Grain loss in main disaster area caused by Wenchuan Earthquake

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Abstract: This paper focuses on grain production loss caused by Wenchuan Earthquake. The damage of the cultivated area as well as the yield of winter wheat has been assessed. In order to estimate winter wheat acreage damaged by the earthquake, airborne CCD images and IRS P6 LISS4 MN data were used. Damaged arable land were extracted by photo interpretation, while winter wheat proportions were collected by ground survey using GVG instrument for plain area or interpreted from airborne images for mountain area. The winter wheat acreage damaged by the earthquake was calculated using winter wheat proportion multiple the area of damaged arable land and statistic at county scale. To estimate wheat yield, reliable agro-meteorological models were selected by taking into account the disperse distribution of winter wheat in mountain area. The results showed that only about 247.1hm^2 of winter wheat were damaged in the twelve main producing counties and the production loss of winter wheat was estimated to 1013778kg. As conclusion, the earthquake did not significantly affect the food production of the whole country. Nevertheless, since all farmers were evacuated in mountain area after the disaster, the problems of harvest in that region producing 220000t of winter wheat need to be addressed.

Key words: earthquake, grain, loss, remote sensing

CLC number: X43/TP79 **Document code:** A

1 INTRODUCTION

A severe earthquake, called Wenchuan Earthquake, occurred on May 12, 2008 in Sichuan, China. The earthquake caused heavy infrastructure damages besides human casualty. Moreover, large area of landslide and temporal barrier lake destroyed large amount of cropland in this main production area including Jiangyou, Shifang, Dujiangyan, Pengzhou, Mianyang and Anxian Counties, raising apprehension of food security for the whole country.

In this context, emergency estimation was carried out to assess an eventual grain production loss in the earthquake area, including the counties Beichuan, Qingchuan, Wenchuan, Anxian, Jiangyou, Maoxian, Mianzhu, Pengzhou, Dujiangyan, Shifang, Lixian and Wenxian. The results of this assessment were released on June 3, 2008, to the central government. This paper aims to introduce the methods used in grain production estimation in emergency case.

2 DATA AND METHODS

2.1 Data

To extract the information on cropland damage, very high resolution images from two different sources were used. 24 IRS P6 LISS4 MN images registered on May 19, 2007 were used to cover an area of 28840km^2. This source of data provided crucial landscape information before the earthquake. 34 strips aero-borne images of airborne images collected on 15, 16, 17 and 23 of May, 2008 enabled us to extract the damage information after the earthquake. This source of information covers an area of 12288km^2. (Fig. 1).

Historical crop acreage, yield and production information from statistical departments and meteorological information, such as daily temperature, precipitation, and solar radiation archive data were also collected for crop yield estimation. 1:100,000 landuse data in 2000 of the earthquake area was also collected to assist crop damaged area estimation.

2.2 Methods

In general, investigation on grain loss focused on the long term impact of natural disasters (Zheng & Huang, 1998; Luo 2007; Wang *et al.*, 2008), such as drought, flooding and high temperature. Studies (Jamieson *et al.*, 1994) were also reported on the effect of drought on biomass accumulation. Recently, more attention was paid to the impact of climate change on crop growth.

Received: 2008-12-16; **Accepted**: 2009-04-08

Foundation: Knowledge Innovation Programs of the Chinese Academy of Sciences (No. KSCX1-YW-09-01) and the National Key Technologies R&D Program of China (No. 2008BADA8B02).

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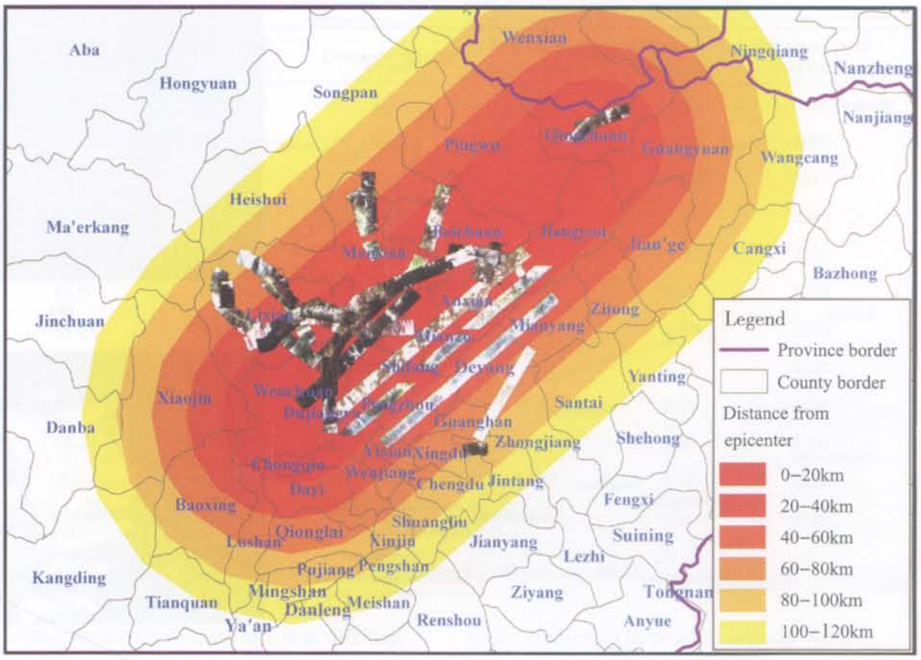


Fig. 1 Distribution of airborne images used for grain damage estimation

Both cropland damage and yield reduction caused by the natural disasters lead to grain production losses. In this emergency study following Wenchuan Earthquake, damage on the crop area and expected yield forecasts were investigated.

According to the crop phenology, winter wheat which was the only main grain crop at the disaster time was targeted in this study. Photo-interpretation of the remotely sensed data was used to extract the information, on cropland damage and the assessment of crop yield was carried out by agro-meteorological yield models.

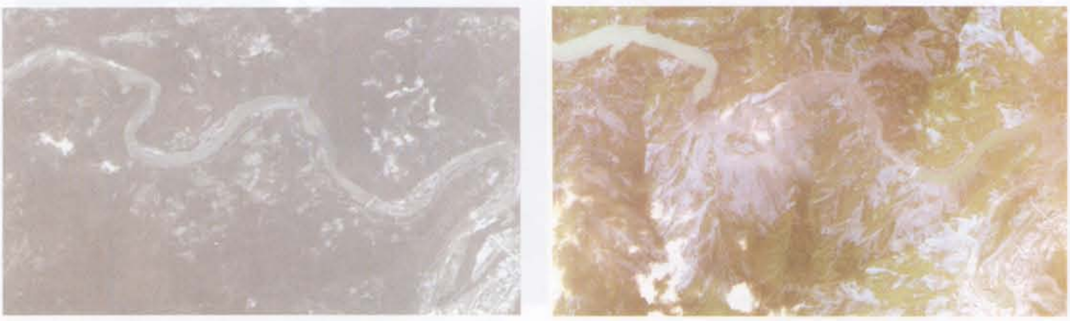
2.2.1 Winter wheat damage area monitoring

The damage on the crop area resulted mainly from landslides or inundation of barrier lakes. Change detection was carried out between the airborne images registered after the earthquake and the IRS P6 LISS4 MN imagery registered before the catastrophe. Meanwhile winter wheat fraction within cropland was derived from airborne photo sampling and ground survey operated by CropWatch programme (Wu & Li, 2004). The winter wheat damaged area can then be computed using the product of cropland damaged area and winter wheat proportion.

(1) Cropland damaged area monitoring

Since cropland damage mainly caused by landslide and barrier lake inundation in earthquake region, photo interpretation combining crop land distribution derived from landuse data. Fig. 2 showed the aerial images after the earthquake and a LISS4 image before the earthquake in Beichuan city. Large area of damaged cropland can be detected and easily extracted by interpretation.

Firstly, the boundary of landslides and barrier lakes was delimited manually on the 1∶100000 land use dataset in 2000. Fig. 3 showed the distribution of the damaged cropland distribution (a) and gave two example of damaged cropland in aero-borne images (b and c). Then, the extracted boundary of damage was merged with the cropland map derived from 1∶100000 landuse dataset. The area of damaged cropland can be computed within the airborne image. The proportion of the cropland



(a) (b)

Fig. 2 IRS P6 LISS-4 image on May 19, 2007 (a) and aerial images on May 16, 2008 (b) around Beichuan county seat

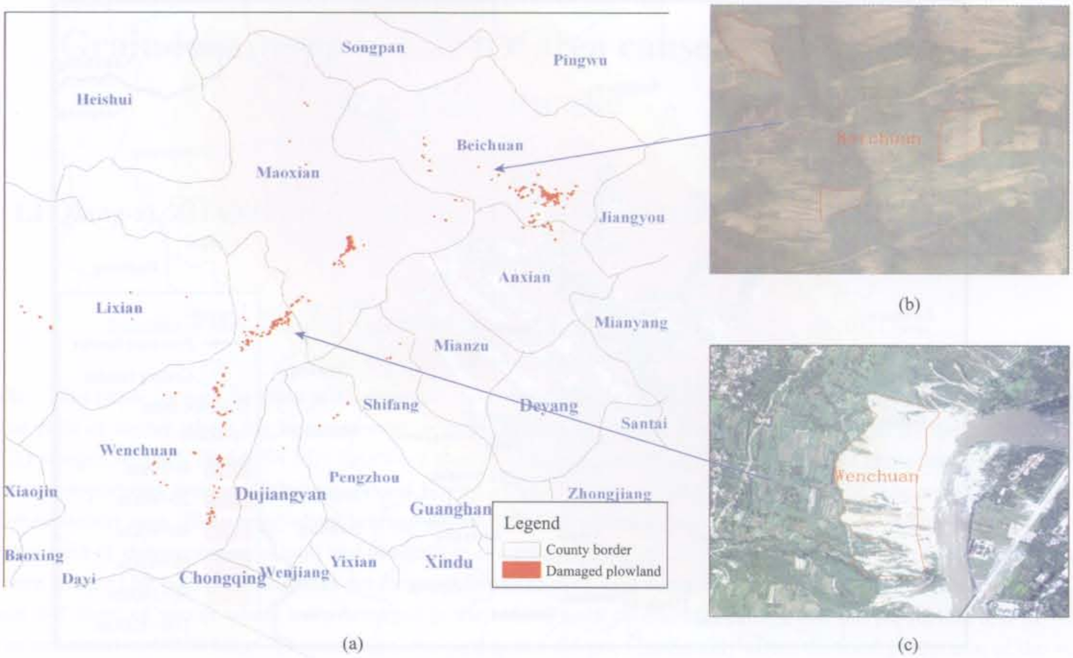


Fig. 3 Arable land damaged in Wenchuan Earthquake

(a) Distribution of damaged arable land; (b) Damaged croplands on aerial image in Beichuan; (c) Damaged croplands on aerial image in Wenchuan

damage for whole disaster region can thus be estimated.

(2) Winter wheat proportion estimation

Two different methods were used to obtain the fraction of winter wheat among different crops. To estimate the fraction of winter wheat in the plain region of Dujiangyan, Shifang, Jiangyou, Anxian and Qingchuan, the ground survey data were collected between April 20 and May 6, 2008, thus before the disaster, using a transect-sampling method (Wu *et al.*, 2004). Fig. 4 (a) shows the survey itinerary in the earthquake area. The winter wheat acreage and its percentage over the total cultivated area in the surveyed region can be derived.

To estimate the proportion of winter wheat in the mountain area in Wenchuan, Beichuan and Pingwu, no ground survey data were available. The photo interpretation was carried out. In this emergency study following Wenchuan Earthquake, 5 representative areas were selected to interpret the proportion of winter wheat. Fig. 4 (a) showed the location of the 5 selected area; the No. 5 area block (Wenchuan block) are detailed in Fig. 4 (b). Winter wheat proportions were calculated using the area of winter wheat and the cropland area within the blocks.

(3) Damaged winter wheat area estimation

The damaged area of winter wheat was estimated based on the winter wheat proportion from transect sampling and photo-interpretation and cropland area at county level (Table 1). Totally there were about 247.1hm^2, which were damaged in the counties of Beichuan, Qingchuan, Wenchuan, Anxian, Jiangyou, Maoxian, Mianzhu, Pengzhou, Dujiangyan, Shifang, Lixian and Wenxian (Table 1).

2.2.2 *Winter wheat yield forecasts*

Since the earthquake area mainly locates around the moun-

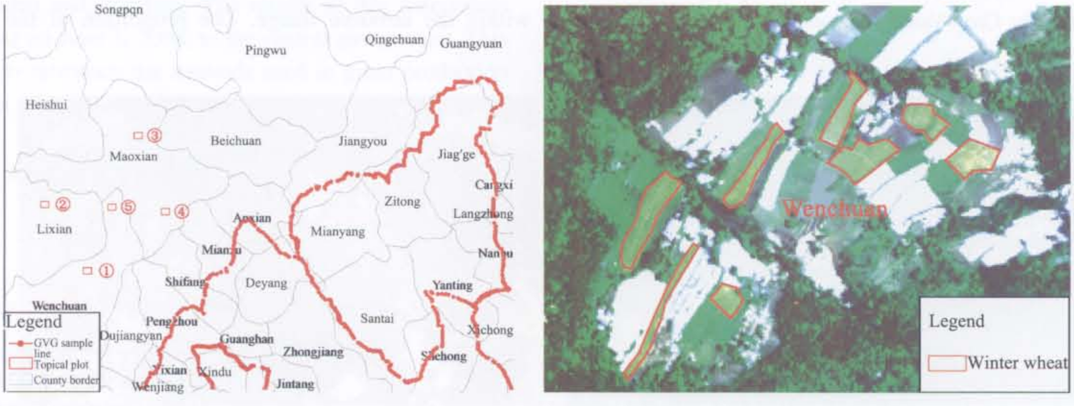


Fig. 4 Winter wheat proportion estimation

(a) Ground survey routes and photo interpretation blocks; (b) Winter wheat fields on aerial image in No. 5 block

Table 1 Grain loss in main disaster area in Wenchuan Earthquake

Province	Counties	Damaged cropland/hm²	Cropland acreage/hm²	Damaged ratio/%	Proportion of winter wheat	Winter wheat acreage/hm²	Expectant yield /(kg/hm²)	Winter wheat production loss/kg
Sichuan	Beichuan	461.40	35346.73	1.31	0.097	44.73	4185	187457
	Qingchuan	351.87	82606.53	0.43	0.083	29.20	4095	119765
	Wenchuan	285.07	9482.93	3.01	0.037	10.53	3015	31729
	Anxian	111.07	70439.27	0.16	0.34	37.73	4380	165239
	Jiangyou	194.47	125305.20	0.16	0.37	71.93	4380	314820
	Maoxian	82.67	12807.20	0.65	0.037	3.07	2280	6979
	Mianzhu	29.67	57675.93	0.05	0.34	10.07	4380	44156
	Pengzhou	29.67	68164.73	0.04	0.34	10.07	4185	42204
	Dujiangyan	24.13	49158.47	0.05	0.34	8.20	4185	34327
	Shifang	15.20	41649.00	0.04	0.34	5.20	4380	22632
	Lixian	7.07	6547.00	0.11	0.037	0.27	2610	683
Gansu	Wenxian	39.93	78904.13	0.05	0.4	16.00	2745	43785
Total		1632.20	638087.13	0.26	—	247.07	—	1013778

tains and the cropland is fragmentarily distributed, it is difficult to estimate crop yield using remote sensing driven yield prediction models due to the mixed-pixel problem. Accordingly, winter wheat yield was predicted based on agro-meteorological models. Many models had been developed before (Mac Donald *et al.*, 1980, Supit *et al.*, 1994; Rijks *et al.*,1998; Meng *et al.*, 2004; Xu, 2007).

Mostly, crop yield estimation is conceptually consists of three different components (Equation 1): trend yield, which is supposed influenced by the background agricultural technology and management level, and remains relatively constant in the region; meteorological contribution which is important in key crop developing phase and random yield contribution, which is interfered by uncertainties besides the above reasons.

$$\text{Yield} = Y_t + Y_w + \Delta y \quad (1)$$

where Yield is crop yield, Y_t is trend yield, and Y_w is meteorological yield, Δy is random yield.

(1) Estimation of trend yield Y_t

Trend yield is relatively stable and can usually be represented by a relationship in function of time. Therefore, it can be estimated based on linear or non-linear function using time-series historical yield data by the least squares error estimation.

Normally, the time-series yield is smoothed to depict the developing trend of crop yield with time. The paper used a moving average method to smooth the yield data (Equation 2):

$$Y_t' = (y_{t-1} + y_{t-(1-1)} + \ldots + y_{t-1} + y_t + y_{t+1} + \ldots + y_{t+1}) / (2l + 1) \quad (2)$$

where Y_t' is the moving average value at time t; l is the half of move, i.e., the half of the moving window.

Then, the following linear regression is used to depict the developing trend of crop yield based on historical time-series yield data (Equation 3).

$$Y_t = a + bx \quad (3)$$

where Y_t is the trend yield, and x is time (the unit of x is year); a and b are the equation coefficients.

(2) Prediction of meteorological yield Y_w

Meteorological yield is supposed to express annually changes of yield due to weather conditions variation. Usually, historical meteorological yield can be substituted by the difference between actual yield and trend yield. Mostly, meteorological yield can be simulated or estimated based on time-series historical meteorological yields and meteorological data in key crop growing phases using multiple regression equation (Xu, 2007).

In this paper, precipitation and temperature are used in multiple linear regression to estimate the meteorological yields.

(3) Random yield Δy

Random yields usually have very high or low values, which only work in abnormal years and are usually negligible (Xu, 2007). Since no abnormal weather conditions occured in the area before the earthquake, this component will not be considered in this study.

2.3 Grain loss estimation

Since the grain loss was mainly reflected by a reduction of winter wheat production, it is obvious to obtain the grain loss by combining the damaged winter wheat area with its predicted yield at county level. The total production loss in these 12 counties was estimated to be 1013778kg (Table 1).

3 RESULTS AND DISCUSSION

3.1 Loss of winter wheat production

Damage to the winter wheat was essentially caused by landslides and barrier lakes inundation in the earthquake region. The area of destructed wheat field is estimated to 247.1 hm², which corresponded to a production loss of 1013.8t.

Although the counties of Dujiangyan, Pengzhou, Shifang, Mianzhu, Anxian and Jiangyou are located in the central area of the disaster, winter wheat damage was only observed in the western mountain area, where winter wheat fields are fragmentarily distributed and only 35% of the cropland was cultivated with winter wheat. In eastern plain area of these counties where winter wheat is the dominant crop, no damage or slight damage was observed (Fig. 5). In other mountainous counties where the earthquake impact was severe, such as Wenchuan, Maoxian, Beichuan, Lixian, Qingchuan, Pingwu, the winter wheat is not the dominant crop (less than 10%), and nearly all fields are located in valley and flat area, which limited in adverse effects of the disaster.

Fig. 5 UVA photo showed winter wheat fields are not damaged in plain area
(Captured above Hanwang in Mianzhu on May 15, 2008)

3.2 Oblique loss of the grain production

Although the damage inflicted to the winter wheat production appeared to be very limited, the majority of the farmers in the earthquake affected area were evacuated out of the life-threatening region. The shortage of the labor during the harvest period will be critical. The total production of winter wheat in mountain areas of the counties Wenchuan, Maoxian, Beichuan, Lixian, Anxian, Jiangyou, Dujiangyan, Shifang, Mianzhu, Pengzhou, Qingchuan and Wenxian is estimated to more than 200000t (Table 2), which is a significant figure in the regional grain production.

Furthermore, the earthquake resulted also in the loss of autumn crop production, including rice, corn, or potato. Especially the paddy fields in basin area were affected due to the destruction of the irrigation system.

4 CONCLUSION

In this study, the methodologies to estimate damaged winter wheat planting area based on earth observation information are reported. The airborne and IRS P6 LISS4 MN imagery constituted the basic remote sensed information sources. Meanwhile, agro-meteorological models were developed to predict winter wheat yield in the main earthquake affected counties. Results showed that about 247.1hm^2 of winter wheat fields were damaged and the total loss of winter wheat production could be amounted to 1013778kg.

Since crop damage was mainly caused by landslide and barrier lake inundation which occurred essentially in mountainous region (Wenchuan, Maoxian, Beichuan, Lixian, Qingchuan, Pingwu) where the winter wheat is only sparsely cultivated, the loss of winter wheat production in the earthquake region was very limited.

However more loss of the grain production could be foreseen, if no measure had be taken to remediate the shortage of the labor resources during the harvest period or to restore the damaged irrigation system for the following growth seasons.

Table 2 Winter wheat expect production in main disaster mountain area during Wenchuan Earthquake

Provinces	Counties	Arable land in mountain area/hm^2	Winter wheat proportion	Winter wheat acreage/hm^2	Expenctant yield/(kg/hm^2)	Winter wheat production/t
Sichuan	Beichuan	46073.67	0.097	4469.15	4185	18703.37
	Qingchuan	63479.24	0.083	5268.78	4095	21575.64
	Wenchuan	9482.93	0.037	350.87	3015	1057.87
	Anxian	41760.28	0.34	14198.50	4380	62189.41
	Jiangyou	9682.71	0.37	3582.60	4380	15691.80
	Maoxian	12807.20	0.037	473.87	2280	1080.42
	Mianzhu	8063.30	0.34	2741.52	4380	12007.87
	Pengzhou	14117.15	0.34	4799.83	4185	20087.29
	Dujiangyan	8974.83	0.34	3051.44	4185	12770.29
	Shifang	4385.35	0.34	1491.02	4380	6530.66
	Lixian	6547.00	0.037	242.24	2610	632.24
Gansu	Wenxian	46359.62	0.4	18543.85	2745	50902.87
Total			—		—	223229.73

Acknowledgements: The author would like to thank the technique section of the Institute of Remote Sensing Applications(IRSA), Chinese Academy of Science kindly provided UVA photo, Professor Zengxiang Zhang in IRSA provided 1:100000 landuse dataset, and Professor Wancun Zhou in the Institute of Mountain Hazard and Environment, Chinese Academy of Science provided crop calendar and proportion information.

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汶川地震粮食受损遥感快速估算与分析

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摘 要: 综合利用灾前 IRS P6 Liss-4 高分辨率数据与灾后的航空影像, 估算粮食受损面积, 并利用同期农业气象数据估算了不同受灾区域粮食作物单产水平, 最终估算得出震区粮食作物受损产量。监测结果表明: 地震造成的 12 个重灾县市冬小麦直接损失 247.1hm^2, 产量约为 1013778kg, 直接影响不大。但受灾地区冬小麦总产量超过 22 万 t, 而且对秋粮作物的种植和生产造成影响, 对中国粮食生产的间接影响不容忽视。

关键词: 地震, 粮食, 损失, 遥感

中图分类号: X43/TP79 **文献标识码:** A

1 引 言

2008-05-12, 四川、甘肃、陕西交界地区发生的里氏 8.0 级地震, 以及随后的上千次余震, 造成了房屋倒塌、人员伤亡、道路交通基础设施破坏等直接性灾害。同时发生大面积山体滑坡和塌方, 以及由此引起的堰塞湖和农田毁坏使人民的生命财产面临着更大的危险。

地震灾区地处中国重点产粮区, 尤其是江油、什邡、都江堰、彭州、绵阳、安县等产粮大县, 对中国的粮食生产起着重要的作用。有关粮食部门和专家非常关心地震灾害对中国粮食生产的影响, 迫切需要对灾区的粮食受损情况进行快速判断。

“中国农情遥感速报系统”于 2008 年 5 月 25 日至 6 月 2 日综合利用灾前与灾后的航空影像和 IRS P6 等数据, 对地震灾区北川、青川、汶川、安县、江油、茂县、绵竹、彭州、都江堰、什邡、理县、文县等 12 个重灾县的粮食受损情况进行了遥感应急监测, 于 2008-06-03 通过《中国农情遥感速报》对外发布, 对加强震区粮食抢收, 稳定国内粮食价格等起到了积极作用。

目前关于自然灾害引起的粮食损失方面, 更多的是关注自然灾害的长期影响, 如郑景云(1994, 1998)、罗小峰(2007)、王晓丽(2008)等的工作, 国外 Jamieson (1994)也曾在干旱对生物量的影响方面有所关注。

2 数据与方法

2.1 数 据

利用地震发生前和发生后的两期高分辨率遥感数据, 用于耕地信息的对比分析与受损区域提取, 用于估算粮食受损面积。具体包括:

(1) 地震发生前。采用 IRS P6 LISS-4 MN 遥感数据, 空间分辨率 5.8m, 共 24 帧, 覆盖面积 28840km^2, 成像时间为 2007-05-19;

(2) 震后数据。采用 2008 年 5 月 15、16、17 和 23 日的飞机航拍数据, 共计 34 个条带, 空间分辨率 2m, 覆盖面积 12288km^2(图 1)。

此外, 还对地震灾区各重点粮食受损县市的作物种植面积、单产和总产历史资料, 以及农业气象站点的气温、降水、太阳辐射等分旬历史观测档案资料进行了搜集, 用于估算作物预期单产水平。并搜集到震区 1:10 万土地利用数据集, 用于耕地解译辅助。

2.2 地震引起粮食受损的快速监测方法

自然灾害主要通过面积与单产两个方面造成粮

收稿日期: 2008-12-16; 修订日期: 2009-04-08

基金项目: 中国科学院知识创新工程重大项目(编号: KSCX-YW-09-01)和科技支撑计划“粮食宏观调控信息保障关键技术研究与应用示范”(编号: 2008BADA8B02)。

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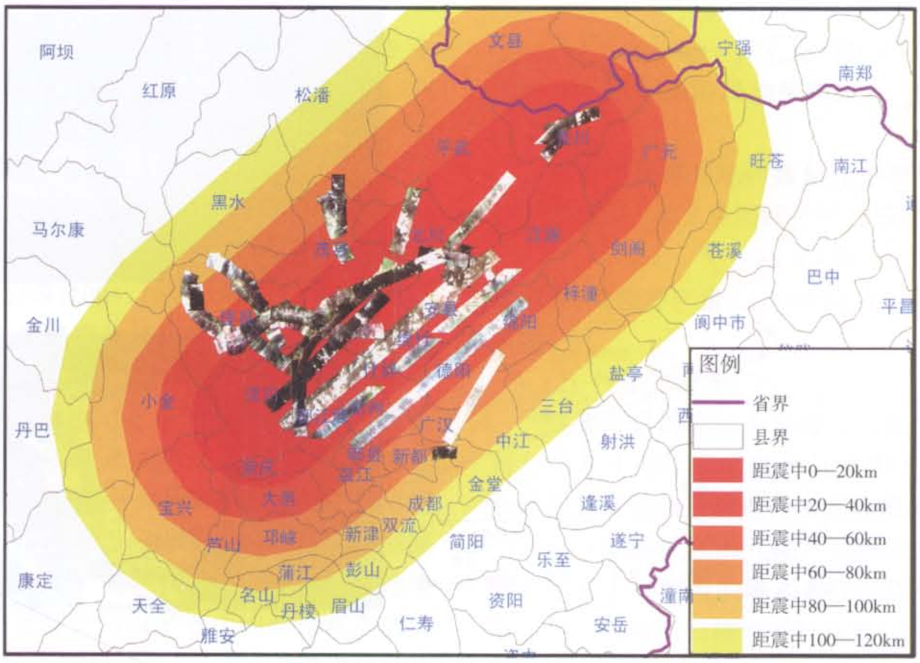


图 1　震后航空遥感影像空间分布

食产量损失。地震主要通过农田损毁方面，使粮食无法正常生长和收获。对于汶川地震的粮食受损遥感监测，集中两个方面：(1) 粮食受损面积的遥感监测。(2) 预期粮食单产的估算。然后据此估算地震灾区的粮食产量受损。

根据地震灾区的农作物种植制度及种植结构，震区受到影响的夏收作物主要是冬小麦。因此本文的监测工作也围绕冬小麦受损的遥感监测。

2.2.1　冬小麦受损面积遥感监测

主要采用目视解译方式进行农田损毁信息提取，同时利用“中国农情遥感速报系统”的运行性平原地区作物种植结构调查信息(吴炳方，1998)，以及利用高分辨率遥感影像解译获取的山区冬小麦种植成数(即耕地内冬小麦所占比例)，得到地震灾区的农田受损毁面积与冬小麦种植成数，冬小麦受损面积可由农田受损比例和冬小麦种植成数估算得出。

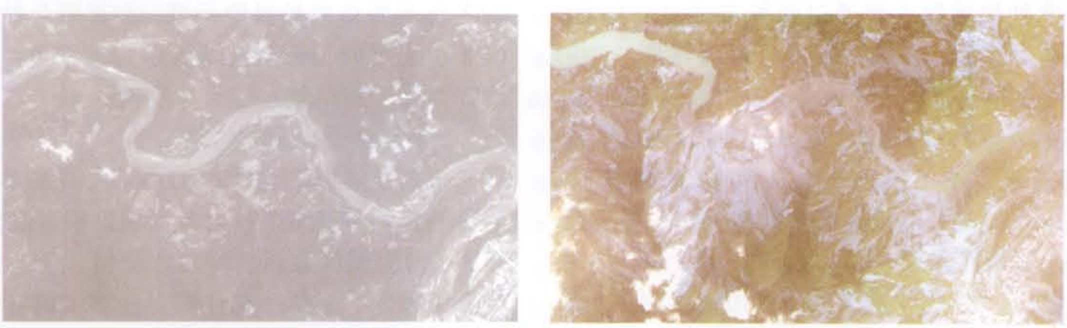
(1) 农田受损面积遥感监测

震区农田受损主要是由于山体滑坡、塌方、堰塞湖等次生灾害导致的农田被侵占和毁坏现象。由于震区地处高山峡谷地区，农田基本分布在山谷地带，且地块破碎，因此最有效的耕地受损信息提取是采用目视解译方式。图 2 为北川县城西部航空影像与 IRS P6 LISS4 影像对比图，从中可以发现大片农田被毁。

① 对照 2000 年 1∶10 万耕地数据库，在耕地分布区范围内，根据滑坡、塌方和堰塞湖等导致农田受损的次生灾害的光谱、形状和位置特征，准确提取次生灾害发生的位置和范围。

② 根据震区农田分布与次生灾害的分布范围，提取农田受损区域和具体的范围。

③ 分县统计农田受损面积。综合 1∶10 万耕地数据库与影像解译信息统计汇总影像覆盖范围内的



(a)　(b)

图 2　北川县震前 2007-05-19 IRS P6 影像(a)和震后 2008-05-16 航空影像(b)

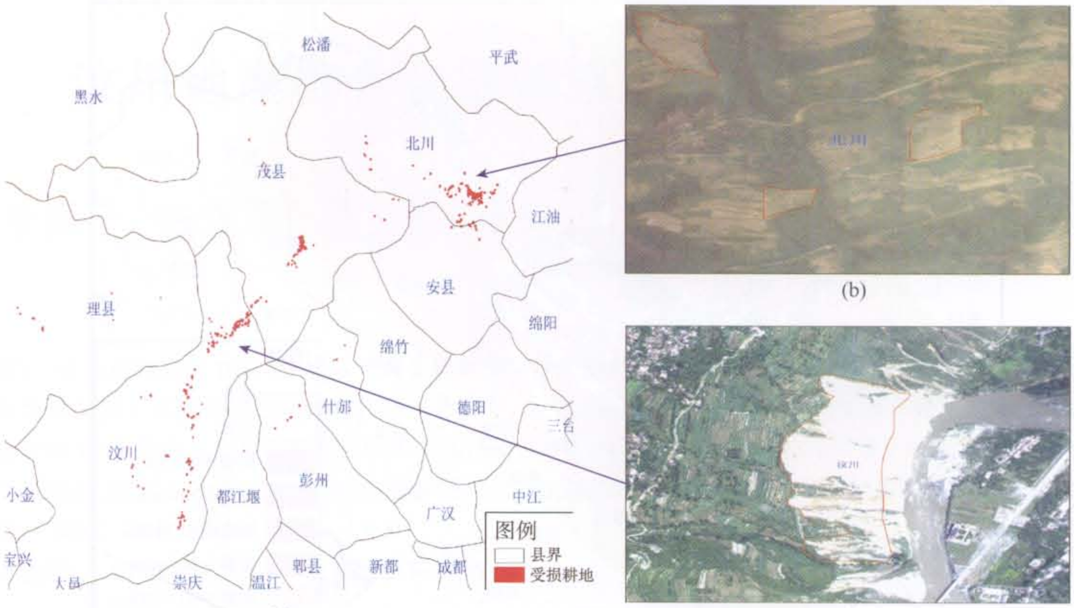


图 3 遥感提取的汶川地震灾区耕地受损分布

(a) 遥感提取震区耕地受损分布图; (b) 北川县耕地受损航空影像示例; (c) 汶川县耕地受损航空影像示例

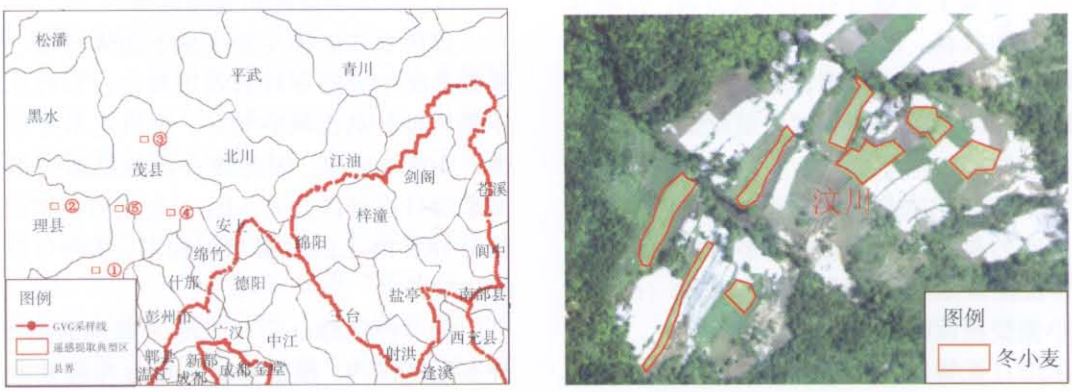


图 4 震区冬小麦种植成数估算方法

(a) GVG 采样线与遥感提取典型区分布图;(b)航空影像上的冬小麦种植地块(影像解译区⑤局部)

农田总面积，估算影像范围内农田受损比例，并根据全县耕地总面积统计各县农田受损总面积。

(2) 冬小麦种植成数估算

冬小麦种植成数主要通过两种方式进行估算，对于都江堰、什邡、江油、安县、青川等县，“中国农情遥感速报系统”为开展冬小麦种植面积估算，已经于 2008 年 4 月 20 日到 5 月 6 日利用 GVG 农情采样系统完成了冬小麦种植成数调查(吴炳方等，2004)(图 4(a))。并可以根据作物种植结构区划进行作物种植成数估算。

对于汶川、北川、平武等处于高山地区的县，因冬小麦种植成数非常低，“中国农情遥感速报系统”未进行作物种植成数调查，本文利用航空影像进行解译。在震区航空影像中选择 5 个典型的未受损区域(图 4(a))，提取冬小麦种植地块，计算冬小麦地块占总耕地面积的比例得到冬小麦种植成数。图 4(b) 为冬小麦种植成数提取示范，在真彩色航片上，灾区冬小麦因处于收割前期显示为黄绿色，其他大春作物因处于苗期基本显示为浅色。

(3) 粮食受损面积估算

根据航空影像解译和 GVG 农情采样系统调查获得的作物种植成数，与前面提取得到的农田受损面积，结合震区北川、青川、汶川、安县、江油、茂县、绵竹、彭州、都江堰、什邡、理县、文县等 12 个重灾县市的耕地面积信息，估算得到小麦受损面积约 247.1hm^2(表 1)。

2.2.2 单产估算

由于震区主要处于高山和山前平原地带，冬小麦等粮食作物零星分布，大量混合像元的存在，利用遥感反演参数不易建立单产和遥感参量间的关系。因此利用农业气象模型估算震区冬小麦单产。农业气象模型是目前作物单产预测最常使用的模型方法，如 Mac Donald 等(1980)、Supit 等(1994)、Rijks 等(1998)、孟庆岩等(2004)、徐新刚(2007)的研究。

利用农业气象模型估算作物单产，往往将农作物单产分解为 3 个部分(公式(1))：① 产量趋势水平部分：由品种改良、施肥水平、管理措施、栽培技术等农业技术进步所带来的平均单产水平，称为趋势产量；② 气象产量部分：由日照、降水、气温等气象因子造成的作物单产相对于单产趋势水平的波动，称为气象产量；③ 随机扰动部分：除上述趋势水平和气象因子之外其他因子造成的作物单产的不确定性的扰动，称为随机产量。

$$\text{Yield} = Y_t + Y_w + \Delta y \quad (1)$$

式中，Yield 为作物单产，Y_t为趋势产量，Y_w为气象产量，Δy 为随机产量。

(1) 趋势产量 Y_t

趋势产量一般比较稳定，通常表现为时间的正函数。因此，趋势产量的模拟通常是将历史产量时间序列按照最小二乘法的原理进行线性和非线性趋势模拟，通常分解为两个步骤：数据平滑处理和构建趋势方程。

数据平滑处理的目的是为了突出作物产量随时间发展变化的趋势和方向，本文主要采用滑动平均法(公式(2))：

$$Y_t' = (y_{t-1} + y_{t-(1-1)} + \cdots + y_{t-1} + y_t + y_{t+1} + \cdots + y_{t+1}) / (2l + 1) \quad (2)$$

式中，Y_t'为 t 点的滑动平均值；l 为单侧平滑时距(点数)。

历史产量时间序列数据经平滑后，即可进行趋势方程模拟，本文采用线性回归模型(公式(3))：

$$Y_t = a + bx \quad (3)$$

式中，Y_t为趋势产量；x 为时间，这里指年份；a, b 为系数。

(2) 气象产量 Y_w

气象产量的模拟主要通过气象产量历史时间序列与当年主要生育时段的气象因子进行相关分析，选定敏感气象因子并进行多元建模(徐新刚, 2007)。

对于地震灾区的气象产量模拟，主要是利用灾区冬小麦生育期内的降水和气温进行相关分析，并建立多元线性回归模型进行估算(表 1)。

(3) 随机产量 Δy

随机产量通常表现为特低或特高的极端值，只有在异常年份起作用，一般忽略不计(徐新刚, 2007)。汶川地震灾区此前整个冬小麦生育期内农业气象条件基本正常，因此本文也忽略不计。

2.3 粮食受损计算

震区粮食受损主要是冬小麦的损失，本文采用冬小麦受损面积乘以冬小麦单产水平，得到震区冬小麦受损产量(表 1)。经统计，震区内北川、青川、汶川、安县、江油、茂县、绵竹、彭州、都江堰、什邡、理县、文县等 12 个重灾县市冬小麦累计受损产量约为 1013778kg(表 1)。

表 1 汶川地震粮食(冬小麦)影响分析

省份	县	受损面积/hm^2	耕地面积/hm^2	受损比例/%	小麦成数	小麦受损/hm^2	单产/(kg/hm^2)	小麦产量受损/kg
四川	北川	461.40	35346.73	1.31	0.097	44.73	4185	187457
	青川	351.87	82606.53	0.43	0.083	29.20	4095	119765
	汶川	285.07	9482.93	3.01	0.037	10.53	3015	31729
	安县	111.07	70439.27	0.16	0.34	37.73	4380	165239
	江油	194.47	125305.20	0.16	0.37	71.93	4380	314820
	茂县	82.67	12807.20	0.65	0.037	3.07	2280	6979
	绵竹	29.67	57675.93	0.05	0.34	10.07	4380	44156
	彭州	29.67	68164.73	0.04	0.34	10.07	4185	42204
	都江堰	24.13	49158.47	0.05	0.34	8.20	4185	34327
	什邡	15.20	41649.00	0.04	0.34	5.20	4380	22632
	理县	7.07	6547.00	0.11	0.037	0.27	2610	683
甘肃	文县	39.93	78904.13	0.05	0.4	16.00	2745	43785
合计		1632.20	638087.13	0.26	—	247.07	—	1013778

3 结果与分析

3.1 粮食直接受损

因山体滑坡、塌方、堰塞湖淹没等原因造成的冬小麦受损，经统计估算，北川、青川、汶川、安县、江油、茂县、绵竹、彭州、都江堰、什邡、理县、文县等 12 个县市累计冬小麦受损 247.1hm^2，约 1013.8t。

由于中心震区地形复杂、地势较高，冬小麦主要分布在河谷地带及低山平缓地区，而盆地内震区冬小麦未受明显影响，油菜等作物因已经收割几乎未受影响。都江堰、彭州、什邡、绵竹、安县、江油等县市尽管处于震中，但冬小麦受损仅限于其西部山区的零星种植区，且部分受损，东部地区为冬小麦主产区，抢收及时，不会受到影响(图 5)。汶川、茂县、北川、理县、青川、平武等县市因处于山区地带，受地震影响稍大，但是由于该地区冬小麦种植比例均在 10%以下，且种植在河谷及平缓地带，受损有限。

图 5　绵竹市汉旺镇无人飞机拍摄照片
(耕地中小麦未受损 2008-05-15)

3.2 粮食间接受损分析

尽管地震对冬小麦产量的直接影响有限，但是由于中心震区，尤其是山区各县人员外撤，冬小麦收割困难。监测表明汶川、茂县、北川、理县、安县、江油、都江堰、什邡、绵竹、彭州、青川、文县受影响区域的冬小麦总产量超过 20 万 t(表 2)，对中国粮食生产的间接影响不容忽视，地震期间，各级政府已经督促并尽最大能力进行了抢收。

此外，汶川地震对大春作物(秋粮作物)造成间接影响，震区各县的玉米、马铃薯等作物因处于苗期，受损也有限，但由于山区耕地受到影响、水保措施受到破坏，且灾民外撤，后续田间管理缺乏，该地区的秋粮生产受到间接影响，只是这些地区秋粮产量很低，可以忽略不计。而盆地内的秋粮作物由于受上游来水的影响，水稻育秧和移栽受到一定影响，但由于地方政府积极组织，水稻生产受到的影响有限。

4 结　论

本文综合利用多种遥感数据，建立了地震灾区冬小麦受损面积的快速解译方法，估算了灾区冬小麦受损面积，同时，利用同期气象数据，估算了震区冬小麦预期单产，估算震区冬小麦受损产量，结果表明：地震造成的 12 个重灾县市冬小麦直接损失 247.1hm^2，产量约为 1013778/kg。

表 2　汶川地震粮食间接影响分析

省份	县名称	山区耕地面积/hm^2	小麦成数	小麦面积/hm^2	单产/(kg/hm^2)	小麦产量/t
	北川	46073.67	0.097	4469.15	4185	18703.37
	青川	63479.24	0.083	5268.78	4095	21575.64
	汶川	9482.93	0.037	350.87	3015	1057.87
	安县	41760.28	0.34	14198.50	4380	62189.41
	江油	9682.71	0.37	3582.60	4380	15691.80
四川	茂县	12807.20	0.037	473.87	2280	1080.42
	绵竹	8063.30	0.34	2741.52	4380	12007.87
	彭州	14117.15	0.34	4799.83	4185	20087.29
	都江堰	8974.83	0.34	3051.44	4185	12770.29
	什邡	4385.35	0.34	1491.02	4380	6530.66
	理县	6547.00	0.037	242.24	2610	632.24
甘肃	文县	46359.62	0.4	18543.85	2745	50902.87
合计			—		—	223229.73

震灾对作物的危害主要是由于山体滑坡、塌方、堰塞湖淹没等原因所致，冬小麦种植主要分布在河谷地带及低山平缓地区，所以大部分地区冬小麦直接受损不明显，而油菜等作物因已经收割几乎未受影响。

汶川、茂县、北川、理县、青川、平武等县市因处于山区地带，受地震影响稍大，但这些区域冬小麦种植比例非常低，粮食受损有限。其他平原地区则由于冬小麦受损轻微，可以忽略。

虽然震灾对冬小麦等粮食作物的直接影响不大，但是由于冬小麦处于收获期，粮食产量占较大比重，地方政府已经加紧了抢收力度，保证了粮食产量的稳定。同时由于部分耕地受损和人员外辙，对震区内秋粮产生了一些不利影响。

致　谢：中国科学院遥感应用研究所科技处提供了震区无人机照片，中国科学院遥感应用研究所张增祥研究员提供了震区耕地分布图，中国科学院成都山地灾害与环境研究所周万村教授提供了灾区作物种植信息支持，在此一并表示感谢。

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