PN-ABT-369

ANNUAL REPORT

Covering period: September 1993 to August 1994

Submitted to the Office of the Science Advisor
U.S. Agency for International Development

"Estimation of seasonal dynamics of arid zone pasture and crop productivity using AVHRR data"

Principal investigator: Prof. A. Gitelson
Grantee Institution: Ben-Gurion University of the Negev

Principal investigator: Dr. F. Kogan
Grantee Institution: National Oceanic and Atmospheric Administration, National Environmental Satellite Data and Information Service

Collaborator: Prof. E. Zakarin
Grantee Institution: Space Research Institute, Kazakh Academy of Sciences

Project Number: CA13-056
Grant Number: AT-MOU-CA13-056

A.I.D. Grant Project Officer:

Project Duration: September 1993 to August 1995

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9 October 1994

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Dear Dr. Rechcigl:

Re: US-Israel AID/CDR/CAR Program
Grant No. TA-MOU-CA13-056
Estimation of seasonal dynamics of arid zone pasture and crop productivity using AVHRR data
Prof. Anatoly Gitelson - BGU Israel
Prof. Edge Zakarin - Kazakhstan

Enclosed please find four (4) copies of the Annual Report, submitted by Prof. Anatoly Gitelson for the above-mentioned project.

With thanks for your cooperation.

Yours sincerely,

Moshe Amir
Director
Department of Research Contracts

cc: Science Attache - US Embassy Tel-Aviv (w/encl 1)
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הרשות למחקר ולפתוח
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טל: 07-472425/6 | פקס: 07-472930 | דאר אלקטרוני:

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Executive Summary:

The purpose of the project is to develop and implement technique for using data observed by the Advanced Very High Resolution Radiometer (AVHRR) flown on NOAA polar orbiting satellites for monitoring seasonal dynamics of arid zone pasture and crop conditions and production and also crop and pasture environment.

Specific goals are: (a) Quantitative estimation of pasture and crop conditions and yield in Kazakhstan; (b) Monitoring droughts.

The archive of the Global Area Coverage (GAC) data from NOAA -9 satellite (starting from 1985) was used for area of Kazakhstan to calculate minimal and maximal values of Normalized Difference Vegetation Index (NDVI). The data was corrected to remove radiometric, geometrical and atmospheric noise. GAC NDVI data was processed using temporal smoothing techniques. This approach helps to remove outliers and emphasize seasonal cycles and weather-related changes in the NDVI time series. Minimum and maximum values of NDVI during period from 1985 to 1993 were found for each pixel for all area of the country. Crop conditions were estimated from numerical analysis of weather-related component of the NDVI: the Vegetation Condition Index (VCI). The VCI provides a numerical approximation of weather impacts to vegetation and also measures vegetation conditions. The VCI was calculated for 1991, 1992 1993 and 1994 and weekly maps of vegetation conditions were created for these years.

The VCI was also used to estimate crop yield. These estimates have been done in the context of weather impact on the entire green vegetation in the area. Since the amount of yield depends on the cumulative impact of weather on crop and pasture, VCI values were estimated also cumulatively and primarily during that part of the growing season which is critically important for vegetation.

To use the produced maps requires to adjust them to local conditions, to parameterize the relationships between remotely sensed data and ground observations. To validate the results, data base of *in-situ* agro-meteorological characteristics was created for three regions of Kazakhstan: Almaaty, Geskazgan and Akmola for a period from 1985 to 1993. The data base includes: total precipitation; temperature; soil moisture; phenology; and biomass (crop height and density).

Since April 1994, radiometric measurements of crop were carried out in Almaaty region. The objectives of the experiment were: to calibrate VCI, to validate satellite-derived environmental and physiological parameters; to verify raw resolution satellite models. Two plots were selected for NDVI measurements. Simultaneously soil moisture, height and density of crop and phenology were measured. The findings will analyze together with radiometric measurement from NOAA-11 satellite using 3*3 box of 1.1 pixels centered around experimental plot.

During the first year of the project two training programs were carried out: radiometric measurements of NDVI using three channel hand-held radiometers, and the use the TELONIX and SUN stations for receiving satellite images and processing the data. Collaboration was aimed at promoting a better understanding of the technique for monitoring of crop conditions and yield in Kazakhstan.

The findings in the first year of the project contribute enough to project objective.

Section I

A) Research Objectives:

The project objectives are to develop and implement technique for monitoring seasonal dynamics of arid zone pasture and crop conditions and production using data observed by the Advanced Very High Resolution Radiometer (AVHRR) flown on NOAA polar orbiting satellites.

Specific goals of the firs year of the project are:

(a) To calculate minimum and maximum values of Normalized Different Vegetation Index (NDVI) for period from 1985 to 1983 in order to produce the maps of Vegetation Condition Index (VCI) for several years.

(b) To collect ground observations of precipitation, temperature, biomass, soil moisture, phenology, and biomass (historical data base) for the period from 1985 to 1993 for all Kazakhstan area.

(c) To collect radiometric measurements at two-three plots in Kazakhstan simultaneously with NOAA satellite measurements and ground observations of some agro-meteorological characteristics.

B) Research Accomplishments:

1. Global Area Coverage (GAC) data were processed for the period from 1985 to 1993 in order to determine the minimum and maximum values of NDVI for each pixel of Kazakhstan area. The weather-related component of NDVI was calculated by normalizing the weekly NDVI values to the amplitude of their change during the years with favorable and unfavorable weather. The weekly weather signal was amplified by ranking it on a linear scale where the minimum value in the multi-year data set equal to 0 and the maximum to 100. Vegetation Condition Index was calculated as

$$VCI=[(NDVI-NDVI_{min})*100]/[(NDVI_{max}-NDVI_{min})]$$

where NDVI, $NDVI_{max}$, $NDVI_{min}$ are smoothed weekly NDVI, its nine-year (1985-1993) maximum, and minimum, respectively for the week "i".

The index was used as numerical approximation of weather impacts on vegetation and as a measure of vegetation conditions. Low values of VCI indicated bad vegetation conditions and possible unfavorable weather impacts (such conditions were found in 1991), while high values of VCI described the opposite situation (as it was found in 1993). To validate the model, the "ground-truth" data will use for all this period of satellite observations.

2. Data base of ground observations was created for three regions of Kazakhstan (Almaaty, Geskazgan and Akmola), for the period from 1985 to 1993. The data base includes:

(a) *Precipitation*: ten-day total precipitation starting from the first ten days in January and ending with the last ten days in December.

(b) *Temperature:* ten-day average starting from the first ten days in January and ending with the last ten days in December.

(c) *Soil Moisture*: for each ten days period starting from the first ten days in April and ending with the last ten days in September.

(d) *Phenology.*

(e) *Biomass*: height of the crop and its density.

At Ben-Gurion University the data will prepare for comparison with the calculated VCI values for each station during all period of satellite and *in-situ* ground observations (1985 to 1993).

3. Field measurements of upwelling radiance and downwelling irradiance were carried out in several plots in Almaaty region since April 1994. Simultaneously above mentioned characteristics (2a-e) were determined. The data will be used to verify satellites-*in-situ* models.

C) Scientific Impact of Collaboration:

Israel and US. scientists developed the requirements to *in-situ* ground-truth data base and the technique for comparison ground observation with satellite data. They processed satellite data for the period from 1985 to 1993, calculated minimum and maximum values of NDVI for nine years period, and determined the VCI for all Kazakhstan area for 1990 to 1994.

Israel scientists organized the training courses in Israel for two Kazakh scientists. During two weeks, field and laboratory measurements of different kinds of soil as well as vegetation were carried out. Kazakh scientists were trained to work with Telonix station to receive the satellite images. Then they learned to work with SUN station to process the images.

Kazakh scientists created data sets of ground observations at three regions of Kazakhstan.

D) Description of Project Impact:

The results of the project were used for estimating of crop conditions in Kazakhstan during spring and summer 1994. The maps of VCI were passed to Kazakh scientists to compare with *in-situ* ground observations. We anticipate to use the maps of VCI for each week since early spring to estimate the weather impact on vegetation. They can be widely used for making a decisions.

E) Strengthening of Developing Country Institutions:

Project investments were used to cover partially cost of Telonix receiving station. The station was used at the first time in Kazakhstan for receiving space images from NOAA satellites.

Project investments were used also for training courses took place in Israel:

- the use hand-held radiometers for measurement of NDVI;

- the use Telonix for receiving NOAA satellite images;

- the use SUN station to process AVHRR images.

Kazakh scientists have acquired new research and managerial skills:

- to estimate vegetation conditions using NDVI and VCI;
- to work and use for atmospheric correction hand-held radiometers;
- to work with Telonix station;
- to work with SUN station;
- to create the data sets *in-situ* ground observations using QUATTRO program.

We expected to finish the development of the data base of *in-situ* ground observations for all area of Kazakhstan until August 1994. It has not been done for many reasons. Among other things is: the ground observations belong to Meteorological survey but not to Academy of Sciences. Therefore, some difficulties take place to obtain the data from institution did not involve in the project.

Much efforts were used to overcome the distance between two Kazakh institutions- Institute for Space Research, Academy of the Sciences and Hydro-meteorological Institute, Meteorological Ministry of Kazakhstan. Up to now data for three regions of Kazakhstan only are available and may be used for comparison with satellite information.

F) <u>Future Work</u>:

Following remains to be done:

- Comparison ground observations with VCI for three regions of Kazakhstan for the period from 1985 to 1993.
- Development of the models as a relationships between VCI and agro-meteorological characteristics of vegetation (such as height and density, yield and so on).
- Development data base of *in-situ* ground observations for all Kazakhstan area for the period from 1985 to 1994.
- Validation of the models by using independent data sets, obtained in 1994.
- Producing the maps of the VCI for each week 1994 and its comparison with *in-situ* ground observations (including radiometric measurements).

Section II

A) <u>Managerial Issues</u>:

In April during visit of Kazakh team in Israel, schedule for Kazakh team until August 10 was created (see *Appendix 1: Progress report 2*). The main point of the Kazakh team work until August 1994 is to produce files with *in-situ* data sets for 80 stations from 1985 to 1993. Also important issue is to install and to start to work with Telonix receiving station in Kazakhstan.

In April 1994, Israeli PI turned over two radiometers, three reference plates, and charging equipment to Kazakh principal investigator. The equipment will use in Kazakhstan for field experiments.

In July 1994, U. S. Principal Investigator Dr. F. Kogan visited Russia and during two weeks he consulted and trained Dr. L. Spivak to process AVHRR images and to calculate the VCI using data on minimum and maximum NDVI values.

Dr. L. Spivak turned over to Dr. F. Kogan data sets *in-situ* agro-meteorological characteristics for station located in Almaaty, Acmola, and Geskazgan regions for a period from 1985 to 1993. He also turned over the results of radiometric measurements in the channels of AVHRR for one (instead of three, as was planned) plot located in Almaaty region.

B) Budget:

In the beginning of the project Institute for Space Research proposed to buy SUN station for processing satellite images using project investments. They assumed to buy Telonix receiving station from other sources. They could not do it, therefore, they bough Telonix receiving station using partially project investment ($12,000). SUN station is available and was bought using other projects investment.

We did not change the budget yet. Nevertheless, we will have to do it in the near future because of unexpected increase in cost of traveling in Kazakhstan and Russia. More than we expected should be consulting by Israeli and US principal Investigators directly in Kazakhstan. More than we expected meetings should be done with Kazakh team. Many problems those we expected to be solved by E-mail and by FAX, can be solved by meeting only.

C) Special Concerns: We do not have any protocols which address special concerns.

D) Collaboration, Travel, Training and Publications: Since the last Management Report (February 1994) following collaborative activities took place:

1. Kazakh team visited Israel on April 6-20. Prof. Zakarin and Dr. Spivak studied the receiving station Telonix, three-channel hand-held radiometers, and participated in field works (see *Appendix 1: Progress Report-2*).

2. On July 14-29, US. Principal Investigator Dr. F. Kogan visited Moscow and Obninsk, where he received the first set of ground data from Dr. L. Spivak and trained him to calculate the VCI from AVHRR images and minimum and maximum NDVI values using PC computer.

3. On August 9-13 Israeli Principal Investigator Prof. Gitelson visited NOAA/NESDIS in order to use the archive of GAC images for comparison with ground-truth data sets obtained by Dr. Kogan in July in Moscow. Together with Dr. Kogan he compared the VCI for years with more favorable weather (1993) with the most unfavorable weather (1991). The comparison showed very high accuracy of estimation of crop state using the VCI.

Progress report-2

"Estimation of seasonal dynamics of arid zone pasture and crop productivity using AVHRR data"

US-Israel AID/CDR/CAD program

Grant No. TA-MOU-CA13-056

Principal investigators

Israel
Prof. A. Gitelson

Kazakhstan
Prof. E. Zakarin
Dr. L. Spivak

This progress report is based on the achievements obtained during a visit of the Kazakh team to Israel on April 6-20, 1994. The second meeting of the two teams in Sede-Boker and Beer-Sheva was aimed:

* To discuss the results obtained in period between the meeting in Moscow (in November 1993) and in Israel,
* At introducing the receiving station TELONICS to Kazakh investigators,
* At training Kazakh investigators to work with radiometric systems.

Technical Aspects.

The Kazakh team studied the receiving station designed by **TELONICS** (USA) in Remote Sensing Laboratory of Ben-Gurion University of the Negev. Three radiometers with spectral bands corresponding to the first and the second channels of AVHRR together with reference plates were prepared. They will use for measuring at plots located in different climatic zones of Kazakhstan. The radiometers and plates were passed to Kazakh team for using during the project period.

Scientific Aspects.

1. The teams discussed a structure of historical data sets those will use in the project. Kazakh team presented the maps of climatic zones and the location of agro-meteorological stations. They suggested to create the historical data sets in two phases. The first one will end in the end of June and will contain files with data from 15 stations quite representative for Almaty, Geskazgan, and Akmola regions of Kazakhstan for 1985 to 1993. These regions located in very different climatic zones of the country and are quite representative for Kazakhstan. The data will be passed to Israel (RSL) and US (NOAA/NESDIS) in the end of June 1994.

At the second stage, *in-situ* data on agro-meteorological variables will be collected for 1985 to 1993 for other 16 regions of Kazakhstan. It would be done by Kazakh team until September 1994.

2. The teams discussed in details the measurements should be taken at experimental plots, located in different climatic zones of Kazakhstan. As it was suggested by Israeli and US teams (see Progress Report-1), the plots should be chosen on the South, on the North, and in the central part of Kazakhstan. Kazakh team described the difficulties take place to control the measurements at such remote from Almaty stations, and suggested to choose for measuring the stations located at Almaty region. They proposed for measuring at least three stations located in very different climatic zones. Israeli principal investigator was forced to agree with the suggestions for measuring in 1994 and then to discuss the possibility to change the location of the stations.

3. During visit, the measurements of reflectances of surfaces with very different NDVI were taken in different areas of Israel (semi-arid and arid zones). The training of Kazakhstanian team was found enough for employment the radiometers in Kazakhstan.

4. Prof. Gitelson informed Kazakh team on results of calculation (on the base of NDVI data) Vegetation Condition Index for Kazakhstan for period 1985 to 1987. It was done in NOAA/NESDIS by US principal Investigator Dr. F. Kogan. He also calculated the minimum minimorum values of NDVI for Kazakhstan for the period 1985 to 1987. Processing AVHRR data will continue.

Operational steps for Up-coming Research Activities

The third phase of the research will end in the end of June 1994 with a meeting of the US Principal Investigator with Kazakh team in Moscow. In Obninsk former All-Union Agro-Meteorological Institute is located. The Institute has agro-meteorological data base for all territory of the former Soviet Union. It should discuss the possibility to use this data base for the project.

Until that meeting, the ISR team will prepare the following:

1. Data sets *in-situ* agro-meteorological characteristics for 15 representative stations located in Almaty, Geskazgan and Akmola regions for a period from 1985 to 1993. Data sets will produce as ASCII files and passed to Israel (BGU) and to the US NOAA/NESDIS.

2. Results of radiometric measurements (crop and pasture reflectances) in the channels 1 and 2 of AVHRR for three plots, located in different climatic zones of Almaty region. The measurements will take three times a month simultaneously with measurements of agro-meteorological variables, noted in "Description of data sets and their collection" (Appendix 1, Progress Report-1).

The RSL and NOAA/NESDIS team will prepare the following:

1. Calculation of VCI for Kazakhstan for each week for period from 1988 to 1989.

2. Correction of minimum minimorum NDVI values using AVHRR data for 1988 to 1989.

During the meeting, the teams developed the schedule of Kazakh team works (See Appendix 1).

The principal investigators suggested to correct the budget at the end of June 1994 according to the real made works. The schedule of the planning work and their approximately estimated costs were specified in Appendix 1.

Both sides also agreed to exchange three-month informal progress reports for the exchange of the up-to-date achievements.

Gitelson Zakarin Spivak