CHINESE GEOGRAPHICAL SCIENCE
Volume 2, Number 3, pp.266–276, 1992
Science Press, Beijing, China

APPLICATION OF REMOTE SENSING TECHNIQUE TO THE INVESTIGATION ON REED RESOURCES OF BOSTEN LAKE

Hua Runkui (华润葵) Li Yuqin (李玉琴)

(Changchun Institute of Geography, Chinese Academy of Sciences, Changchun 130021, PRC)

ABSTRACT: It is efficient and reliable to investigate the reed resources of Bosten Lake in Xinjiang, characterized by complicated types of reed land and very different reed growth using colour infrared aerial photos, Landsat images and multi band imagery. At first, on the basis of Landsat images and relevant data, we analyzed the ecological environment of the studied area, the characteristics of reed land types and imaging mechanism to determine the program for abstracting remote sensing information and aerial photographic conditions. On the processed Landsat images and aerial photos, we considered typically geographic features and reed land types, preselected ground sampling sections and sites, then determined indexes classifying reed land types according to sampling data and image characteristics, established various interpretation keys, drew distribution maps of reed land types and measured the area of various types of reed land following geometric correction. On the other hand, based on sampling values and habitat conditions of reed, we divided the studied area into a number of pieces, estimated weight per unit area with weighted average method one piece by one piece, finally calculated the total reserve of reed resources.

KEY WORDS: remote sensing application, reed resources, resources inventory, Bosten lake

I. INTRODUCTION

Bosten Lake is in the Yanqi basin east of the Tianshan Mountain in the Xinjiang Uygur Autonomous Region. It covers an area of 988 square kilometers and is the biggest fresh water lake in the inland of China. In the front of the Kaidu River delta southwest of

the reed swamp develops (Fig.1).

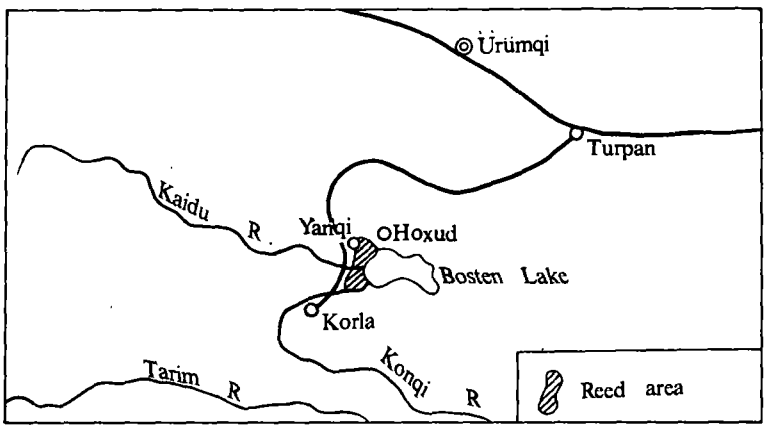

Fig.1 The location of reed area in Bosten Lake (1:6,600,000)

The reed swamp of this region receives an ample supply of snow melt water and ground water, so that it has very good water conditions. The soil consists principally of humus swampy soil, peat soil and saline peat soil. The region is in the hinterland of Eurasia continent, the climate belonging to dry climate and the sunshine being long, the accumulated temperature high, the range of temperature of day and night large during reed growing season. This makes it very suitable for the growing and developing of reed. So the reeds of Bosten Lake are very tall in height, the stems are very thick, the leaves luxuriant, the fibre long. Bosten Lake is one of the most important places that produce high quality reed in China.

But the long period needed for the developing of reed swamp will inevitably leads to the thickening of the reed root, which will cause water nourishment to become out of balance. In the higher zone of the reed land, the land surface water is scarce in supply, and the ground water table is below 0.5 meters, the land surface is alkali, forming saline peat soil, which seriously restrains the growth of reed, giving rise to natural reed degeneration. In recent years, due to the decreasing of water level of Bosten Lake and unreasonable government management, the tendency of degeneration has been aggravated. Only in the peripheries of the river and lake, and in the lowlying land where the water condition is better, where the land receives the drainage and irrigation of farmland water and where the content of the soil's organic matter is high, the reeds can have slight development. As was stated above, the difference of environmental conditions leading to the intricate property of growth and distribution of the reeds of Bosten Lake bring into some difficulties for reed resources inventory. From August 1981 to April 1982, we made an investigation of the reed resources of Bosten Lake, by compiling the distribution maps of reed resources, measuring the area of the various reed land types, and calculating the reserve quantity of reed re-

sources by using the method of checking preselected ground samplings and judging the weight per unit area of each piece of every type, and also by using the infrared color aerial photos and Landsat images. We did this through a remote sensing technique. All this provides a recent resources base for the construction of paper making in Korla City of southern Xinjiang.

II. THE INTERPRETATION OF SATELLITE PHOTOGRAPHS

The remote sensing inventory of resources usually uses the method of combining aerial and satellite photographs. This method may also be divided into the two parts below. One is that the satellite photographs coordinate the sampling investigation of big scale aerial photographs and ground sampling investigation. The other method is that aerial photographs coordinate satellite photos to preanalyze the ground characteristics of the studied area and imaging mechanisms in order to determine the optimal program and aerial photographic conditions, to preselect the ground sampling zone, as the supplement data of aerial photos interpretation in order to correct the regional misinterpretation due to aerial photos lacking fidelity (Fig.2).

By analyzing the satellite photographs, it can be seen that the ecological condition of reed in Bosten Lake is more complicated, the growth tendency very different, the images of reed land types in photographs are influenced by either the heavily saline soil or the influence peat soil, making the interpretation of types more difficult. The integral reflectance ratio of the near-infrared wave band of reed which grows very well and the more heavily saline soil was measured to be respectively 0.57 and 0.63 in the MSS-7 satellite photographs, and in the field it measured 0.59 and 0.65 on the spectrometer. Because the reflectance ratio of both ground objects are very close on the near-infrared wave band, they appear white in the MSS-7 satellite photographs. And because the reflectance ratio in both saline peat soil on which small and sparse reeds grow, and reeds that grow moderate are very close, they both appear grey in the MSS-5 satellite photographs and aren't easily distinguished. It is obviously possible to interpret incorrectly the reed land types using the simple band image under ordinary circumstances. So, it is therefore necessary to combine two or more wave band images.

To determine the photographic and positive developing conditions on the basis of analyzing satellite photographs, that is to determine the remote sensing wave band, the type of image, the exposure of photographs and positive processing condition, the image density on the satellite photographs of different wave band of the different ground objects of reed land in Bosten Lake was exchanged specifically into the reflectance (Table 1), and further the diagram of relationship between the reflectance standard deviation and wave band is drawn (Fig.3). It can be seen from Fig.3 that the green, red and near-infrared remote sensing wave bands may be selected to recognized reed land types of Bosten Lake.

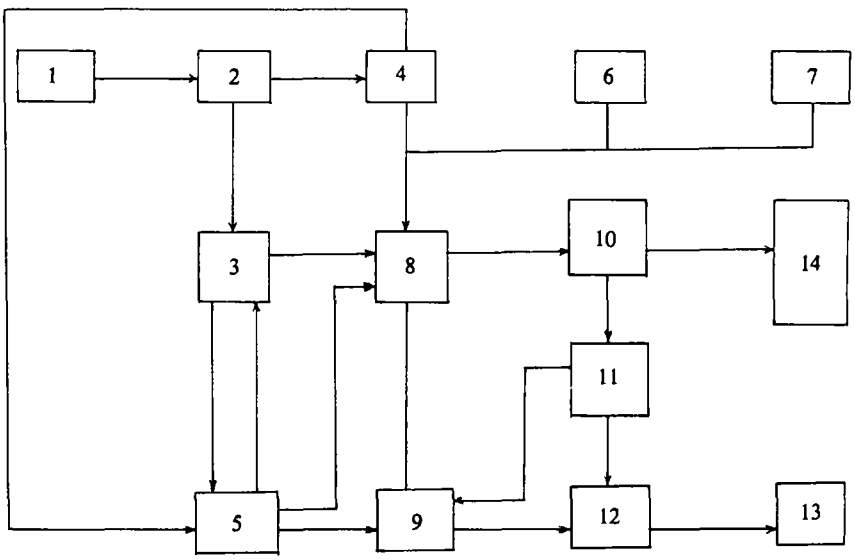

Fig.2 Process of investigation on reed resources of Bosten Lake with the remote sensing method

1. Satellite photographs
2. Characteristics of reed land types and analysis of image mechanism
3. Satellite image processing and abstraction of reed land types information
4. Color infrared aerial photographs
5. Preselected ground sampling
6. Low altitude, ground photograph
7. Relative image, script data
8. Establishment of interpretation keys of reed land type and interpretation
9. Unit weight judgment
10. Geometric correction transforming to image
11. Area measuring of each piece and every type
12. Calculation of reserves of various type
13. Total reserve of reed resources
14. Delineation and printing

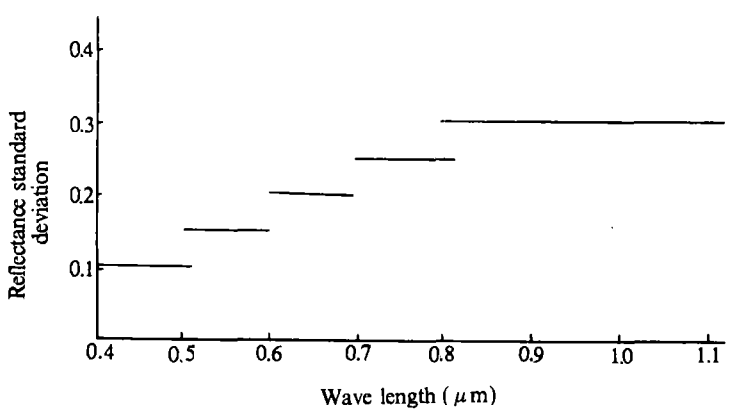

Fig.3 Relation between reflectance standard deviation of ground spectrum and wave band in a reed section of Bosten Lake

So it is suitable to adopt the color infrared aerial remote sensing of wave length 0.5—0.58μm. Since the wave bands of multi—spectrum photographs have the flexibility of selecting various types of images and correcting photographic exposure, using the narrow wave band multi—spectrum photographs may get a better result. The reflectance ratio of relevant objects in Table 1 is substituted into the calculative formula of photograph exposure, the best photographic exposure of the reed land of Bosten Lake can be calculated. Because the remote sensing inventory will not only inventory abstract of information of reed land types, but also judge water body elements (such as organic matter of water), this element should be considered in selecting the types of photos and determining the photographic exposure. In order to give prominence to reed land types, two kinds of exposure and two kinds of processing positives were adopted for the infrared color photo negatives, further improving the spectrum resolution of the reed types.

Table 1 Reflectance of various bands of features in reed sections of Bosten Lake

Type	Wave band			
	MSS—4	MSS—5	MSS—6	MSS—7
Saline land	0.58	0.61	0.63	0.63
Saline peat soil	0.28	0.31	0.33	0.35
Humus swampy soil	0.16	0.18	0.15	0.13
Reed	0.35	0.32(Oct.)	0.61	0.57(Oct.)
		0.18(Aug.)		0.65(Aug.)
Water body	0.21	0.16	0.12	0.04

III. GROUND PRESELECTING SAMPLING

Ground sampling investigation is a necessary step of a remote sensing resources inventory. Its aim is to get the unit area weight of the reed land of various types and to build up the interpretation keys of reed land types. The ground sampling adopts the two methods of preselected sampling and random sampling.

On the basis of satellite photographs and recently taken infrared color film preinterpretation, according to the image features of the reed land in remote sensing imagery, reed lands are vaguely divided into 4 types, then the ground sampling section is selected in the imagery. The selection of the sampling section will consider the representative characteristics of geomorphology, hydrology, soil and other geographic factors. The sampling site is selected from the sampling section, with the selection of sampling site principally considering characteristics in the same sampling section.

Field specimen investigation is done on the basis of selected section and the sampling

site. The selected specimen should principally represent the average value of the sampling site and get the limited value of reed unit area weight of the sampling site. The unit weight average value is the weight of per unit area of the sampling site.

The random sampling is used as the supplementary means of preselecting sampling. It doesn't consider the image features of aerial and satellite photographs, but it carry out vertical and horizontal profiles investigation in the selected sampling section. After having been sampled, it will compare with the aerial and satellite photographs.

To adopt the two methods, not only gives play to the priority of remote sensing technology, but also avoids the manned difference caused by the unilateral, which may exist in the preselected sampling. Twenty-seven sampling sections, 79 sampling sites, were selected and the 163 specimens were measured in this.

IV. THE INTERPRETATION OF REED LAND TYPES

On the basis of various remote sensing data and the ground sampling data obtained above, reed land types may be divided, the interpretation symbol of the type may be built and the type distribution may be read.

1. The Classification of Reed Land Types

According to the image feature in the remote sensing image, and the ground sampling data, considering the natural condition of reed growth in and the different utilization value, the reed land of Bosten Lake is classified into 4 types, the classification indexes are shown in Table 2.

Table 2 Classification indexes of reed land types of Bosten Lake

Indexes	Height (m)	Stem diameter (cm)	Coverage (%)	Dry weight per unit area (kg/ m^2)
First type of reed	> 3.5	> 1.2	> 80	> 1.5
Second type of reed	2.5–3.5	0.8–1.2	60–80	0.8–1.5
Third type of reed	1.5–2.5	0.5–0.8	40–60	0.4–0.8
Fourth type of reed	< 1.5	< 0.5	5–40	< 0.4

2. The Establishment of Interpretation Keys of Reed Land Types

Interpretation keys are the basis of classifying reed land types, the interpretation keys being built according to the image feature of the various indexes in remote sensing imagery and geomorphology, hydrology and soil conditions.

The reed is hydrophilous plant, the first type of reed grows high and densely on the edges of the lake, river and in lowlying land, where the water conditions are good, the soil is

fertile, the organic matter content high, and the salt content low. The surface of this region is uneven, with many ditches and hollows where the crown of the reed is identical with the rise and fall of the surface of the land, which has caused many shallow areas so that the image feature of bright red fine hair globe appears in the infrared color aerial photographs.

The second type of reed grows mostly in the damp regions without stagnant water. In these regions the soil is made up of peat soil, the content of its organic matter is 4%—5%, the content of salt is only 1%, the ground surface is smooth, and the reeds grow evenly so that they appear an even red in the imagery.

The height of the first and second type of reed is over 2.5 meters, the highest reed measuring 4—6 meters, so they represent an obvious shadow on the water surface. The height of the reed is calculated on the basis of the sun angle and the width of shadow on the photographs.

The third type of reed grows in the place far from the river, the lake and the low-lying land, where water is insufficient, the surface of the land is drier with slight salinization so that the reed doesn't grow well. The coverage is also small, so they're represented by a spot of orange and yellow-green on the images.

The fourth type of reed grows in the higher area of the reed section, the water condition seriously scarce, the content of salt there more than 11%, the soil saline peat soil, making the reed sparse and small and because it grows yellow earlier in the section, it appears yellow-green in color on the infrared photographs. The main interpretation keys are listed in Table 3.

Table 3 Interpretation keys of color infrared images of reed land types of Bosten Lake

Type	Direct marks		Indirect marks		
	Color hue	Shape	Feature of landform	Hydrologic feature of topsoil	Soil type
First type of reed	Light red	Fine globe shape	Shallow lowland by river and lake edge	Shallow stagnant water	Humus swampy soil
Second type of reed	Red	Flat shape	Transition zone between shallow lowland of river and lake and flat land	Damp	Peat soil
Third type of reed	Yellow and green between orange and red	Spot shape	Flat land	Drier	Peat soil
Fourth type of reed	Yellow and green	Irregular spot shape	High flat land	Extremely dry	Saline peat soil

3. The Distinguishment of Reed Land Types

Distinguishment of reed land types is mainly based on the interpretation keys of various types in infrared color aerial photographs combined with satellite photographs, superlow—space photographs, ground photographs, topography map and other relevant geographical data, using the relevant analysis method to do synthesis analysis.

This distinguishment is to adopt the visual interpretation method. Because the color in the infrared color aerial photographs hasn't been corrected by the radiation emittance, the density and hue are not be true to the original in the center and edge of both the single image and between the images, leading to the interpretation keys to be inconsistent and easily produce incorrect interpretation. It is obvious that the photo received the influence of matter microreflection of ground objects. This influence seriously decreased the resolution of image. So, ground object images of different phases up to the nadir point in the overlapping strip should be consulted as much as possible.

On the other hand, satellite photographs have the priority of high macroscopic unbalance, but the correction on the loss of aerial photos by adopting the interpretation method of combining aerial and satellite photographs can be used. Furthermore, by uniting the interpretation keys of various aerial photos we can improve the accuracy of interpretation. The super—low space and ground photographs are also important data worth consulting.

V. MEASUREMENT OF REED LAND AREA, ESTIMATION OF WEIGHT OF EACH TYPE AND CALCULATION OF TOTAL RESERVES

After the reed land types have been distinguished, the distribution map of types which hasn't been corrected can be obtained. Then the map can be geometrically corrected and transformed on the 1:5 geography map which has been spot spread and mosaic. Finally, the area is measured for each piece and every type by using STANLEY Automatic Reading Integral Calculating Device, which uses English units and makes the error less than 1.4% when the digital map area measurement device produced by our country.

The estimation of per unit weight is more complicated. From Table 2 we can see that the indexes of per unit weight of the same type of reed have a bigger amplitude, and the total reserves may be error if the arithmetic value of per unit weight of each sampling site of every type is used as the only calculated standard of the total reserve in the whole region not considering the weighed weight of area which every sampling site represents.

To improve the precision of interpreting the resources reserve, when interpreting, every type of reed should be classified into many subsets of per unit weight, except when drawing up the four types of reed, then the weight average of every example is used as the unit

weight of that type of reed.

Because the growing condition and growth tendency of reed in the whole reed region are different and the reed section may be classified into many pieces in the distribution map based on the image feature of the aerial photographs corresponding with the field measurements per unit weight of the ground sampling site, showing the condition and tendency of growth. Then the level of per unit weight of reed land types may be estimated in each piece of every type, for example, although the type of reed is the same the per unit weight of different sampling sites is different, showing that the image features which they correspond with some differences. On the other hand, water and soil conditions are poor, the reeds grow uneven, and they appear so shatter so it is necessary to do a synthetic, and reject and accept when interpreting. It is very easy to classify the whole region into many sections based on these differences. The reed land of Bosten Lake is classified into 16 sections in this inventory.

After the sections were classified, the per unit weight subset can be estimated for each piece and every type.

Even if the same type of reed is in the same section, we may distinguish the difference in per unit weight based on the sampling site, therefore it is necessary to consider the weight of the area and determine the subset of per unit weight of each piece and every type. The per unit weight subset can be estimated based on the image features of the sampling site in other sections if there are not enough or no sampling sites in the section. On the other hand, because of the restraint of the scale of the image, reed land types in some images are seriously shattered and the type spots are too small. This can't be shown by scale, must be synthesized, received and rejected, then the weight must be done based on the tendency of synthesizing, receiving and rejecting.

By using these methods, each type of reed land in Bosten Lake is classified into 7 per unit weight subsets, thus four types are classified into 28 per unit weight subsets.

The per unit weight of each piece and each type in the 16 sections has been estimated, thus the per unit weight of every reed type in the whole region may be finally calculated. Assume Qi is the per unit weight of i type of reed,

$$Qi = \frac{\sum_{i=1}^{n} g_{ij} A_{ij}}{\sum_{i=1}^{n} A_{ij}}$$

Q_{ij}—the subset of per unit weight of i type of reed in j pieces

A_{ij}—the percent of i type of reed in j pieces in the total area of the types

After the per unit area weight of the various types of reed was calculated, the total reserves of reed resources may also be calculated. Assume w is the total reserves of resources,

$$W = \sum_{i=1}^{4} Q_i \cdot S_i$$

S_i—the total area of i type of reed

V. ERROR ANALYSIS

The errors in remote sensing inventory are found in two areas: geometric error and the estimation error of per unit weight.

1. Geometric Error

The 1:50,000 topographic map which is a spread mosaic has been adopted as the standard of geometric correction and area measurement. The geometric error that is less than one thousandth may be omitted. The error is less than or equal to $\pm 0.7\%$ by using these two kinds of area measurement devices when measuring the area.

2. Estimation Error of Per Unit Weight

Because the per unit weight is estimated after having analyzed many-side factors and adopting many times of weight, each type of reed land in Bosten Lake has been classified into 7 subsets of unit weight, the maximum estimation error of each type is no more than one seventh of the amplitude of unit weight of that type. After having been calculated, we see that the error of this part is less than or equal to $\pm 9.9\%$.

VI. CONCLUSION

The remote sensing technique is a more advanced method of resources inventory. This remote sensing inventory saved 85% in expenses and over 90% more in man power than regular ground inventory.

In remote sensing inventory of reed resources, three key steps are:

1) To analyze the type of reed land, and the image mechanism, to select the best method of abstracting information.

2) To do ground preselected sampling based on the image of the film.

3) To judge the unit weight of each piece and every type and the three main steps to improve the accuracy of resources interpretation.

The selection of chart technology should be based on the concrete situation of the studied area. In general, the reed land is easily distinguished from the surrounding objects, the spectrum characteristics of reed land is less influenced by background, they grow evener, and satisfactory results can be produced by combining the dense segment of single wave bands with the ground sampling. In the regions where reed land types are more complicated, and the growth is very different, the background influence is bigger, it is more convenient to adopt the more complicated method mentioned in this article.

REFERENCES

[1] 杨利普.博斯腾湖合理利用问题.自然资源，1980（1）.