clearly, and prove that the area of irrigated farms reaches up to one sixth of the wetlands in the Ili River basin. The proportion is far smaller than that for the Aral region. This may be the main reason why the Balkhas area has fewer problems with cultivation, and in a sense, with the nature conservation of wetlands which is a treasure chest of wild life.

Wetlands conservation, revegetation of the Tsugai forest, and the Saksawool woodlands are needed for the restoration and the conservation of natural productivity and biodiversity in the arid desert areas of Middle Asia.

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