MAPPING AND ASSESSMENT OF GRASSHOPPER HABITAT BASED ON LANDSAT TM IMAGERY IN THE QINGHAI LAKE REGION OF CHINA

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ABSTRACT

In the Qinghai Lake region of China, rangeland grasshoppers are the insects which not only harm seriously grasslands and livestock farming, but also have induced critical environmental problems. Although a great deal of effort on the basis of conventional methods has been made to monitor the grasshopper occurrence and, however, ideal results have not achieved mainly due to remote location and bad accessibility of the region, in conjunction with insufficient funds and facilities for the monitoring. In this study, a classification scheme of grasshopper habitats was designed firstly, and grasshopper habitats being most closely related to grasshopper occurrence were classified from Landsat TM images, achieved 84.23% in classification accuracy. In addition, an assessment on the classified grasshopper habitats was conducted against their probability of grasshopper occurrence and by means of the index system and the grade system developed in this study and used for estimating probability of grasshopper occurrence. Finally, a total 12 test sites were selected randomly from the study area, and the examination on the reliability of habitat assessment was carried out using *in situ* data collected in field. The results showed that within these test sites there were 8 ones which demonstrated a close relation between the grade value calculated from the systems and real grasshopper densities estimated in field. The remaining 3 sites displayed more or less deviations between the calculated grade values and the real grasshopper densities and, nevertheless, which could be well explained. Therefore, it was concluded that the methodology developed in this study are feasible and reliable.

1 INTRODUCTION

Rangeland grasshoppers (Orthoptera: Acrididae), the insects jeopardizing grasslands in northern and northwestern China, have brought serious harms to local livestock farming and induced critical environmental problems such as grassland degradation and soil loss (Ni *et al*., 1999). During the past long period, a great deal of effort based on the conventional methods has been made to monitor the occurrence and plague of grasshoppers in these regions. Nevertheless, the ideal results have not achieved for several reasons, such as remote location and bad accessibility, in conjunction with insufficient funds and facilities for grasshopper control. Consequently, it has become indispensable to use advanced technology such as remote sensing to realize the monitoring more efficiently of grasshopper occurrence.

Since early 1970’s satellite data such as Landsat MSS and TM or NOAA AVHRR have been used in monitoring of occurrence and plague of migratory locusts in many regions such as Northern Africa, Middle East, Australia and other regions (Pedgley, 1973; Hielkema & Howard, 1976; Hielkema, 1980; McCulloch & Hunter, 1983; Sinha & Chandra, 1985; Tucker *et al*., 1985; Bryceson, 1989). In these works the most commonly used is ‘indirect’ approach, namely, monitoring on locusts was through their ‘habitats’ instead of directly from satellite sensors in space. The reason why this approach was applied is because the body size of locusts is too small to be detected directly from satellite sensors. According to the ‘indirect’ approach, correlation analysis between habitat elements and locust activities was conducted and, in addition, probability of locust occurrence was estimated usually quite effectively and precisely. Unfortunately, the similar approach has not been used in the study of rangeland grasshoppers until late 1990’s.

Compared with the migratory locusts such as desert locust (*Schistocerca gregaria* Forskal), rangeland grasshoppers have their notable features, such as much smaller in body size, more dispersive in spatial distribution and nearly absent in migrating ability. All these features have made it much more difficult to monitor them directly from satellite sensors (Ni *et al*., 2003). Therefore, it has become an urgent task to explore how to use satellite data to assist the grasshopper monitoring more efficiently.

2 STUDY AREA

The Qinghai Lake region in eastern Qinghai Province of China is situated at 36°32′-37°15′N and 99°36′-101°47′E (Fig. 1)（Liu *et al*., 2004）. The elevation of the region ranges 3 200 m to 4 200 m above sea level, and its climate is characterized with dry, cold, and windy. Annual temperature averages only -2.3℃ with the annual precipitation of 325-397 mm and annual evaporation of 1 500-1 752 mm (Ni *et al*., 2007). The region is the most important livestock base for sheep grazing in Qinghai Province. However, damage from grasshoppers to grasslands has become a critical problem accompanied with the increasingly serious and frequent occurrence and plague in recent two to three decades, which has induced not only degradation of grasslands and declination of grass productivity, but also deterioration in the environment (Jiang *et al*., 1999).

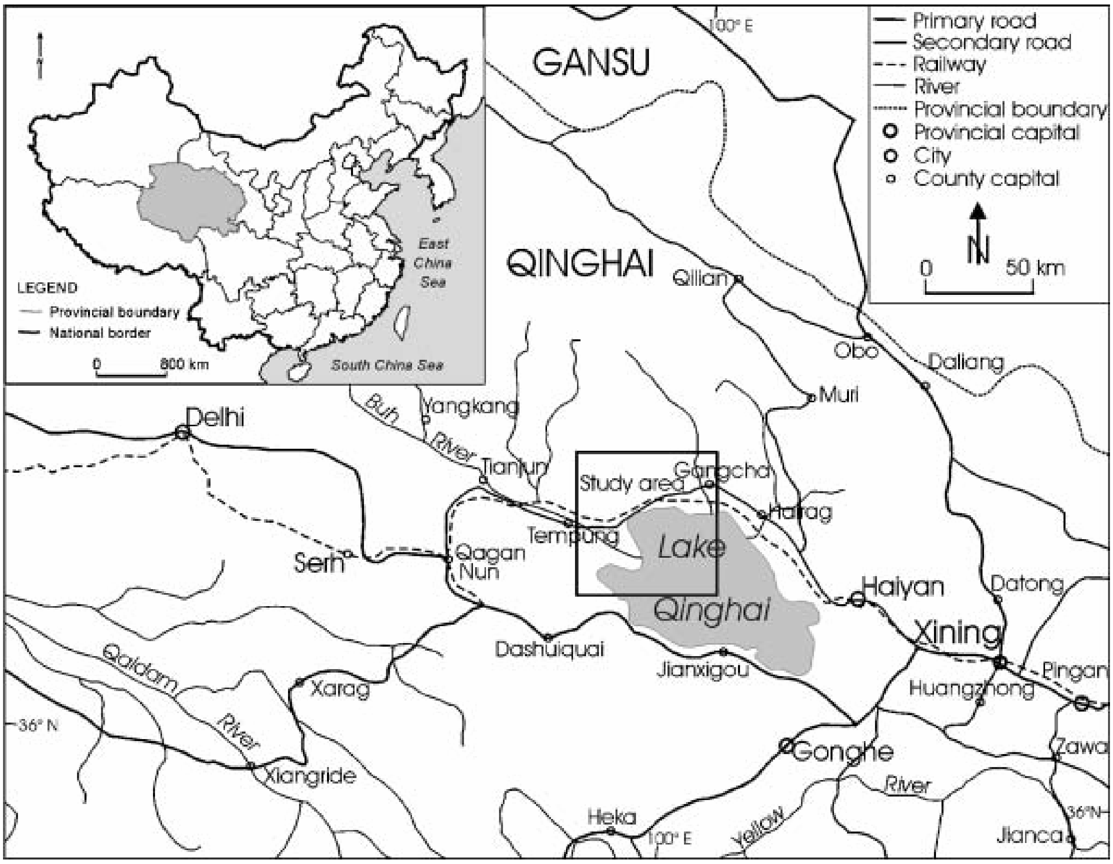


Figure 1 Location of the study area

There were ten species of grasshopper dominated in the region. They are *Myrmeleotettix palpalis* (Zub.), *Chorthippus dubius* (Zub.), *Choethippus fallax* (Zub.), *Angaracris barabensis* (Pall.), *Angaracris rhodopa* (F.-W.), *Gomphocerus licenti* (Chang), *Dasyhippus barbipes* (F.-W.), *Calliptamus abbreviatus* (Ikonn), *Bryodema luctusum luctuosum* (Stoll), and *Bryodemella tuberculatum dilutum*(Stoll).

3 DATA AND METHODS

A total of 118 sampling sites were selected from the study area and based on the topographic map on a scale of 1:100 000 and the grassland map on a scale of 1:250 000. These sampling sites were visited during July to August of 2000-2003 (Liu *et al*., 2005). At each site, the data being relevant to grasshopper occurrence, i.e., landform, vegetation, soil and moisture condition were collected and, at the same time, grasshopper density was estimated based on grasshoppers manually ensnared by a net. In addition, the climatic data i.e., temperature, precipitation and evaporation were obtained from local meteorological stations in conjunction with field observation at some sampling sites. All these data were processed in laboratory and a database was set up and used in follow-up analysis.

The remotely sensed data used in this study were Landsat TM images with 133/34 and 133/35 in row/line and received in June to August of 1999-2002. Firstly, the image data were corrected radiantly and geometrically with assistance of GPS data of the selected control points on the TM images. Secondly, using the Gaussian maximum likelihood classifier and by means of the software ENVI 4.0 grasshopper habitats were classified. Finally, an examination on accuracy of the classification was conducted using *in situ* data collected in field.

Following the habitat classification, assessment on grasshopper habitats in terms of probable occurrence of grasshopper was carried out. Firstly, an index system for habitat assessment was designed. It was consisted of the habitat elements, i.e., the components of topography, vegetation and soil, and their ratings with indices representing the probability of grasshopper occurrence. Secondly, in order to examine reliability of the approaches developed in this study, a total 12 test sites were selected randomly from the study area and were assessed using the index system and the *in situ* data collected in field.

4 RESULTS AND DISCUSSION

4.1 Classification of grasshopper habitat

4.1.1 Classification scheme of grasshopper habitat

Habitat of insects refers to a spatial unit on ground in which individuals, population or community of the insects undergo their life cycle (Yan & Chen, 1998), and it is usually consisted of a number of environmental elements such as landform components, soil properties, moisture conditions together with vegetation types and their characteristics. These elements within a same type of habitat usually have a certain degree of similarity. Classification of grasshopper habitat means a grouping of habitats with similarity in feature of the environmental elements. Therefore, grasshopper habitats belong to a same type would be more or less similar in grasshopper species and grasshopper density. However, it should be mentioned that when grasshopper habitats were classified more attention should be paid to those elements which dominate the kind of habitat in terms of features and function.

Based on the above-mentioned considerations and using *in situ* data collected in the study area, a classification scheme of grasshopper habitat was designed as shown in Table 1. The table shows that there are six kinds of grasshopper habitat which have a close relation with grasshopper occurrence, and each of them is relatively similar in dominant grass species and grasshopper species. This scheme was used in habitat classification of the study area based on the Landsat TM images.

4.1.2 Image Classification of grasshopper habitat

Training data are indispensable for the supervised classification of grasshopper habitat based on remotely sensed imagery. In this study, firstly, a total of 189 training areas were selected from the Landsat TM Images and assisted by the *in situ* data. In addition, a statistical analysis on spectral features of these training data was conducted

Table 1 The classification scheme of grasshopper habitat

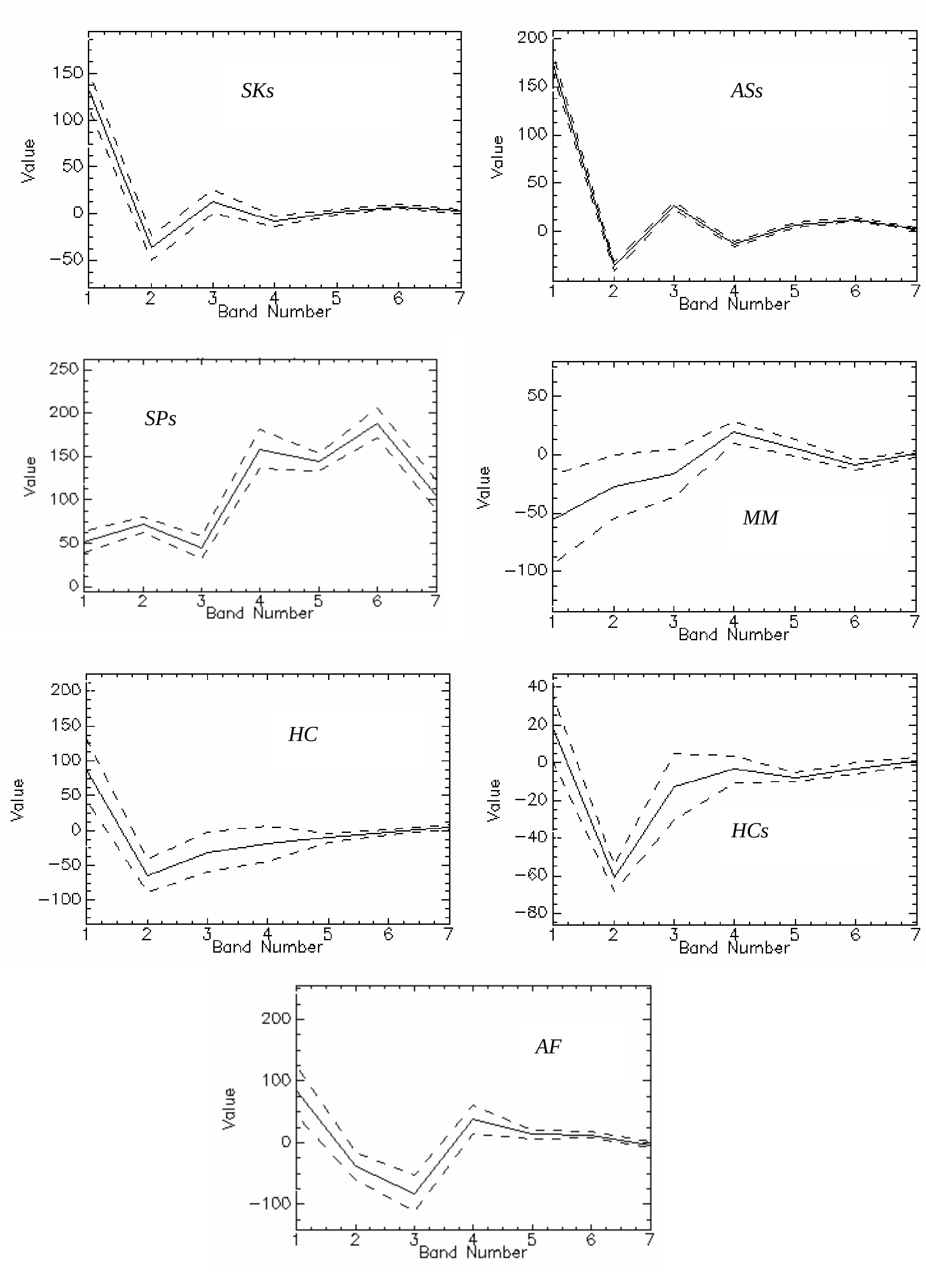
Habitat type	Dominant grass species	Dominant grasshopper species
1)Steppe dominated by *Stipa Krylovii*	*Stipa Krylovii* Roshev. *Stipa breviflora* Griseb.,*Agrophyron cristatum* (L.) Gaertn., *Orimus kokonorica* (Hav.) Keng	*Chorthippus dubius* Zub., *Myrmeleotettix palpalis* Zub.
2)Steppe domi. by *Achnatherum splendes*	*Achnatherum splendes* (Trin.), Nevski, *Agrophyron cristatum* (L.) Gaertn., *Orimus kokonorica* (Hav.) Keng	*Chorthippus dubius* Zub., *Myrmeleotettix palpalis* Zub.
3)Steppe domi. by *Stipa pupurea*	*Stipa pupurea* Griseb., Kobresia parva (Nees) Wang et Tang ex Y.C. Yang, *Kobresia capillifolia* (Decne) C. B. Clarke, *Leymus secalinum* (Gergi) Tzvel	*Chorthippus dubius* Zub.
4)Marsh meadow	*Blysmus sinocompressus*	—
High-cold meadow	*Kobresia humilis*,(C. A. Mey) Serg., *K.obresia capillifolia, Kobresia pygmaea* (C.B. Clarke),*Stipa* spp., *Potentilla* spp.	*Chorthippus fallax* Zub., *Chorthippus dubius* Zub.
5)High-cold shrub meadow	*Salix cuplaris* Rehd., *Potentilla fruiticosa* L., *Caragana jubata* (Pall.) Poir., *Kobresia capillifolia* (Decne) C. B. Clarke, *Kobresia humillis* (C. A. Mey) Serg., *Polygonum viviparum* L.	*Chorthippus fallax* Zub., *Chorthippus dubius* Zub.
6)Abandoned farmland	*Stipa Krylovii* Roshev. *Stipa breviflora* Griseb., *Achnatherum splendes* (Trin.)	*Chorthippus dubius* Zub., *Myrmeleotettix palpalis* Zub.

and the results (Fig. 2) were used in the classification of grasshopper habitat in the study area. Moreover, field examination on the classification accuracy was carried out at 50 randomly selected sites, which showed the classification achieved 84.23% in overall accuracy.

4.2 Assessment of grasshopper habitat

4.2.1 Assessment methods

Based on an analysis of the relation between the habitat elements and probability of grasshopper occurrence an index system used in habitat assessment was established as shown in Table 2. It can be found that all habitat elements were divided into three categories, i.e., vegetation, topography and soil, and each of them was further divided into several elements. In addition, each element was divided into four grades which were coincided with the degrees of probability of grasshopper damage to grassland, i.e., serious damage, rather serious damage, general damage and no damage. Based on



SKs: Steppe dom. by *Stipa Krylovii*; *ASs*: Steppe dom. by *Achnatherum splendens*; *SPs*: Steppe domi. by Stepa pipurea; *MM*: Marsh meadow; *HC*: high-cold meadow; *HCs*: High-cold shrub; *AF*: Abandoned farmland

Figure 2 Spectral statistics of the training data

Table 2 The index system for grasshopper habitat assessment

Habitat element		Damage degree of grasshoppers to grassland			
		Seriously (□)	Rather seriously (□)	General (□)	No damage (□)
Vegetation	Vegetation index (NDVI) (F_1)	0.24-0.38	0.18-0.24 or 0.38-0.45	0.12-0.18 or 0.45-0.50	<0.12 or >0.50
	Dominant species (F_2)	*Stipa Krylovii* or *Achnatherum splendens*	*Stipa purpurea*	*Stipa purpurea*, *Kobresia* spp.	*Kobresia* spp. or *K. tibetica*
	Total coverage (F_3)	<60%	60% -75 %	75% -85 %	>85%
Topography	Elevation (*F*4)	3200-3300 m	3300-3400 m	3400-3500 m	>3500m
	Aspect (*F*5)	S	AE or SW	NE or NW	N
Soil	Soil type (*F*6)	Light chestnut	Chestnut	Dark chestnut	Marsh soil or high-cold meadow soil
	Texture (*F*7)	Loam	Sandy loam	Clay loam	Sandy
	Moisture content (*F*8)	15-25%	<15%	25-35%	<15% or >35%

this index system, a scheme for grading grasshopper habitat in terms of probability of grasshopper occurrence was established (Table 3).

4.2.2 Verification on the method

In order to verify the index system and the grading scheme a total of 12 test sites were selected from the study area and were taken to examine the reliability of the method used in this study (Table 4).

Table 4 shows that, in a total of 12 test sites there are 8 test sites which demonstrate

Table 3 The scheme for grading grasshopper habitat

Grade of probable occurrence of grasshopper	Elements used in habitat assessment								Grade value (*F*)
	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	
□	16.0	12.0	16.0	8.0	8.0	8.0	5.6	6.4	>70.0
□	12.0	9.0	12.0	6.0	6.0	6.0	4.2	4.8	50.0-70.0
□	8.0	6.0	8.0	4.0	4.0	4.0	2.8	3.2	30.0-50.0
□	4.0	3.0	4.0	2.0	2.0	2.0	1.4	1.6	<30.0

Table 4 The assessment on grasshopper habitat for selected sites

Site No.	Habitat type*	Elements used for habitat assessment								Total	GD**	Grade
		F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8			
1	*SKs*	16	12	12	8	8	8	5.6	6.4	76.0	50	□
2	*SKs*	16	12	8	8	6	8	5.6	4.8	68.4	23	□
3	*HCsm*	4	3	4	4	2	2	2.8	1.6	23.3	6	□
4	*SKs*	12	12	4	8	4	8	5.6	4.8	58.4	13	□
5	*SPs*	12	9	12	6	8	6	5.6	3.2	61.8	35	□
6	*ASs*	16	12	8	8	6	8	5.6	6.4	70.0	16	□
11	*HCm*	4	6	12	2	6	2	2.8	1.6	36.4	4	□
13	*SKs*	16	12	12	8	8	8	5.6	6.4	76.0	50	□
30	*SPs*	12	9	12	6	8	6	5.6	3.2	61.8	30	□
31	*ASs*	16	12	16	8	8	8	5.6	6.4	80.0	52	□
32	*SPs*	12	9	16	6	8	6	5.6	4.8	67.4	55	□
34	*ASs*	16	12	12	8	6	8	5.6	4.8	72.4	30	□

*Code □ *ASs* (Steppe dominated by *Achnatherum splendens*); *HCm* (High-cold meadow); *HCsm* (High-cold shrub meadow); *SKs* (Steppe domi. by *Stipa Krylovii*); *SPs*(Steppe domi. by *Stipa purperea*).

**GD--Grasshopper density (heads/ m^2) observed in field.

good relations between grade value (*F*) calculated from the grading scheme and grasshopper density observed in field. However, in the remaining 4 sites there are 3 sites, i.e., the sites No. 4, 31 and 34, which have grasshopper densities observed in field lower than the grade values resulted from the assessment using the method developed in this study. The field checks on these sites indicated that the major reason for these deviations was that these sites had experienced with chemical spray for grasshopper control just in the previous year. There was only one test site (site No.5) which had lower grasshopper density than that inferred from the calculated grade. The reason why it deviated from the normal needs further explored. From theseresults it would be concluded that the methods developed in this study were feasible and reliable.

5 CONCLUSIONS

The study showed that in the regions like the Qinghai Lake region of China which have remote location and bad accessibility, it was feasible to monitor effectively rangeland grasshoppers through the grasshopper habitat classification and assessment using satellite image data. In this study, a total of 6 types of grasshopper habitat which were closely related to grasshopper occurrence were classified from Landsat images, based on the *in situ* sampling site data and using Gaussian maximum likelihood classifier. The field examination indicated the accuracy of habitat classification achieved 84.23% on an average.

Following the grasshopper habitat classification an assessment on grasshopper habitats

was conducted in terms of the probability of grasshopper occurrence. Using the index system and the grade scheme developed in this study, a total of 12 test sites were selected randomly from the study area, and were assessed against probability of grasshopper occurrence. The results showed that in these 12 sites there were 8 sites which demonstrated a good relation between the grade values obtained using the methods developed in this study and the grasshopper densities observed in field. In the remaining 4 sites, there were 3 sites which demonstrated some deviations in the grade values calculated using the methods in this study from and the grasshopper densities observed in field. The major reason for these deviations was that these sites had experienced with chemical spray for grasshopper control just in the previous year.
There was only one test site (site No.5) which had lower grasshopper density than that inferred from the calculated grade. The reason needs to be explored in future. Therefore, it would be concluded that the methods developed in this study and for grasshopper habitat assessment were feasible and reliable.

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REEFRENCES

Bryceson K P (1989). The use of MSSdata to determine the distribution of locust eggbeds in the riverina region of New South Wales, Australia. *International Journal of Remote Sensing*, 11:1749-1762.

Hielkema J U (1980). Remote sensing technique and mothodologies for monitoring ecological conditions for desert locust population development. Tech/series, FAO/USAID/INT/349/FAO, Rome.

Hielkema J U and Howard J A (1976). Application of remote sensing technique for desert locust survey and control. Technical series, AGP/LCC/76/4. FAO, Rome.

Jiang J J, Ni S X, Gong A Q, Wang W J, Zha Y, Wang J C and F. Foss (1999). Grassland degradation and its control in region around Qinghai Lake. *Pedosphere*, 9(4): 331-338.

Liu Y S, Hu Y C and Peng L Y (2005). Accurate quantification of grassland cover density in an alpine meadow soil based on remote sensing and GPS. *Pedosphere*, 15(6):778-783.

Liu Y S, Zha Y, Gao J and Ni S X (2004). Assessment of grassland degradation near Lake Qinghai, West China, using Landsat TM and in situ reflectance spectra data. *International Journal of Remote Sensing*, 25(20):4177-4189.

McCulloch L, Hunter D M (1983). Identification and monitoring of Australian plague locust habitats from Landsat. *Remote Sensing of Environment*, 13:95-102.

Ni S X, Jeffrey A. Lockwood, Wei Y C, Jiang J J, Zha Y and Zhang H L (2003). Spatial clustering of rangeland grasshoppers (Orthoptera: Acrididae) in the Qinghai Lake region of northwestern China. *Agriculture, Ecosystems and Environment*, 95:61-68

Ni S X, Jiang J J, Wang J C, Gong A Q and Wang W J (1999). Landscape ecology of the region around Qinghai Lake, Qinghai Province of China based on remote sensing. *Journal of Environmental Sciences*, 11(11):211-215.

Ni S X, Wang J C, Jian J J and Zha Y (2007). Rangeland grasshoppers in relation to soils in the Qinghai Lake region, China. *Pedosphere*, 17(1): 84-89.

Pedgley D E (1973). Testing feasibility of detecting locust breeding sites by satellite. Final Report to NASA on ERTS-1. Experiment. COPR London.

Sinha P P and Chandra S (1985). Monitoring desert locust breeding habitats through satellite imagery. *Plant Protection Bulletin*, 37(3-4):29-32.

Tucker C J, Hielkema J U and Roffey J (1985). The potential od satellite remote sensing of ecological conditions for survey and forecasting desert locust activity. *International Journal of Remote Sensing*, 6(1): 127-138.

Yan Z C and Chen Y L (1998). Impact of grazing on habitat structure and habitat selection of grasshoppers of *Leymus chinensis* prairie. *Acta Ecologica Sinica*, 18(3):278-282.