

QUANTITATIVE APPROACH FOR SATELLITE MONITORING OF LOCUSTS MASS BREEDING AREAS

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KEY WORDS: Agriculture, Research, Ecosystem, Hazards, Locusts, Recognition, Decision Support

Best results in application of satellite locusts monitoring are obtained by using satellite data of high spatial resolution. In the same time, a satellite monitoring of locusts mass breeding areas in operational mode needs a high repetition (every day data) of survey. But, satellite instruments of high spatial resolution have enough big period of time between surveys of the same point of Earth ~ 14 days. That is why it is very difficult to use high resolution satellite data in an operational mode. Satellites with spatial resolution from 250 m up to 1000 m (NOAA(AVHRR), Terra, Aqua (MODIS) provide possibility to acquire daily data for the region of monitoring. Therefore, these data are more suitable for the locust population monitoring in an operational mode. But lower spatial resolution derives necessity to realize the higher sensitivity of such data. The standard size of object in case of locusts monitoring is few order of magnitude smaller than a spatial resolution of satellites data. That is why there is no chance to map locusts directly. The main idea of such methodology is to use the quantitative measuring approach of remote sensing (so called “non direct mapping”). It is necessary to retrieve from satellite data the set of quantitative characteristics of surface, which are derives the state of ecosystem, as well as the locust population. The next step of this technique is a calibration of this multi-dimension space of parameters by using results of locust accounts. After that it is possible to determine quantitative characteristics of ecosystem, strongly correlated with a locust population. The multi-dimensional links of locust population and a set of these characteristics could be used on the locust mass breeding areas mapping.

Introduction

The observing climate warming (Climate Change, 2001) leads to significant changing of ecosystems. As the result, during the last decades the locusts problem still actual at the Southern part of West Siberia (Russia). For example, from 1996 up to 2001 the mass breeding of Italian locusts (*Calliptamus italicus* (L.)) (Latchininsky et al., 2002) was observed in that area. That is why a need of practical system of agriculture protection from locust begins actual for the total region of the Southern part of West Siberia.

One element of such agriculture protection system is the technique of decision support, which optimizes solutions of decision-makers. Such techniques should process information about a location, time and a rank of locust hazard. Taking into account the giant area of the Southern part of West Siberia, satellite observations are economically more suitable for the data collection. But, there are some limitations for a choice of suitable satellite data:

1. Dimensions of locusts is few order of magnitudes smaller than a spatial resolution of satellites data.
2. A satellite monitoring of locusts mass breeding areas in operational mode needs a high repetition (every day data) of survey.

That is why there is no chance to observe locusts directly by using even high resolution satellite data. More over, because of low repetition (~15 days) it is very difficult to use high resolution satellite data and results of these data application (Ma et al., 2005) in the operational mode. In the same time satellites of average spatial resolution - NOAA(AVHRR), Terra, Aqua (MODIS) (250 m - 1000 m) could provide possibility to acquire daily data for the total region of monitoring. In this case there is the chance to find “window” of a good weather even in a cloudy period.

Thus the main tools should be satellites of average spatial resolution – EOS satellites. But the first above mentioned limitation determines the application of the quantitative

measuring approach of remote sensing (so called “non direct mapping”). In this case the high sensitivity of EOS satellites sensors could be realized completely. More over, quantitative approach provides possibility to expand results obtained at a local area to the total region.

1. THE METHODOLOGICAL APPROACH FOR NOAA & TERRA (MODIS) SATELLITE DATA APPLICATION ON THE LOCUSTS OBSERVATION

The main idea of satellite data application on the recognition of objects, dimensions of which are smaller than spatial resolution is explained by figure 1.

The first two stages of data processing are similar to the standard technique. The main goal of third (the inverse problem) stage is to prepare an information base by retrieving different geophysical characteristics of surface. In case of a locusts observation these physical characteristics should be sensitive to the environment conditions, which locusts prefer. There are a volume and a type of vegetation, soil moisture, a soil temperature, a type of soil, an angle and an azimuth of slopes of surface relief, etc.

The object recognition is the goal of the last stage of information flow. It could be done on the base of multidimensional regressions or/and neural networks algorithm by using direct calibration (results of locusts account at the test site). After enough long experience multidimensional statistical models of mapping objects could be built and used for the recognition. The result of such methodology is the map of observing objects (in our case – the locust population density) and maps of probability of object presence, probability of false alarm and probability of object missing. Thus, the output of this technology has probability character.

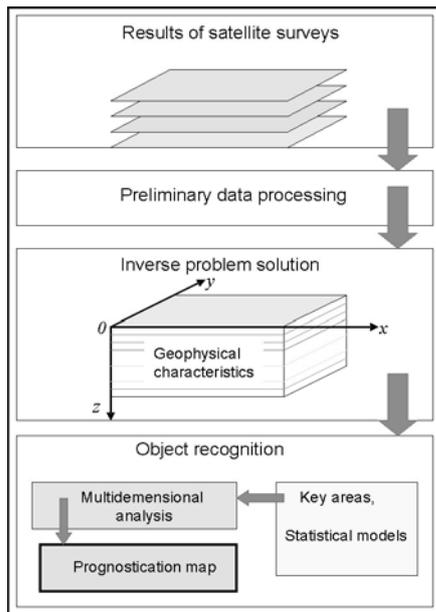


Figure 1. The suggested information flow for locusts observation by using average resolution satellite data.

2. THE FIRST APPLICATION OF METHODOLOGY ON LOCUST MAPPING

2.1. The test site choice

First of all, the correct choice of the test site is carried out. NOAA(AVHRR) and Terra(MODIS) data, as well as DEM SRTM (90 m spatial resolution) were collected for the total region of the Southern part of West Siberia. After that, maps of the convective heat flow, the thermal inertia, the evaporation rate, the vegetation index are compiled for the total region in the scale 1:500 000 by using these satellite data and special algorithm and software (Gorny, 2004). These geophysical characteristics, together with DEM are used for the region zoning. The zoning is done with help of unsupervised classification. As the result two major classes are mapped. These classes cover a steppe and a forestry- steppe areas. The locust test-site is placed in the Southern-West part of Novosibirsk Oblast' of Russia. The test-site includes two above mentioned classes (landscapes). Proportion of areas of these landscapes inside the test-site are the same as for the total region. The dimensions of the test-site are 90 km x 60 km. Inside the test-site 30 key areas 2 km x 2 km are located with help of Landsat TM data and results of unsupervised classification of the convective heat flow, the thermal inertia, the evaporation rate, the vegetation index and DEM. Key areas are distributed inside above mentioned classes, by using results of locust accounts, made during the last 5 years (Fig.2). The dimensions of key areas are chosen taking into account the spatial resolution of NOAA(AVHRR) data. 30 points for locust accounts and ground investigations of geophysical characteristics and vegetation are placed systematically according a uniform network inside each key area.

2.2. The information base

Locusts population density is accounted inside each key area of the test site during the Spring (the end of May), Summer (the middle of July) and Autumn (the middle of September) seasons of 2005. Simultaneously series of NOAA(AVHRR) and

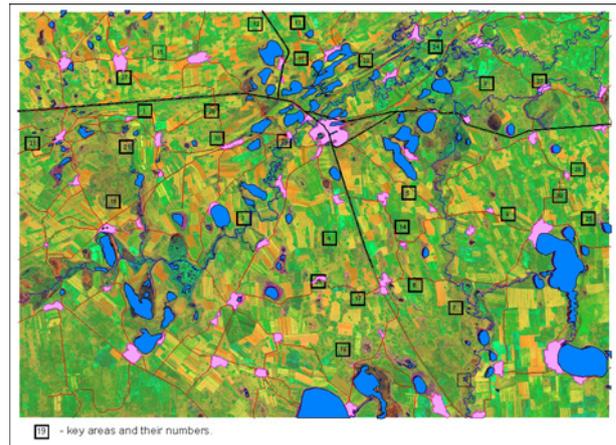


Figure 2. Landsat TM image of the Novosibirsk locust test-site. Key areas shown as squares. Roads, urban areas and the hydro-net are put on the satellite image.

Terra(MODIS) scenes for day, morning, evening and night time of days are acquired. After the standard preliminary processing of these data the algorithm of the convective heat flow, the thermal inertia, and the daily averaged evaporation rate determination and mapping (Gorny, 2004) is applied (Fig. 3).

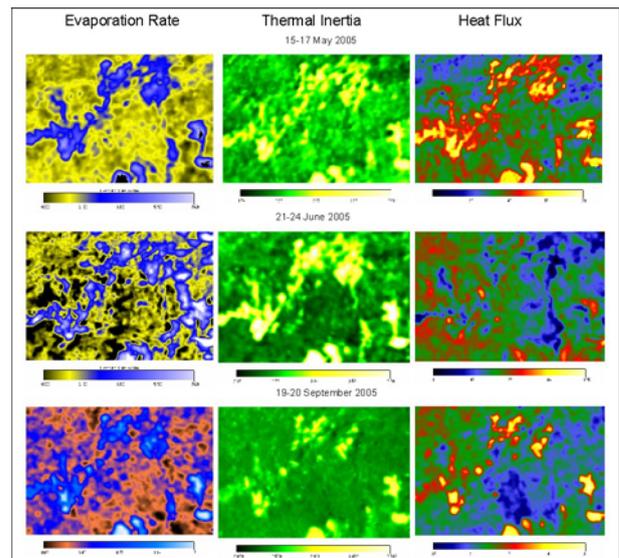


Figure 3. Seasonal variations of the evaporations rate, the thermal inertia, and the heat flux during 2006 at the Novosibirsk locust test-site.

Additionally, the vegetation index (NDVI) (Fig. 4) is retrieved from Terra(MODIS) data according the standard algorithm.

2.3. The analysis of geophysical characteristics sensitivity to locust population density

During the next stage of project the above mentioned geophysical characteristics of surface, retrieved from results of satellite observations are correlated with the results of field accounts of locust population density at key areas inside the test-site. The one example of such correlation is shown at the figure 5. The daily averaged evaporation rate of surface depends

on the moisture supply in a ground and on a possibility of vegetation to evaporate water. It is well known fact that soil moisture is the important characteristic, strongly influencing on a locust population density (Latchininsky et al., 2002). For the region of Southern part of West Siberia the general dependence is: - higher soil moisture – less a locust population density. Analysis of figure 5 shows that there is not simple dependence of the evaporation rate and locusts population density. The thing is that during 2005 a locust mass breeding is not observed. That is why one may suggest that spatial distribution of locust population during 2005 is more random than regular. That is why our technology has the low sensitivity, because of the low

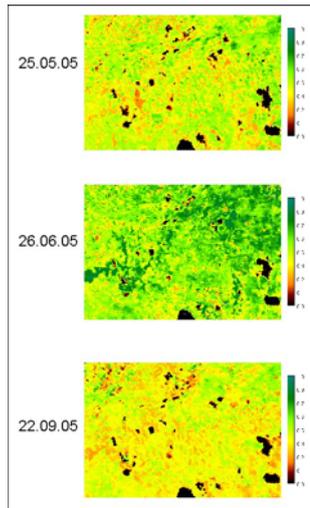


Figure 4. The seasonal variations of vegetation index during 2006 at the Novosibirsk locust test-site.

informative signal (low signal to noise ratio). In spite of this difficulty the following regularity can be formulated: - the high locust population densities are observed only in areas with the low evaporation rate. But, in the same time, the low locust population densities too in areas with the low evaporation rate are observed, too.

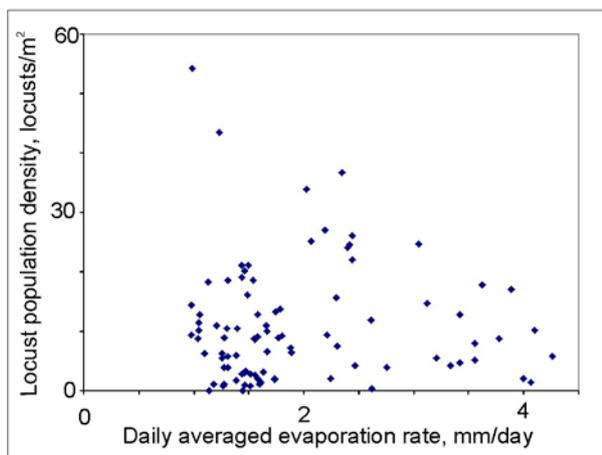


Figure 5. The locust population density versus the evaporation rate during July 2006 at the Novosibirsk locust test-site.

This preliminary result proved the major suggestion, which determined the choice of above mentioned quantitative methodology: - there is not unique characteristic of landscape,

which strongly correlates with the locust population density. That is why, it is necessary to map other quantitative characteristics of surface, which are important for the locust ecology and only by such way there is possibility to compile practically useful prognostication maps.

2.3. The preliminary result of the methodology application

The first prognostication map as the result of quantitative approach for satellite monitoring of locust mass breeding areas is shown by at the figure 5. Areas with locust population density higher than 10 locusts/m² are colored by red. The comparison of these areas locations with the locations of most locust populated areas, recoded during the Spring 2000 – the period of mass breeding (magenta at the map) exhibits enough good correlation.

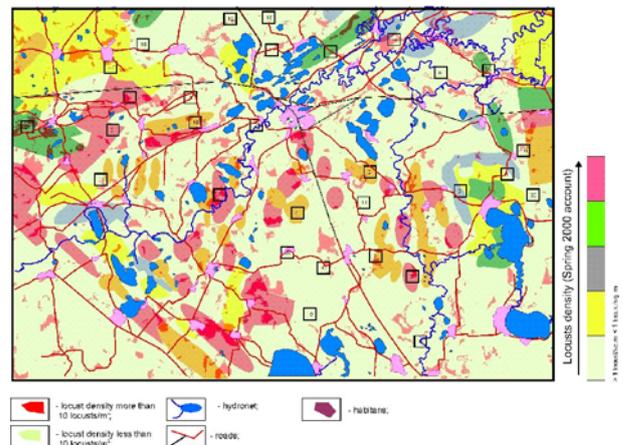


Figure 6. Results of the quantitative methodology application. The map of locust mass breeding areas prognostication. Places with the locusts population higher than 10 locusts/m² during the July 2005 marked by the red color. Results of locusts account, carried out during the Spring 2000, when the locusts mass breeding was observed, are coded by the color scale at the right side.

That is why there is the hope that when the new period of locust mass breeding will start a confidence level of results of this methodology would be better.

3. CONCLUSIONS

The first cycle of technology application is carried out and proved initial suggestions:

- 1) The system of EOS satellites of average spatial resolution (NOAA(AVHRR) Terra/Aqua(MODIS) provide high guarantee to collect satellite data for the cloudiness conditions of Southern part of West Siberia. That is why the system of EOS can be used as the main tool for the regional monitoring in the operation mode.
- 2) The sensitivity of EOS satellites is enough to sense variations of quantitative geophysical characteristics of landscape, which are important to locust ecology.
- 3) The coincidence of areas of high locust population density, recorded in 2000 and 2005, shows that locust prefer some landscape conditions. This fact could help to the agriculture protection from locusts.

Acknowledgements

This research was executed as the part of project No 2908 “Remote sensing technology development for a locust mass breeding areas mapping in order to secure ecologically safety measures of agricultural fields protection” funded by International Science and Technology Center.

The field accounts at the Novosibirsk locust test-site in 2005 managed and supervised by RACEM (the city of Kirov) and Prof. M.G.Sergeev (Novosibirsk University). Field locust accounts are carried out by “Troika” Ltd (the city of Novosibirsk).

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