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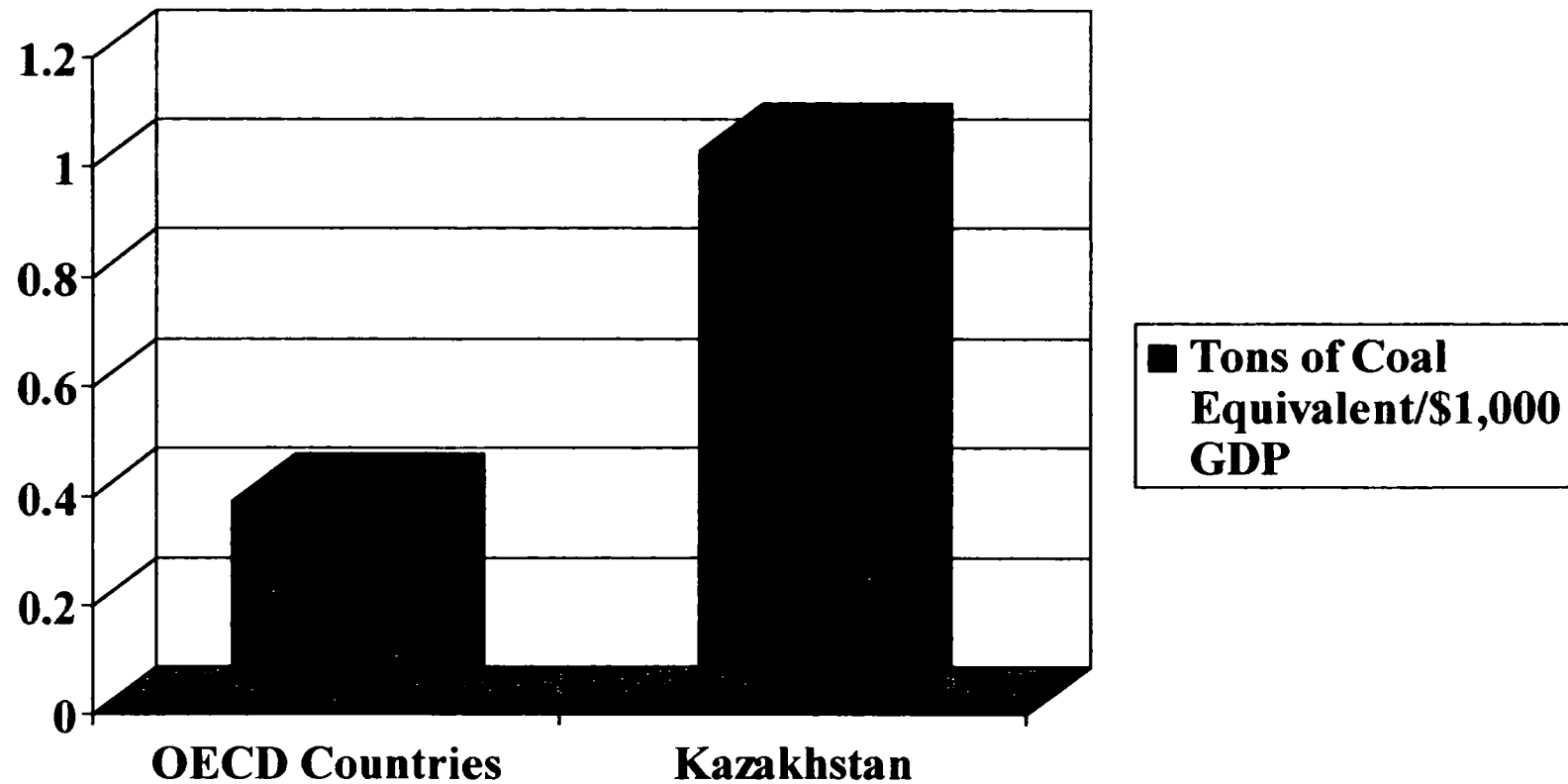
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27 - Global Climate Change - Kazakhstan

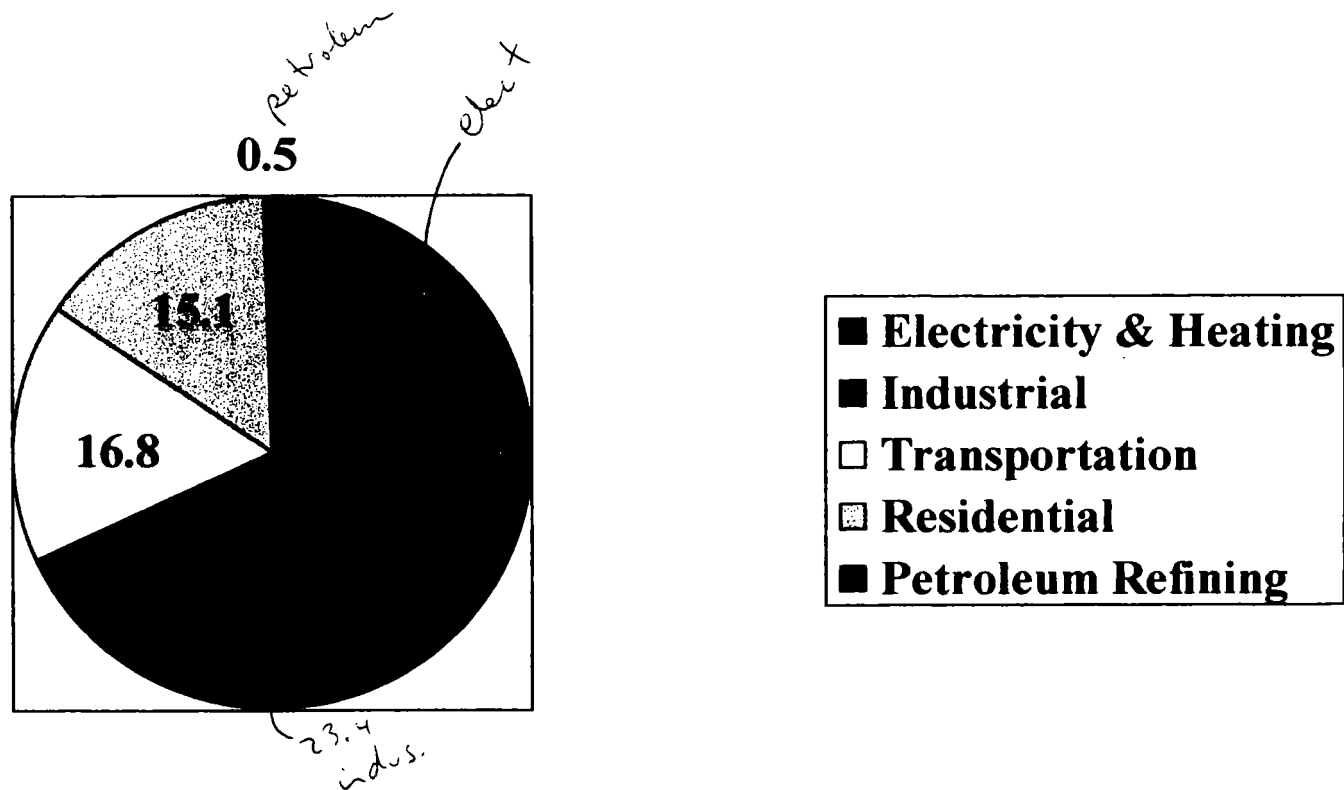
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Energy Intensity

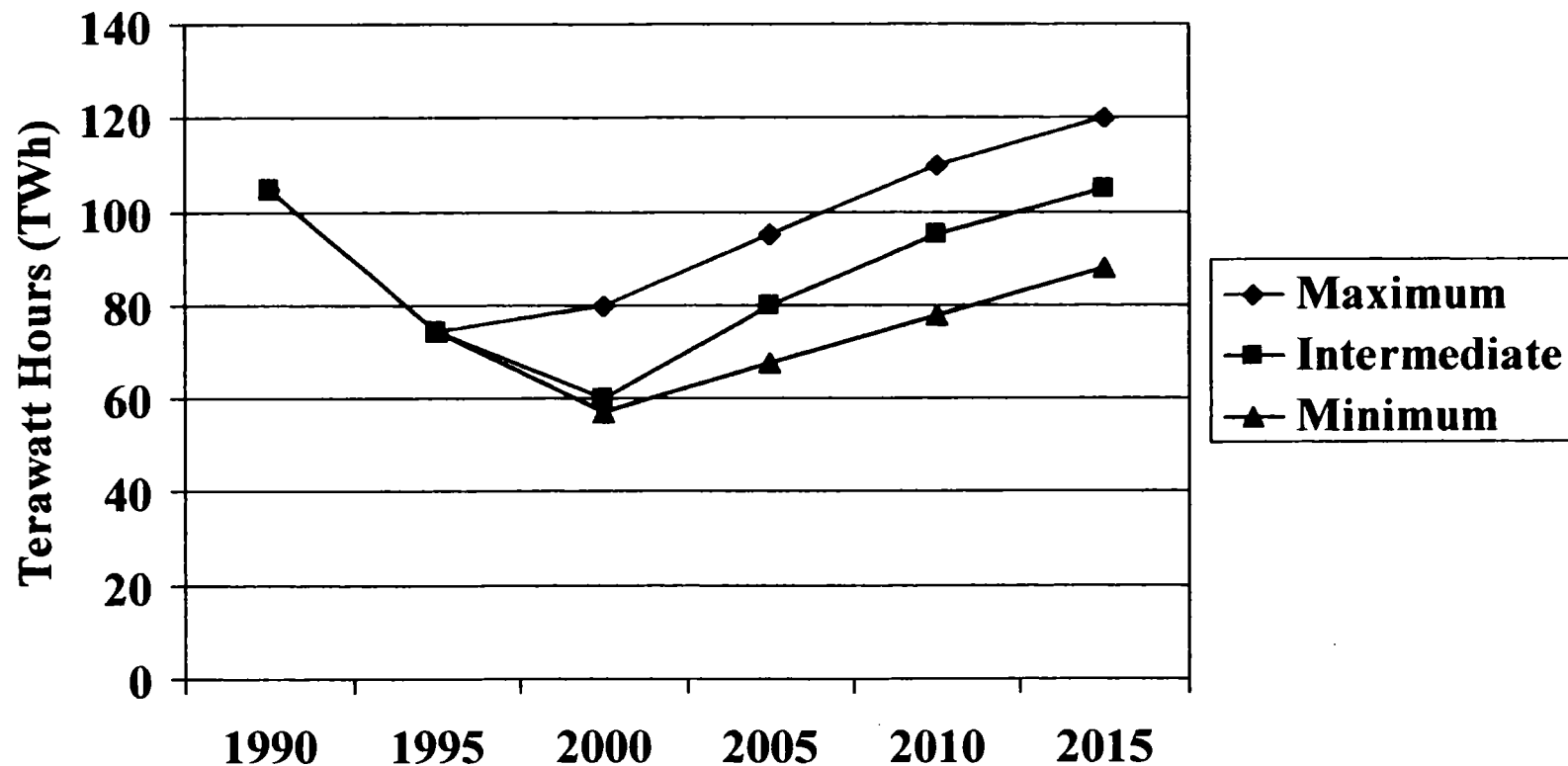


% Breakdown of Emissions Sources (1990)

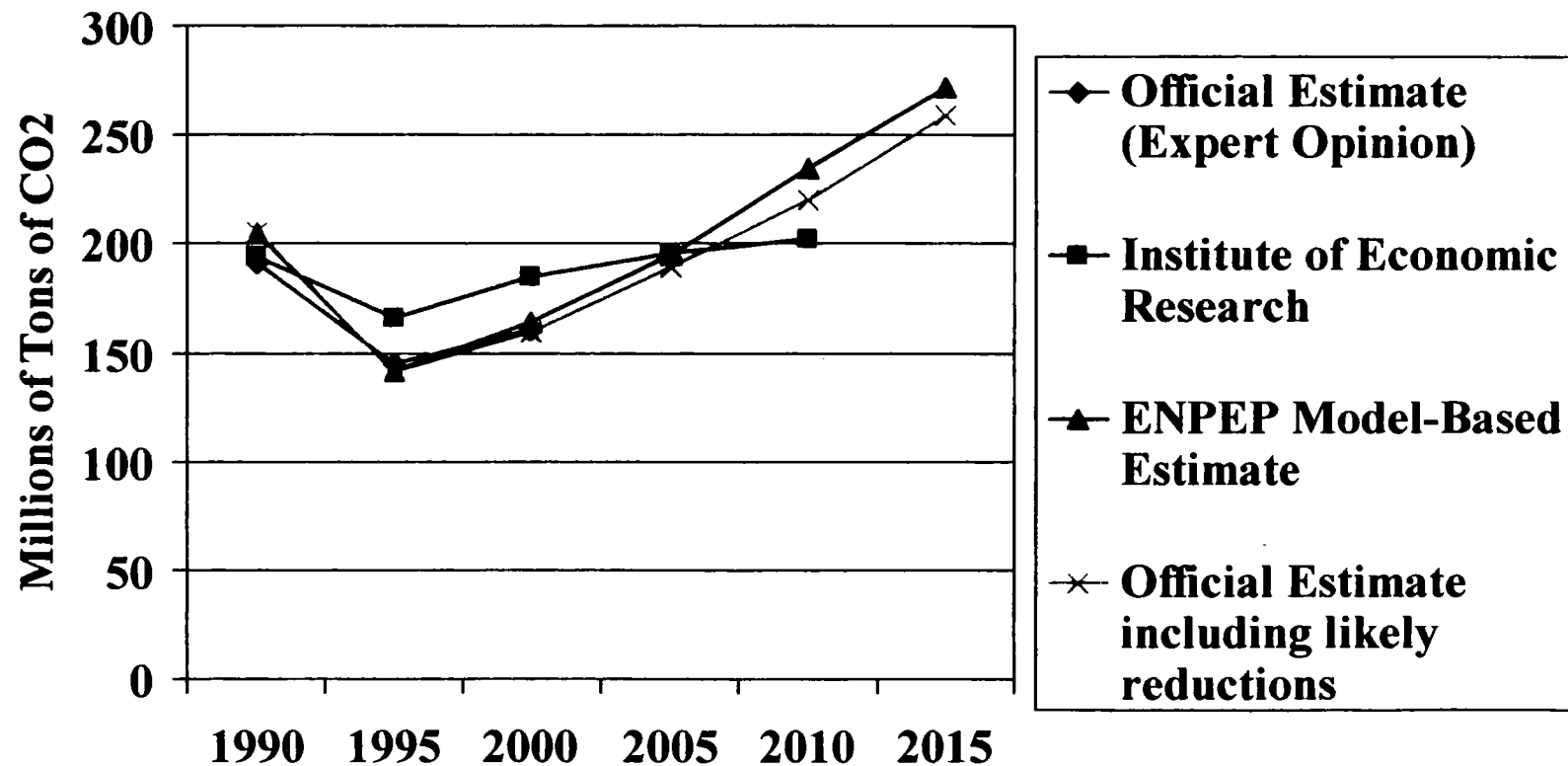


Electricity Demand Projections

According to Different Energy Development
Scenarios



Forecasts of CO₂ Emissions



The Goal:

For Kazakhstan to be :

- **a full member of FCCC Annex I (effective o/a October 1999), committed to a reasonable binding emission reduction target for 2008-2012, and**
- **participating (from 2000 onward) in a functioning world market for emission trading – initially, and for as long as possible, as a net seller of TERUs.**

Meeting the Goal: Political Leadership and Will

- **The GOK's economic, environmental and energy leaders must understand the benefits to Kazakhstan of participation and the legal and institutional requirements for success.**
- **Further, they must be willing and able to make hard policy choices, probably in the face of some opposition, in order to create the conditions for success.**
- **Tangible actions must include development, passage and implementation of key laws, standards and policies on environment; energy-sector restructuring, privatization and regulation; energy pricing and market reform; and overall investment and finance.**
- **A key principle to which GOK leaders must "buy in" will be that the solutions and benefits are best achieved through approaches in which outcomes are market-determined and private parties play key roles.**

Meeting the Goal: Private Participation

- **The private sector – especially foreign investors in Kazakhstan's energy systems - must be full partners in the FCCC effort, with full understanding and appreciation of the goals and an opportunity to benefit.**
- **The private sector will be the single most important source of investment capital and the primary buyers and sellers of Kazakhstan's emission reduction credits.**
- **Private companies operating in Kazakhstan will be in a position to make critical decisions on specific initiatives leading to reduced emissions – especially in the rehabilitation of thermal power plants.**
- **Participation of private companies will depend their opportunities to act as decision-makers and realize significant financial benefits from emissions trading.**

Meeting the Goal: Information and Analysis

- **The 1994 emissions inventory needs to be completed.**
- **Credible economic forecasts need to be developed and employed through modeling as the basis for alternative scenarios for energy demand and emissions forecasts.**
- **Additional sectoral analyses need to be undertaken for energy, transportation, industry and household energy use and emissions.**
- **Project-level feasibility analyses and demonstrations need to be undertaken to determine potential for energy savings and emissions reduction, along with costs and benefits.**
- **A binding emissions reduction target needs to be set at a level that is realistically achievable and may be exceeded in order to extend Kazakhstan's time to benefit from selling TERUs.**

Meeting the Goal: Energy-Sector Actions

- **Ongoing Restructuring and Privatization:**
 - **Unbundling, privatization and decentralization of power generation and distribution need to be completed.**
 - **80% of generation capacity is now privately owned, but regulatory issues remain to be resolved before major investments will be undertaken.**
 - **Distribution companies need to be restructured, decentralized for commercial viability and made available for private investment.**
 - **Natural gas needs to be demonopolized, prepared for private investment and assessed for viability as a contributor to GHG emission reductions.**

Meeting the Goal: Energy-Sector Actions

- **Increased Energy Efficiency:**
 - **Since over 80% of greenhouse gas emissions come from coal-fired power plants, these must be rehabilitated to improve efficiency – starting with low-cost measures estimated to hold potential for up to 20% savings.**
 - **End-use efficiency improvements should be pursued in transportation, residential heating and industrial processes (along with clean production/waste minimization and environmental management systems).**
 - **The manufacturing sector appears particularly promising, with potential for 25-40% fuel savings and 10-20% electricity savings in the metal, chemical and refining industries.**

Meeting the Goal: Energy-Sector Actions

- **Rationalized Energy Markets:**
 - **Tariff subsidies need to be removed, with provisions for a social safety net targeted to low-income households.**
 - **Metering, billing and collections need to be improved (including action to cut off service to delinquent customers).**
 - **Regional mechanisms for trade in power, water and natural gas need to be further developed and effectively implemented.**
 - **Eventually, an efficient wholesale power market needs to function throughout the region.**

USAID's role:

- **Long-term advisors are in place working on environmental policy and economics, on power-sector restructuring and regulation, and privatization, and on oil and gas regulatory development.**
- **Work to date with the Ministry of Environment has contributed to understanding and motivation of key GOK actors and to Buenos Aires announcement.**
- **Energy efficiency work and analysis of key industrial sectors and municipal heating systems has demonstrated potential for energy savings and emission reductions.**
- **USAID Country Studies Program has played a critical role in developing emissions inventories and projections.**

Next steps: Work will continue on all of the above, and...

We can help CEA with the next steps:

Timing for team visit is critical, but post-election uncertainties and cautious outlooks may be impeding schedule commitments.

USAID and Amembassy/Almaty are coordinating preparations closely.

USAID will fund expenses of key counterparts participating, through our Environmental Policy TA contract.

Delivery of CEA paper to Kazakh counterparts may require fast-track translation and dissemination (which can be facilitated in the field).

USAID/Washington and USAID/Almaty are prepared to participate in CEA team and to make available resources, advisors and programs to promote this initiative.

Our comparative advantages: the policy framework and energy-sector actions.

Our principal implementing partners: Hagler Bailly and EPIQ (HIID and IRG).

FINAL REPORT

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

PN-ABY-317

sn. 98795

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

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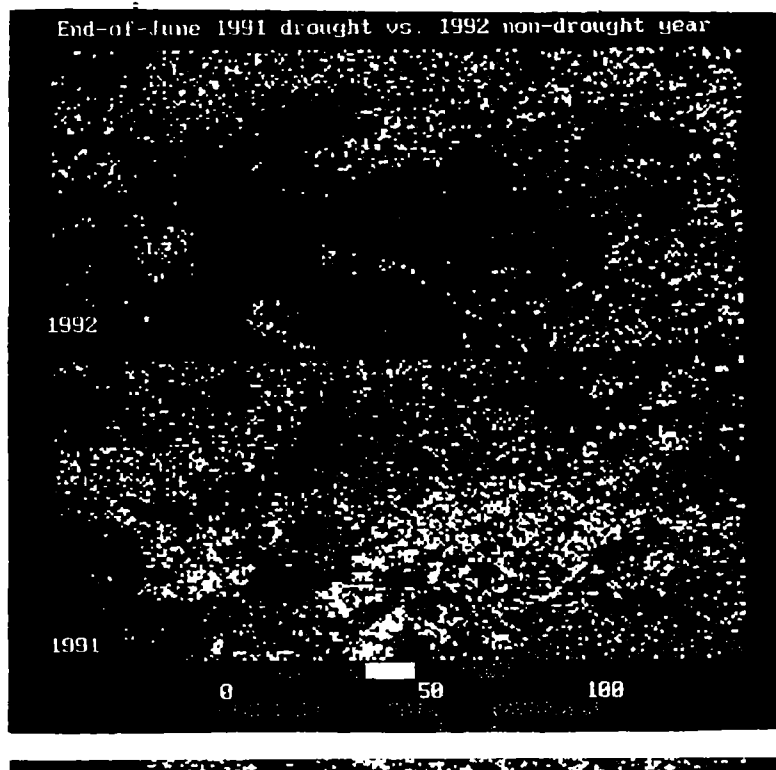
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US-Israel AID/CDR/CAD program, Grant No. TA-MOU-CA13-056



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III. Executive Summary

Most of Kazakhstan's pasture and crop land is located in arid and semi-arid zones with limited amounts of precipitation. Drought is the most typical phenomenon of the Kazakhstan climate, and occurs every two to four years. The climatic conditions of Kazakhstan cause a two to three fold variation in agricultural production from year to year and put considerable constraints on the Kazakhstan economy and its sustainable development. In order to mitigate harsh climatic and weather conditions, efficient management of water resources, and advanced estimation and planning of agricultural production are required. Fulfillment of these tasks is impossible without thorough monitoring of the crop environment and conditions, assessment of weather impacts, and estimation of crop and pasture production over a large area, drought detection and the monitoring of drought expansion, duration and impact.

Weather data are the primary sources of information used presently in Kazakhstan for monitoring the environment. Unfortunately, weather-watch systems have serious shortcomings due to insufficient density of weather observations and their scarcity in real time. The current economic situation in Kazakhstan puts additional constraints on conventional observation systems for monitoring the environment, because the number of weather stations is sharply decreasing and the quality of environmental observations is deteriorating

As the result of this project, we developed

scientific principles, hardware and software background of a non-conventional system that will use NOAA operational polar-orbiting satellites for quantitative assessments of pasture/crop conditions and productivity in Kazakhstan.

The system includes:

- * completely integrated and self-contained, High Resolution Picture Transmission receiving station with tracking antenna and positioner and receiver/demodulator/sectorizing subsystems;
- * on-line PC IBM 486 for data collection and initial processing;
- * image processing hardware and software for data processing, storage and distribution;
- * algorithms for converting satellite radiances into a new Vegetation Condition Index (VCI);

- * algorithms for converting the VCI into ground-derived environmental and agricultural characteristics such as: seasonal dynamic of pasture and crop conditions, their productivity, drought detection, and monitoring..

The developed algorithms were validated against ground measurements collected by conventional and remote sensing techniques in several areas of Kazakhstan with different climates and economic development.

The results of this research will be used to improve monitoring of the environment, especially those conditions and phenomena that have an unfavorable impact on pasture and crop productivity. These results will also help to increase the accuracy of agricultural production estimates and provide better spatial and temporal coverage. Such improvements, in turn, will help to develop a more efficient system for management of water resources and to improve agricultural planning. Since satellite data collection has global coverage, this system will serve as a prototype for similar systems in other parts of the world where ground observations are limited or not available at all.

The results of this project will help Kazakhstan to start using new remote sensing technology for drought monitoring. The delivered hardware, software, and proposed concept and methods, will provide a basis for a new, complete and efficient drought-watch system. This system will be the main contributor to a program of early warning crop and pasture hazardous condition assessments and predictions of agricultural production. The findings of this project will also help to increase the accuracy of agricultural production estimates, spatial distribution of production and timeliness of delivery of these estimates to customers.

The main beneficiary institutions in Kazakhstan will be, first, our collaborators, the Institute for Space Research, and the National Meteorological Administration; other institutions to benefit include the Ministries of Agriculture, Environment, Water Resources and Kazakhstani Government.

All project goals were achieved. Scientific principles, hardware and software of the non-conventional system which will use NOAA operational polar-orbiting satellites for quantitative assessments of pasture and crop conditions and productivity in K were developed. In addition, several other important tasks were accomplished:

- * calibration of satellite-derived indices versus ground data at experimental sites;
- * remote aircraft measurements together with ground observations;
- * near real-time monitoring drought and vegetation conditions in 1995.

Future work should include:

- * launching a system for receiving satellite images and real-time monitoring of drought, and monitoring of crop and pasture conditions and their productivity;
- * developing satellite data base for the entire Kazakhstan.
- * calibrating and validating the algorithms for major crop- and pasture-producing regions of Kazakhstan.

4. Research objectives and innovative aspects

4.1 Introduction

Kazakhstan occupies 2,717,000 km² of territory, which is equivalent to almost one third of the United States of America. The economy of Kazakhstan is highly dependent on agriculture, which has grain and livestock production orientation. In recent years, grain crops were produced on an area 23 to 25 million hectares, while 200 million hectares of grass lands provided the main source for feed.

Agricultural production is highly dependent on climate and weather. Most of Kazakhstan's crop and pasture land is located in arid and semi-arid zones with a limited amount of precipitation. Fluctuations of rainfall during the growing season from year to year are large and put severe additional constraints on agriculture, because farmers have to cope with water deficit. Drought is the most typical phenomenon of the Kazakhstani climate, occurring every two to four years. Intensive droughts were observed in 1989, 1991 and 1993, causing variation in total grain production from 12 (1991) to 30 (1992) million metric tons. Droughts in Kazakhstan are often accompanied by dessicative wind and sometimes continue for several consecutive years.

In order to mitigate these harsh climatic and weather conditions, efficient management of water resources, and advanced estimation and planning of agricultural production and pasture conditions are required. Fulfillment of these tasks is impossible without thorough monitoring of crop environment and conditions, assessment of weather impacts, and estimation of large scale crop and pasture production. Also drought detection and monitoring of its expansion, duration, and impact are very important tasks.

At presents weather data are the primary sources of information widely used to monitor the environment. Unfortunately, weather-watch systems have serious shortcomings because weather data characterize point locations rather than an area, and meteorological stations are not equally distributed. The problem of the low density of weather station becomes especially acute in areas with marginal climatic resources such as Kazakhstan. In addition, weather data are quite often not available in real time or they are incomplete due to political, economic, or even just communication problems. The current economic situation in Kazakhstan puts additional constraints on the conventional system for monitoring the environment because the number of weather stations is sharply decreasing and the quality of environmental observations is deteriorating.

Observations from meteorological satellites routinely provide more complete, timely and much better spatial coverage of the earth's surface and environment than do weather stations. Over the past decade, satellite-derived vegetation indices, particularly those which are derived from NOAA polar orbiting operational satellites, have shown excellent potential for monitoring vegetation,

timely and much better spatial coverage of the earth's surface and environment

and environmental parameters and phenomena (Tucker et al., 1985; Marlingreau, 1986; Prince et al., 1986; Townshend et al., 1986; Tucker et al., 1986; Justice et al., 1986; Rao et al., 1990; Ohring et al., 1989; and NOAA, 1989, Kogan, 1987, 1995a, b). Presently, a considerable amount of the AVHRR-based data are archived and can be used for monitoring weather impacts, assessment of crop and pasture environment and conditions, and for estimating crop and pasture production.

However, in order to use the NOAA operational satellite data in Kazakhstan it was necessary to adjust them to local conditions, to parameterize the equations, to develop algorithms for data correction, calibration and use, to validate the results and to transfer new technology. This project provides answers to all of these problems.

4.2 Objectives

The overall goal of this project was to develop

scientific principles, algorithms, hardware and software for a non-conventional system that will use NOAA operational polar-orbiting satellites for quantitative assessments of pasture and crop conditions and productivity in Kazakhstan.

The system includes:

- * The High Resolution Picture Transmission (HRPT) satellite receiving station with tracking antenna and positioner and receiver/demodulator/sectorizing subsystems;
- * on-line PC for data collection and initial processing;
- * image processing hardware and software for data processing, storage and distribution;
- * development of a new Vegetation Condition Index (VCI);
- * algorithms for converting the VCI into ground-derived environmental and agricultural characteristics.

Specific tasks included:

- * development and implementation of algorithms for using data observed with 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, as well as and also crop and pasture environments.

- * quantitative estimation of pasture and crop conditions and yield;
- * assessment of seasonal dynamics of pasture and crop productivity for major ecological zones of Kazakhstan;
- * development of algorithms for drought detection and the monitoring of drought development, extent, duration, and impact on vegetation on a large area;
- * development of remote sensing and ground-truth PC data bases for efficient use and distribution;
- * transferring new remote sensing technologies and skills in using operational satellite data for sustainable agricultural development in Kazakhstan.

4.3 Strengthening the Scientific and Technical Capacity of Kazakhstan

This project combines scientific and operational aspects of remote sensing, agricultural meteorology, agronomy, soil physics, and management and optimization of water use. It will promote the use of advanced remote sensing scanners, computing methods and PCs for accurate and timely estimation of pasture and crop productivity in arid zones. The remote sensing methods and techniques employed in Kazakhstan will extend the application techniques towards efficient use of water in agriculture and arid zone pastures. This work has strengthened collaboration between the developing country and countries with advanced technologies.

Most of the work was conducted in Kazakhstan. Drs. E. Zakarin and L. Spivak (Kazakhstan) managed the installation and operation of the satellite receiving station and the hardware for recording, processing, and achieving the data. They and Dr. L. Lebed managed collection of ground-truth data both from the test fields and from conventional sources in Kazakhstan. Researchers from Kazakhstan visited Israel to learn new technologies. Remote sensing data from a large area were collected in the USA from NOAA's archive of the Global Vegetation Index (GVI) data set. Drs. A. Gitelson (Israel) and F. Kogan (USA) transferred technologies and trained Kazakh specialists in system development and application. They also participated in ground-truth data collection and training the staff how to measure spectral characteristics of vegetation and atmosphere, using instruments belonging to the J. Blaustein Institute for Desert Research (Israel).

4.4 Innovative aspects

First time

- * satellite operational technologies were applied to
 - estimation of crop and pasture conditions and productivity over a large area with different ecological and climatic zones;
 - drought detection and monitoring in an area of extreme continental climate.
- * algorithms were developed for quantitative assessment of crop and pasture productivity;
- * the developed algorithms were validated against ground measurements collected by conventional and remote sensing techniques over a large area of Kazakhstan.

5. Methods and Results

5.1 Rational

5.1.1 *Vegetation as an indicator of the environment*

Vegetation is the most important part of land ecosystems. Climate, soil, geographic features and ecological resources influence vegetation, changing its productivity and distribution and largely determine the vegetation type and amount in a given region.

On a short-term basis, changes in vegetation are mainly controlled by weather fluctuations. Vegetation responds to environmental changes through redistribution of the energy and water fluxes inside the atmosphere-vegetation-soil continuum. Transpiration and evaporation are the most important processes that control the partitioning of net radiation into latent and sensible heat fluxes and redistribution of water between surface run-off and infiltration. The latter processes regulate the amount and movement of water in the soil and, finally, its availability to vegetation. Uninterrupted flow of water in the soil creates an environment for development of root systems and delivery of water to leaves. This, in turn, activates evapotranspiration, reduces sensible, and increases latent, heat fluxes and stimulates a healthy environment for excellent growth and high productivity of vegetation. Lack of water in the soil causes the opposite flow of processes, leading to an unhealthy environment and, consequently to low productivity of vegetation. Thus, the state of vegetation and changes in this state, act as a signal vis-a-vis vegetation condition and production and indirectly characterize environmental conditions.

One of the most attractive properties of vegetation is its ability to reflect past environmental conditions. These accumulated conditions alter the flow of physiological processes, that, in turn, lead to the changes in vigor, density, and greenness of vegetative surface. The possibility to estimate antecedent conditions as they are reflected in vegetation appearance is especially useful for the assessment of cumulative environmental impacts, necessary for forecasting vegetation growth, development, and production.

5.1.2 *The Normalized Difference Vegetation Index*

The concept of the vegetation index is based on green vegetation's differential reflection radiance in the visible (0.58-0.68 channel 1 or Ch1) and near infrared (0.725-1.10 channel 2 or Ch2) wavelength. Spectral measurements in these channels are responsive to the chlorophyll content, and to the structure of the mesophyll and corresponding water content in leaves (Tucker and Sellers, 1986). These physiological properties determine low spectral reflectance in Ch1 and high reflectance in Ch2. The difference between the bands was found

to relate to such properties of vegetation as leaf area index, photosynthetic capacity, and biomass (Sellers, 1985) and through time to the vegetation environment (Goward et al., 1985). This difference is usually normalized and named the Normalized Difference Vegetation Index (NDVI) which has the following expression:

$$NDVI = (Ch2 - Ch1) / (Ch2 + Ch1)$$

Extensive applications of NDVI data for global vegetation mapping have been demonstrated in many publications (e.g., Tucker et al., 1985; Malingreau, 1986; Townhsend et al., 1986; Prince et al., 1986; Justice et al., 1986; Ohring et al., 1989). Recently, a new algorithm has been developed that offers new opportunities for monitoring climate and land surface parameters and phenomena. This algorithm was verified and shown to be useful for monitoring drought, weather impacts, vegetation conditions, soil moisture, and productivity of ecosystem and agricultural crops (Kogan, 1987, 1990, 1995; Kunkel et al., 1991).

However, by the very nature of remotely sensed data, satellite-derived environmental measurements are indirect and require calibration and validation by actual ground observations. The application of the developed algorithms to new areas requires the verification of these algorithms against ground measurements and in most cases modification and adjustment of these algorithms to the environmental geographic and economic conditions; parametrization of the models' coefficients is also needed.

5.2 Data description

Two data sets were applied in this study: remote sensing data obtained from NOAA polar-orbiting operational satellites and conventional (actual or "ground-truth") data obtained from weather station observations, measurements of vegetation characteristics and radiances in field experiments.

5.2.1 Satellite data

These data were collected from the Global Vegetation Index (GVI) data set that is produced by NOAA's National Environmental Satellite Data and Information Service (NESDIS), described in Tarpley et al. (1984) and Kidwell (1990). The GVI is produced by sampling and mapping the 1-km daily radiance, measured by the Advanced Very High Resolution Radiometer (AVHRR) on board NOAA polar orbiting satellites, to a 16 km map. Radiances measured in the visible and near infrared wavelengths are used to calculate the NDVI.

The daily maps of GVI parameters (radiance, NDVI, satellites and sun angles) are integrated over a seven-day period by saving those values that have the largest difference between radiance for the near infrared and visible wavebands during the seven days for each map cell. This procedure has the effect of

minimizing cloud contamination in the weekly composite. The weekly GVI data from April 1985 through 1995 were used in this project.

5.2.2. Ground measurements

Ground measurements were collected from weather station observations and measurements in field experiments.

Weather observations were obtained from 69 stations during the 1985-1994 period. The locations of the stations are shown in Fig. 1 and Table 1. Weather observations included 10-day total precipitation (mm) and average temperature (°C), end of 10-day soil moisture (mm), phenology and density of vegetation (number of plants per square meter).

During the growing seasons of 1994 and 1995, the biomass of winter wheat and spring barley (three plots) was measured at station Aksinger, 36874 (Almaty), and that of grass at four plots of station Aidarly, 36819 (Almaty). The locations of these plots are shown in Fig. 2. Simultaneously with biomass, radiance was measured with hand-held and airborne radiometers. These measurements were made in the spectral bands corresponding to Ch1 and Ch2 of the AVHRR sensor. The NASA-designed hand-held radiometer was used to measure upwelling radiance of vegetation and a reference plate. The reflectance of vegetation was determined as a ratio of crop to plate radiance. The reflectance was measured in twenty different locations of each plot and average and median values were calculated.

An airborne radiometer (two channels field photometer DPF, designed by the Institute for Experimental Meteorology, Russia) was used to measure the radiance in the same Ch1 and Ch2 spectral bands as the AVHRR sensor. These measurements were carried out once from a MI-4 helicopter along route A shown in Fig. 2.

5.3 Algorithm development

A fundamental constraint to the application of satellite-derived NDVI for vegetation monitoring is the presence of considerable noise which is comparable to the estimated environmental signal. The largest noise comes from fluctuating transparency of the atmosphere, especially the presence of clouds and aerosols. The other major causes of instability are changing sun and sensor geometry, bi-directional reflectance of the atmosphere and surface, satellite orbital drift, uncertainty in the sensor calibration, and methods of sampling, calculating and mapping of these data (Gutman, 1991; Goward et al., 1991). To minimize cloud effect, the temporal compositing procedure (integration over 7 days) is currently used. However, this procedure creates some other noise in GVI data. As the result, the seasonal curve of the NDVI is very erratic (Fig. 3). These fluctuations must be removed from the data before their application. In addition, NDVI values

Table 1. WMO Station number,coordinates and the name of Kazakhstan regions (oblast).

AKMOLA

N Station	Latitude	Longitude	Height
<i>28978</i>	52.32	68.45	399
<i>35078</i>	51.49	68.22	308
<i>35081</i>	52.24	70.14	332
<i>35082</i>	52.21	71.48	397
<i>35085</i>	52.00	70.57	384
<i>35173</i>	51.37	69.50	305
<i>35179</i>	51.06	69.30	324
<i>35188</i>	51.08	71.22	348
<i>35191</i>	51.37	73.08	397
<i>35283</i>	50.50	72.18	426
<i>35284</i>	50.35	70.00	331
<i>35376</i>	49.53	69.31	350
<i>63902</i>	52.00	69.50	214
<i>63904</i>	51.39	69.11	283
<i>63905</i>	51.16	70.44	322

ALMATY

N Station	Latitude	Longitude	Height
<i>36744</i>	45.28	75.13	362
<i>36819</i>	44.08	75.51	498
<i>36870</i>	43.21	77.01	847
<i>36874</i>	43.27	76.16	643
<i>36877</i>	43.14	76.18	814
<i>36885</i>	43.22	77.28	1098
<i>36894</i>	43.36	78.15	606
<i>36897</i>	43.18	78.15	2216
<i>36905</i>	43.20	79.28	1273
<i>64801</i>	43.22	77.28	1091

Table 1 (cont.)

JESKAZGAN

N Station	Latitude	Longitude	Height
35478	48.52	68.06	790
35497	48.51	72.52	656
35498	48.37	73.41	724
35576	48.18	69.39	361
35582	48.41	71.40	488
35663	47.50	66.45	505
35671	47.48	67.43	350
35683	47.54	70.28	796
35687	47.21	70.42	471
35699	47.27	74.49	619
35777	46.41	68.20	276
35884	46.02	70.12	328
35895	46.07	73.37	400

KARAGANDA

N Station	Latitude	Longitude	Height
35198	51.03	74.00	372
35386	49.55	71.48	422
35391	50.11	72.43	420
35393	50.13	74.18	450
35394	49.48	73.08	555

KOKCHETAV

N Station	Latitude	Longitude	Height
28877	53.19	68.06	319
28888	53.55	71.30	101
28966	52.49	66.58	227
28984	52.57	70.13	398
28986	52.56	71.05	196

Table 1 (cont.)

KUSTANAI

N Station	Latitude	Longitude	Height
28764	54.29	65.47	161
28843	53.47	62.06	187
28952	53.13	63.37	121
28957	52.41	62.36	208
63505	51.42	61.42	262

NORTH

N Station	Latitude	Longitude	Height
28687	54.54	70.27	134
28766	54.22	67.00	153
28775	54.02	68.26	115
28785	54.26	70.55	127
28863	53.53	67.25	150

PAVLODAR

N Station	Latitude	Longitude	Height
28993	53.07	74.12	126
28999	52.44	74.58	115
29808	53.22	76.19	118
29802	53.49	76.32	114
36012	52.24	78.10	149

TURGAI

N Station	Latitude	Longitude	Height
35064	52.04	65.37	252
35067	51.53	66.20	222
35069	51.54	67.18	386
35163	51.36	67.26	261
35169	51.03	66.18	267

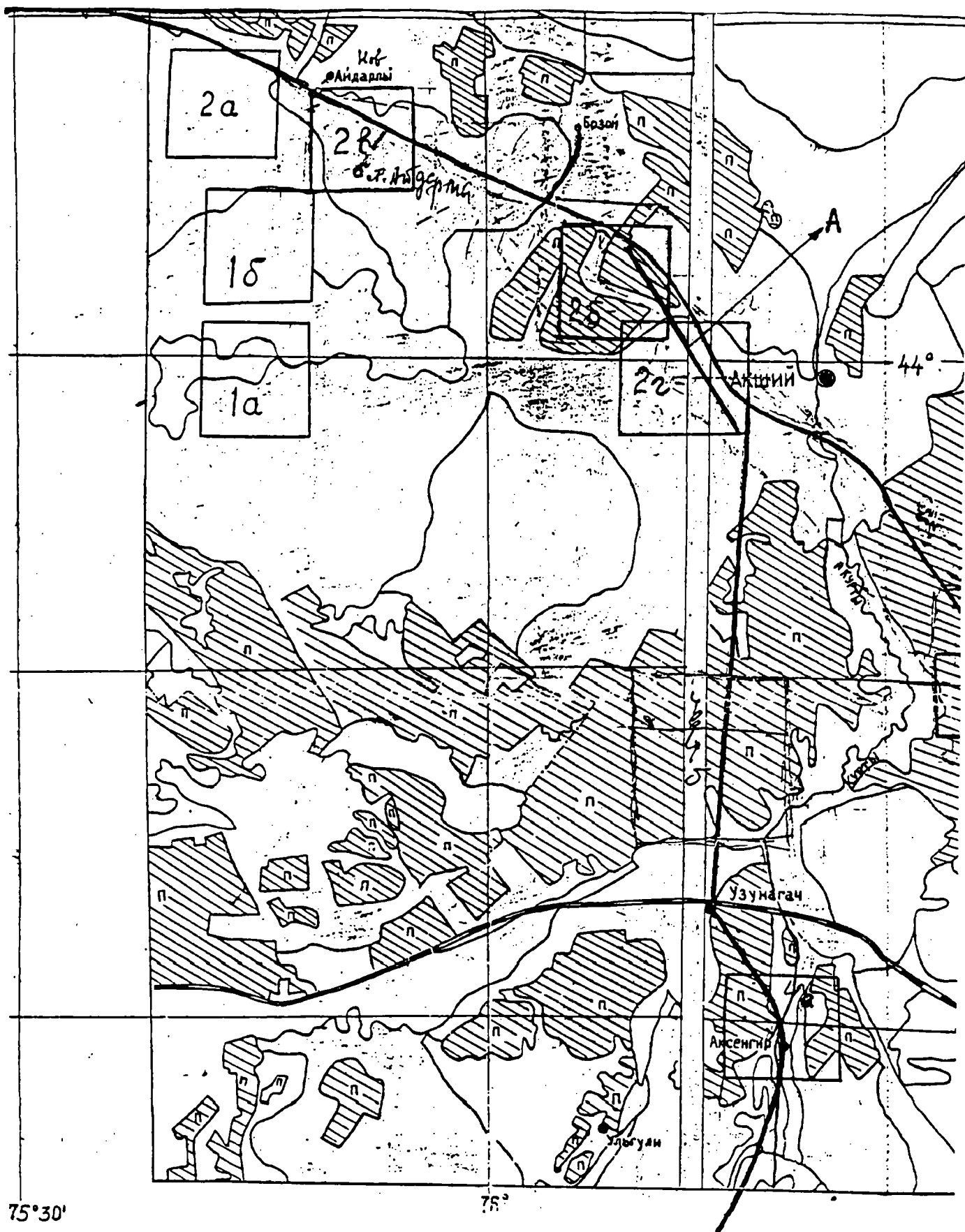


Fig. 2. Location of experimental plots. A is the route of airborne radiance measurements.

reflect the combine influence of ecology and weather on vegetation. Moreover, the weather signal in the NDVI value is much weaker than the ecological one. That is why the weather signal is not easily detectable (Kogan, 1987; 1990). Since the objectives of this proposal required estimation of weather-related NDVI, this portion of the NDVI must be separated from the total NDVI value.

5.3.1 Principles of the algorithm

An algorithm was designed to reduce noise and to enhance the weather-related component in time series of NDVI data. Since complete physically-based corrections for all atmospheric effects and for various land surfaces are not available, temporal fluctuations were removed by smoothing the weekly NDVI time series with a compound median filter (Velleman et al. 1981). This technique was superior to others in eliminating outliers, emphasizing the annual vegetation cycle and weather-related NDVI fluctuations (van Dijk et al. 1987; Kogan 1987, 1990). The smoothed curve in Fig. 3 illustrates this superiority.

After smoothing year-to-year, differences caused by weather variations in NDVI became more apparent (Fig. 2 in Kogan, 1995a). Following this approach, the NDVI quantifies both spatial differences between productivity of ecosystems (ecosystem component) and year-to-year variations in each ecosystem due to weather fluctuations (weather component). The ecosystem component is mainly controlled by such slow changing environmental factors as climate, soil, topography, and vegetation type that determine the amount and distribution of vegetation on the Earth. The weather component of NDVI is controlled by weather parameters (rainfall, temperature, wind, etc.) which determine vegetation state and greenness during the annual cycle.

The weather component of NDVI is superimposed on the ecosystem component. Maximum amount of vegetation is developed in years with optimal weather since such weather stimulates efficient use of ecosystem resources (for example, increase in the rate of soil nutrition uptake). By contrast, minimum vegetation is developed in years with extremely unfavorable weather conditions (mostly dry) which suppress vegetation growth directly and indirectly through a reduction in the rate of ecosystem resources use. For example, lack of water in drought years reduces considerably the amount of soil nutrition uptake. The absolute maximum and minimum of NDVI calculated from several years of data that contain extreme weather events can be used as criteria for quantifying these extreme conditions.

In this project, we calculated the highest and the lowest NDVI values during 1985-1993 for each of the 52 weeks of the year and for each pixel. The resulting maximum and minimum NDVI were used as the criteria for estimating the upper (favorable weather) and the lower (unfavorable weather) limits of the ecosystem resources. These limits characterize the "carrying capacity" of Kazakhstan's ecosystems. Since the minimum and maximum NDVI curves delineate the contribution of ecosystem component in the NDVI value for the cases with the

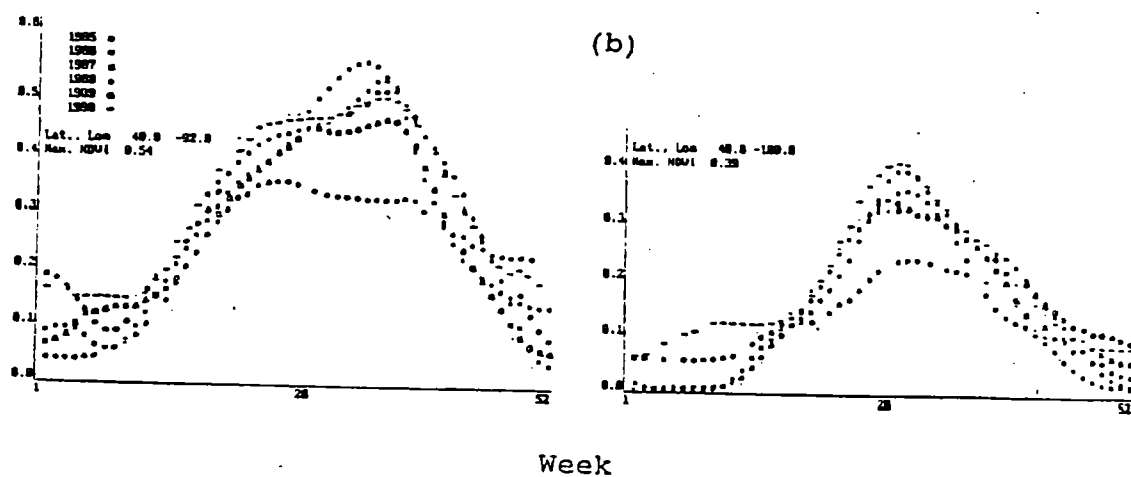
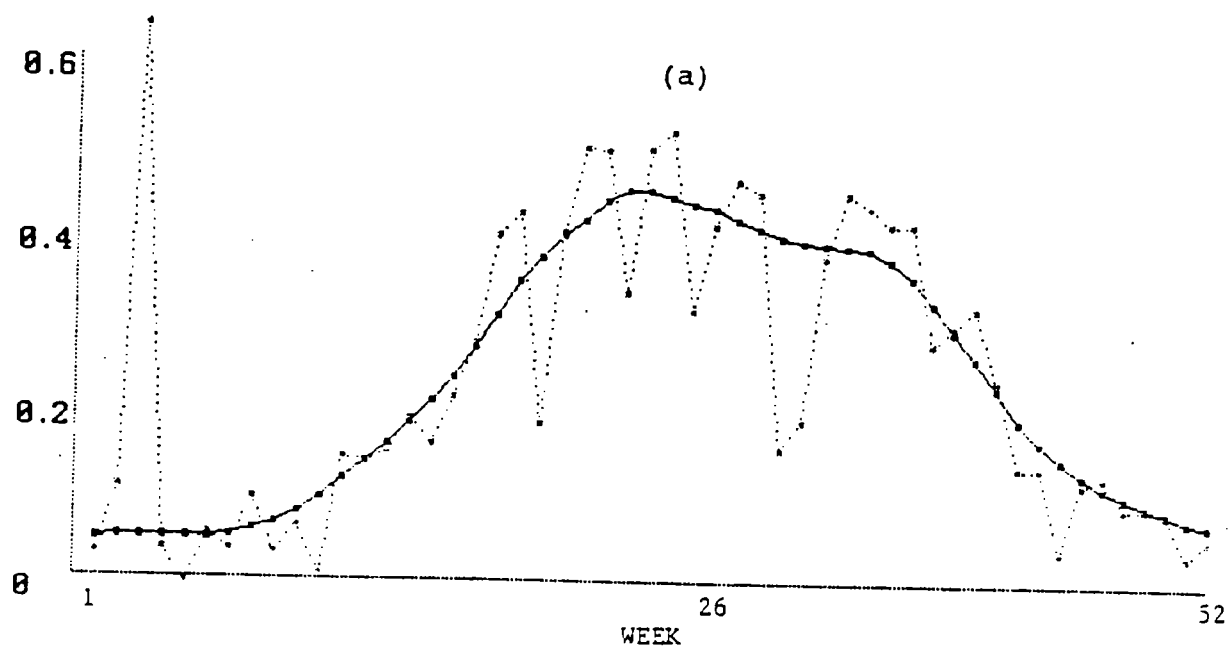


Fig. 3. Weekly NDVI: smoothed (solid line) and unsmoothed (dotted line) for one 16 km x 16 km pixel (lat 39.14, long -80.86) in 1987 (Kogan, 1995a).

most extreme weather, the area between these curves largely approximates the weather-driven component of the NDVI .

Figure 4 shows the weekly maximum and minimum NDVI curves for selected ecosystems (one pixel for the ecosystem) typical for Kazakhstan. Each ecosystem has its own NDVI signature in terms of NDVI value, shape of the curve, rate of NDVI change during leaf appearance and senescence, and partitioning of NDVI value into weather and ecosystem components. The northern Kazakhstan has the highest NDVI values with clearly defined seasonal dynamics and smaller total area of weather (blue envelope) versus ecosystem components (green area). This type of seasonal dynamics is typical for Kazakhstan steppe zone with 400 to 500 mm of annual precipitation. Moving to the south, the NDVI decreases, does not show distinctive seasonal dynamics, and has an almost equal contribution of weather and ecosystem components into the integrated area under the maximum curve. This represents Kazakhstan's semi-arid and desert climate.

Figure 4b shows stratification of the whole Kazakhstan area (for each 16 km by 16 km grid) based on the maximum and minimum NDVI averaged for the middle of the growing season (May through August). It should be noted that nine years of data hardly satisfy statistical requirements to formulate reliable conclusions. However, the concept of the minimum NDVI suggests the existence at least one year in the study period with drought such as 1991 in Kazakhstan. For near-optimal weather several years of data were used. Verification showed that even for such a small sample there is a very good correspondence between spatial distribution of NDVI-derived zones in Fig. 4b and spatial distribution of vegetation and climate zones based on *in-situ* data.

5.3.2 Vegetation Condition Index

For vegetated regions the integrated area of the weather-related NDVI component is smaller than the ecosystem one. Consequently, the weather impacts on vegetation are not easily detectable from NDVI data. When the NDVI was used for assessment of these impacts and drought detection, the weather component of the NDVI was enhanced by separating it from the ecosystem component (Kogan 1987, 1990, 1995a). Therefore, the weather-related NDVI envelope (blue area in Fig. 4a) was linearly scaled from zero, minimum NDVI to 100, maximum NDVI for each grid cell and week. The resulting parameter was named the Vegetation Condition Index (VCI) defined by the following expression:

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

where NDVI, $NDVI_{max}$, and $NDVI_{min}$ are the smoothed weekly Normalized Difference Vegetation Index, its multi-year maximum, and multi-year minimum, respectively, calculated for each pixel.

(A)

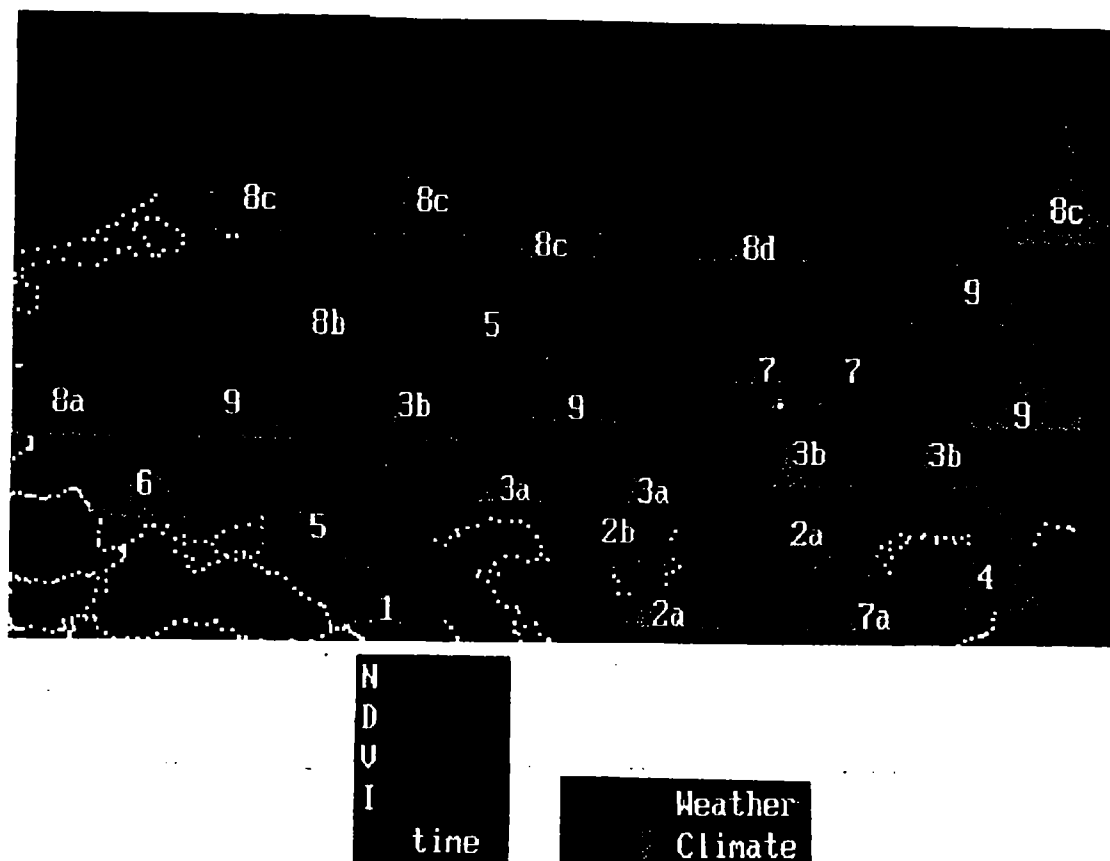


Fig. 4. Multiyear maximum and minimum NDVI: (A) weekly for a single pixel in the main ecological zones of the former Soviet Union, including Kazakhstan (the southeast quadrant), and (B) May-August average. These data were used to estimate the contribution of the ecosystem and weather component in NDVI value. The NDVI time series in (A) are shown for the ecological zones (Atlas of the USSR's Agriculture, 1960): 1) broadleaf forest of Caucasus, annual precipitation 1200-1600 mm; 2) desert, less than 150 mm (a) shrubs and saxaul, (b) wormwood and saline; 3) semi-desert (a) southern, 150-200, (b) northern, 200-250 mm; 4) mountain alpine meadow; 5) flood meadow; 6) steppe, chernozem soil, 500 mm; 7) steppe, chestnut soil, 250-350 mm; 8) forest (a) broadleaf, 600-700 mm, (b) dark coniferous, 500-600, (c) pine, 500-600 mm, (d) mid-taiga dark coniferous, 400 mm; 9) prairie.

(B)

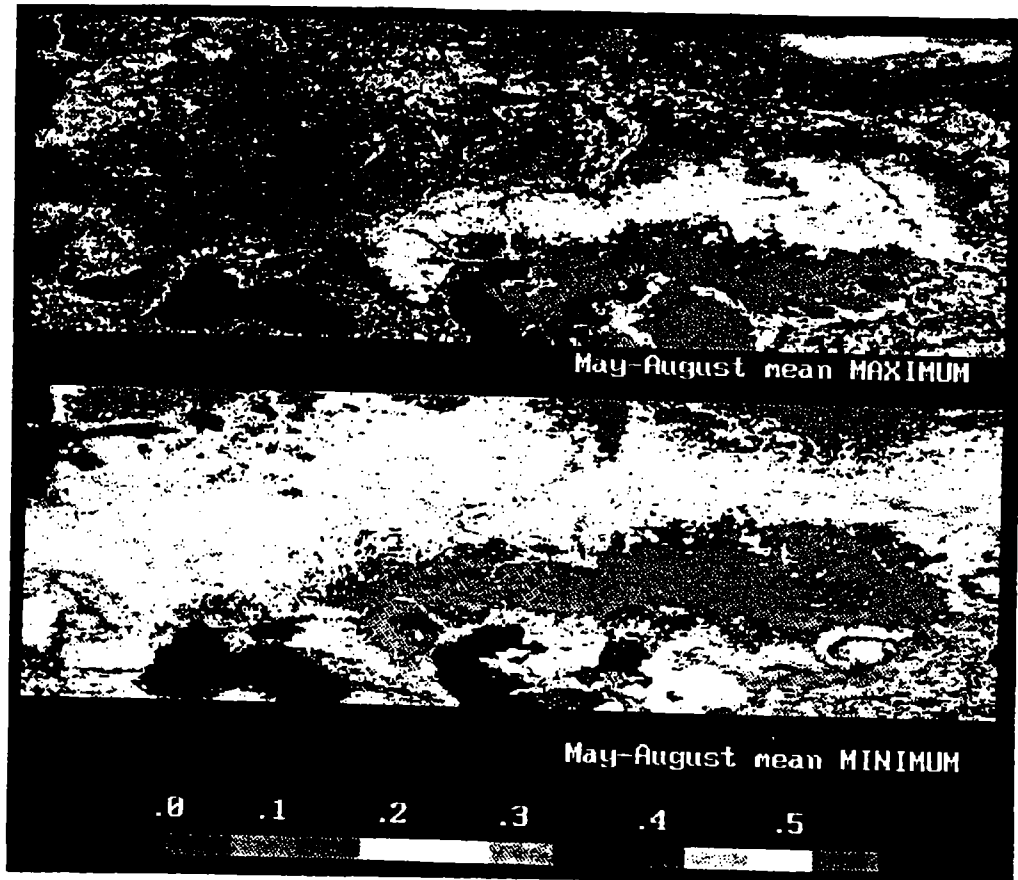


Fig. 4.

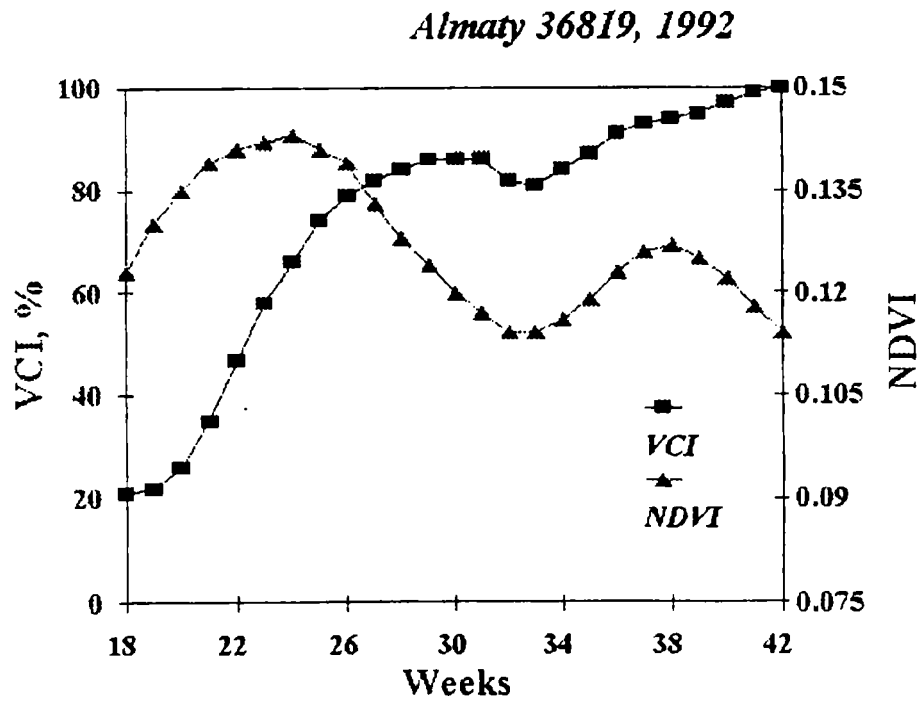
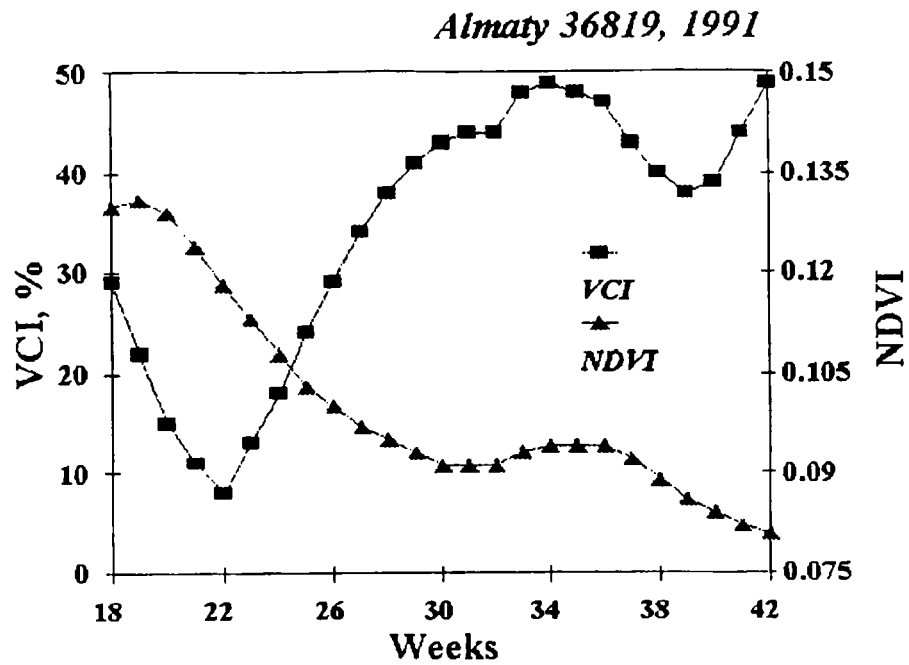


Fig. 5. NDVI and VCI dynamics at station 36819 (Almaty) in (a) 1991(dry conditions), and (b) 1992 (favorable conditions).

The VCI approximates the weather-related component in the NDVI value. It changes from zero to 100, corresponding to the changes in vegetation conditions from extremely unfavorable to optimal. We should note that NDVI can also be used for estimation of vegetation conditions but only for one location. If we need to compare the vegetation state in different ecological and climatic zones, the VCI will provide more accurate estimates. Figure 5 shows NDVI and VCI dynamics on one of the test sites in Kazakhstan during two years with extremely different weather conditions. Although NDVI had very similar dynamics during these years, the VCI indicates that the dynamics of vegetation conditions were very different and VCI values in 1992 were two to three times larger than in 1991. The difference between the NDVI and VCI is clearly demonstrated by Fig. 6. This relationship indicates that the same VCI value corresponds to several different NDVI values: two for weeks 10 to 30 and even three for weeks 44 to 48.

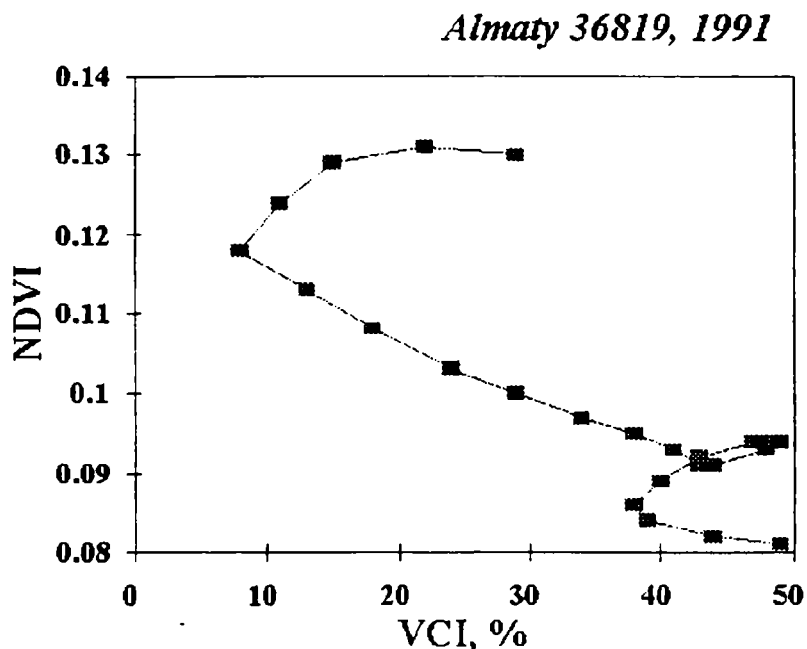


Fig. 6. Relationship between NDVI and VCI for station 36819 (Almaty) in 1991.

The VCI application for drought analysis was investigated in our earlier publications. VCI values appropriate for drought detection and monitoring were determined by correlating US crop yield with VCI (Kogan 1995a, b). The 20 percent yield reduction during drought years was associated with 0 to 35 of VCI. This range was accepted as a VCI-derived drought indicator. In order to use the VCI as a tool for assessment of vegetation conditions it should be calibrated

against some weather-dependent characteristics of vegetation, such as vegetation height, density, biomass, and yield of pasture and crops. Therefore, the largest part of this project was devoted to collecting the above-mentioned vegetation characteristics.

5.4 Results of the 1994 ground measurements at test sites in Kazakhstan

Since satellite measurements relate to large, non-uniform areas we investigated first, spatial and seasonal variations of NDVI, measured by a hand-held radiometer, and, second, compared them with ground measurements of vegetation biomass, which also shows non-homogeneous behavior.

5.4.1 Spatial variation of NDVI

Figure 7 shows the spatial variation of NDVI during the growing season for grassland (a) and spring barley (b). Each plot had size 100x100 m. Both vegetation types showed clear seasonal dynamics of NDVI with a maximum being reached from the end of May through June. The maximum of NDVI over the barley plot (b) occurred later due to late planting. This indicates that in addition to the natural spatial variability NDVI values also characterize spatial variability, due to agricultural technology. As seen from the coefficient of variation (Fig. 8), natural spatial variability of NDVI can reach as much as 30 %.

It can be larger if technological changes contribute to this variability as indicated in Fig. 7b (plot b).

Spatial variation of NDVI was also measured by photometer on board a helicopter along the 20-km transect of pasture fields (c) and (d) on August 12, 1994. As can be seen, the one-time measured spatial variation was extremely large for each of these fields and, particularly between the fields (19 % and 35 %). Extreme NDVI values changed from 0.11 to 0.22 for field (d) and from 0.05 to 0.017 for field (c), and, what was the most important, from 0.05 to 0.22 between the fields. This clearly indicates that spatial non-uniformity of earth surface plays a very important role and should not be overlooked when NDVI is used to calibrate environmental and agricultural characteristics. It also indicates that the NDVI should not be interpolated over space even if it is used for large-scale climatic, ecological, and agricultural monitoring.

Since the atmosphere distorts satellite-derived radiance and calculated NDVI, we also investigated its dynamics against NDVI measured on the ground. The 1994 NDVI dynamics derived from the NOAA-11 polar-orbiting satellite were matched with NDVI dynamics derived from a hand-held radiometer (Fig. 10). Unfortunately, the period of this comparison is short because we did not have ground measurements prior to week 19, and satellite measurements were

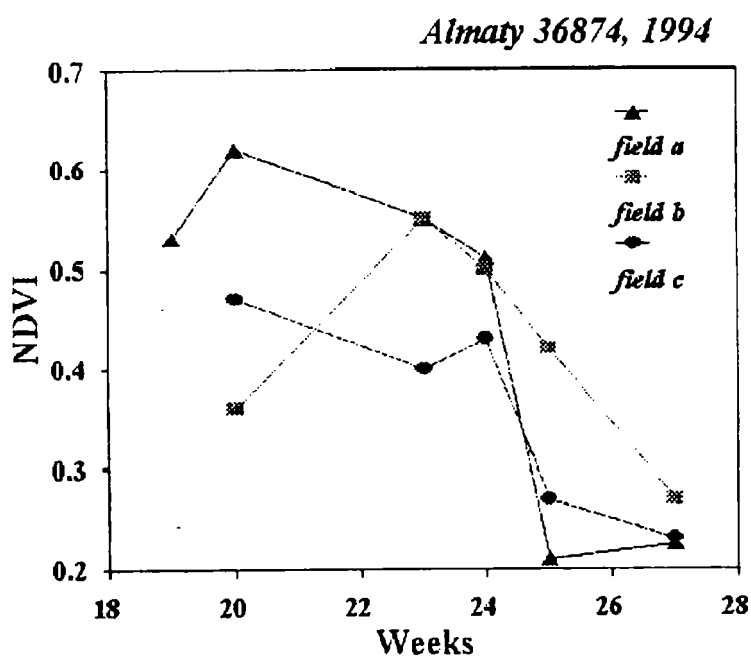
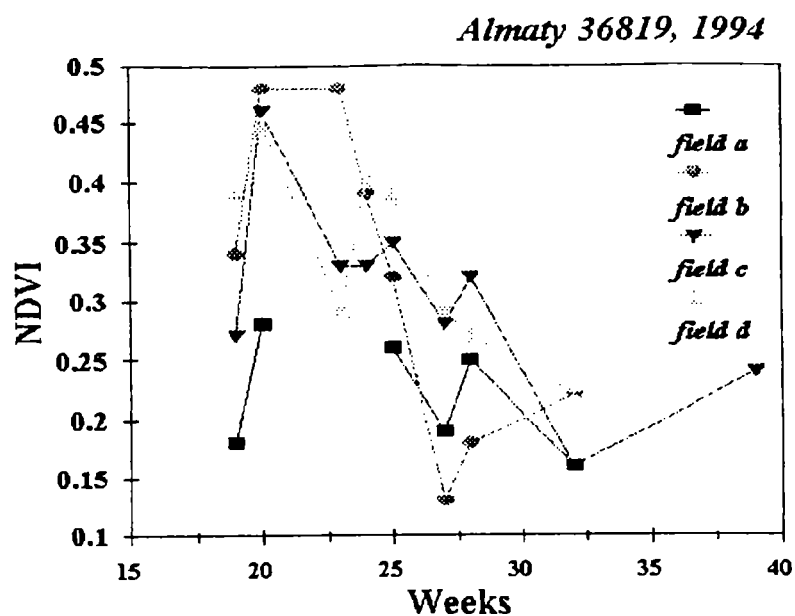


Fig. 7. The 1994 seasonal dynamics of median NDVI values at experimental plots (100 by 100 m) of four fields (a,b,c,d) for station 36819, pasture, (A), and three fields (a,b,c) for station 36874, spring barley (B) in the Almaty region. Median values for each plot were derived from at least 20 random measurements of reflectance over space.

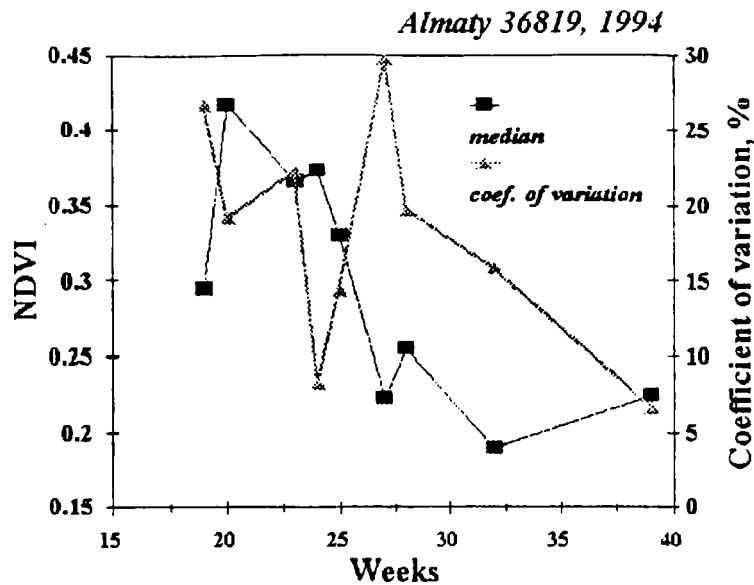


Fig. 8. Seasonal dynamics of median NDVI values and its coefficient of variation for all plots shown in Fig. 7a in 1994 for station 36819 (Almaty region). These values were derived from four pasture plots.

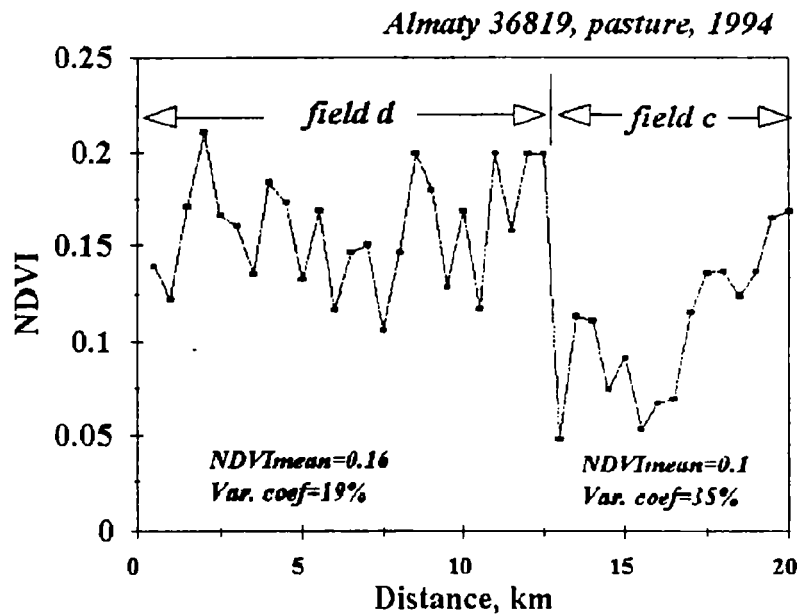


Fig. 9. Spatial variation of NDVI along a 20 km transect through pasture fields (c) and (d) at station 36819 (Almaty) measured by photometer DPF on board a helicopter on August 12, 1994.

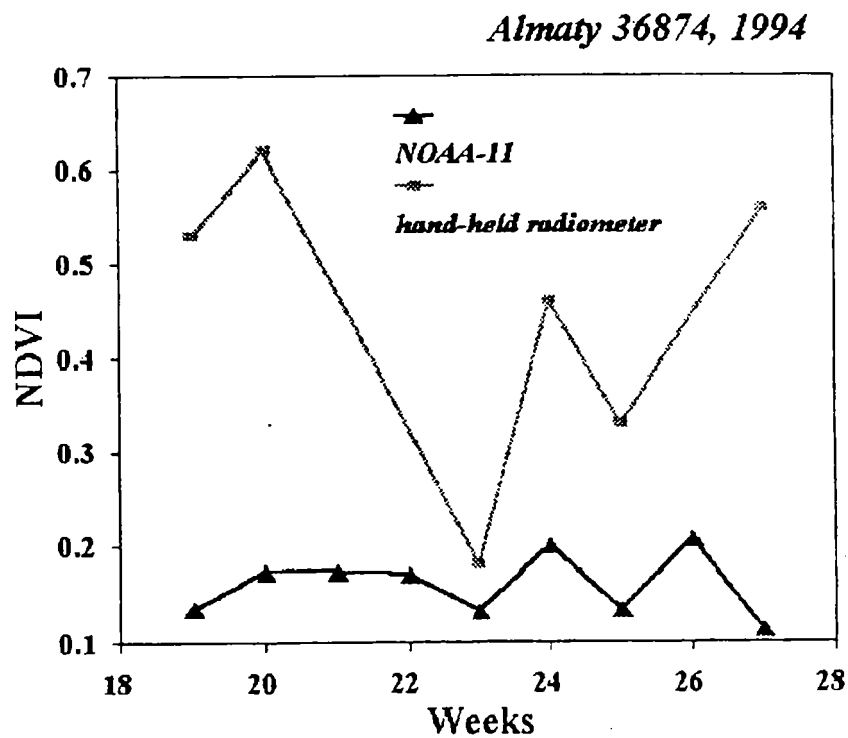
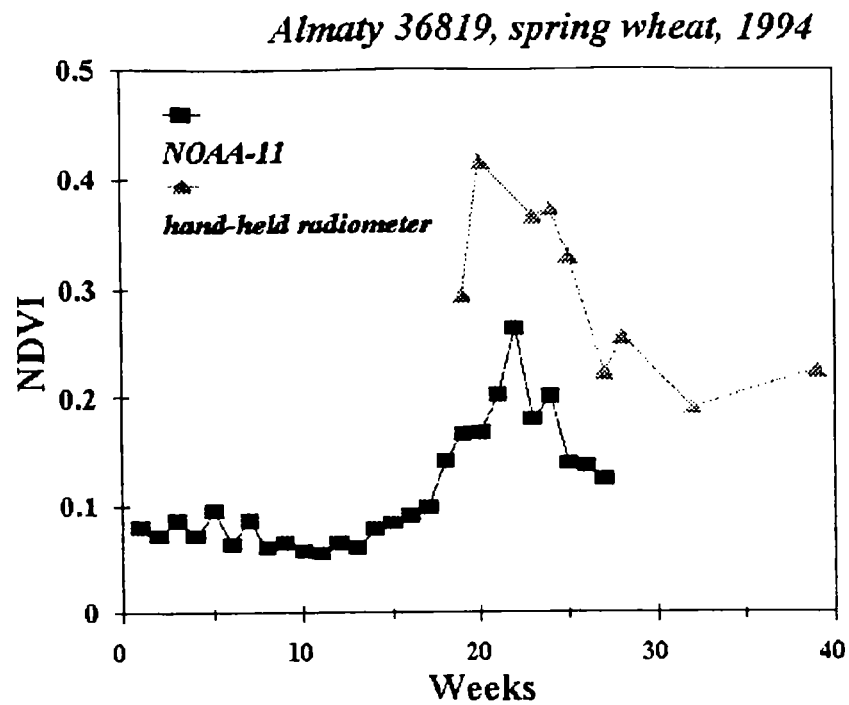


Fig. 10. Averaged NDVI for 3 by 3 of 16 km resolution pixels calculated from the NOAA-11 polar-orbiting satellite and median NDVI retrieved from hand-held radiometer measurements shown in Fig. 8.

unreliable after week 27 due to deterioration of satellite data. Figure 10 also shows that ground measurements of NDVI are higher than those by satellite due to known effects of light attenuation by the atmosphere.

5.4.2 Spatial variation of biomass

One of the important result of this project was the simultaneous measurement of biomass and radiances. This allowed us to compare biomass and NDVI dynamics. Figure 11a shows the dynamics of pasture biomass at four fields of station 36819. Biomass at plot (b) was much higher than at other plots. As a result, the average biomass for all plots was relatively large (Fig. 11b) as well as standard deviation, which accounts for 30 to 40 percent of average biomass variation.

The relation between ground-measured 4-plot median NDVI and biomass is very strong (Fig. 12a). However, if all observations of biomass and NDVI are included (all four plots and all nine dates), then the relationship deteriorates and levels off for the biomass between 4 and 6 t/ha. Similar behavior of the median NDVI/biomass relationship is observed for spring barley (station 36874, Fig. 13), although the number of observations especially for biomass above 5 t/ha, is not sufficient to reach a reliable conclusion.

5.5 Large area calibration of the Vegetation Condition Index

The results of section 5.4 above clearly indicated that the vegetation indices can be converted into biomass values of crop and pasture measured at the experimental plots. This conclusion alone answered one of the important project objectives that remote sensing data can be successfully used for monitoring vegetation productivity and environmental conditions. Crops and rangeland occupy nearly 200 million hectares of Kazakhstan and are located in very different climatic and ecological zones. Precipitation fluctuates from 100 mm in desert areas to more than 1000 mm in foothills. The NDVI cannot be used for vegetation monitoring over a large area with extremely diversified environmental conditions and consequently, vegetation productivity. Therefore, the attempt was made to find out whether AVHRR-derived VCI can be used as an indicator of vegetation productivity on a large area. Unfortunately, the volume of work in large-area data collection and processing did not allow us to fulfill this task for the entire area of K. We were only able to collect, process and explore a limited amount of data.

5.5.1. Specifics of data preparation

The average VCI data for the area of 48 km by 48 km (3 by 3 GVI pixels) were collected around six weather stations with the experimental plots. These stations are located in southern (Almaty region), central (Jeskazgan), and northern

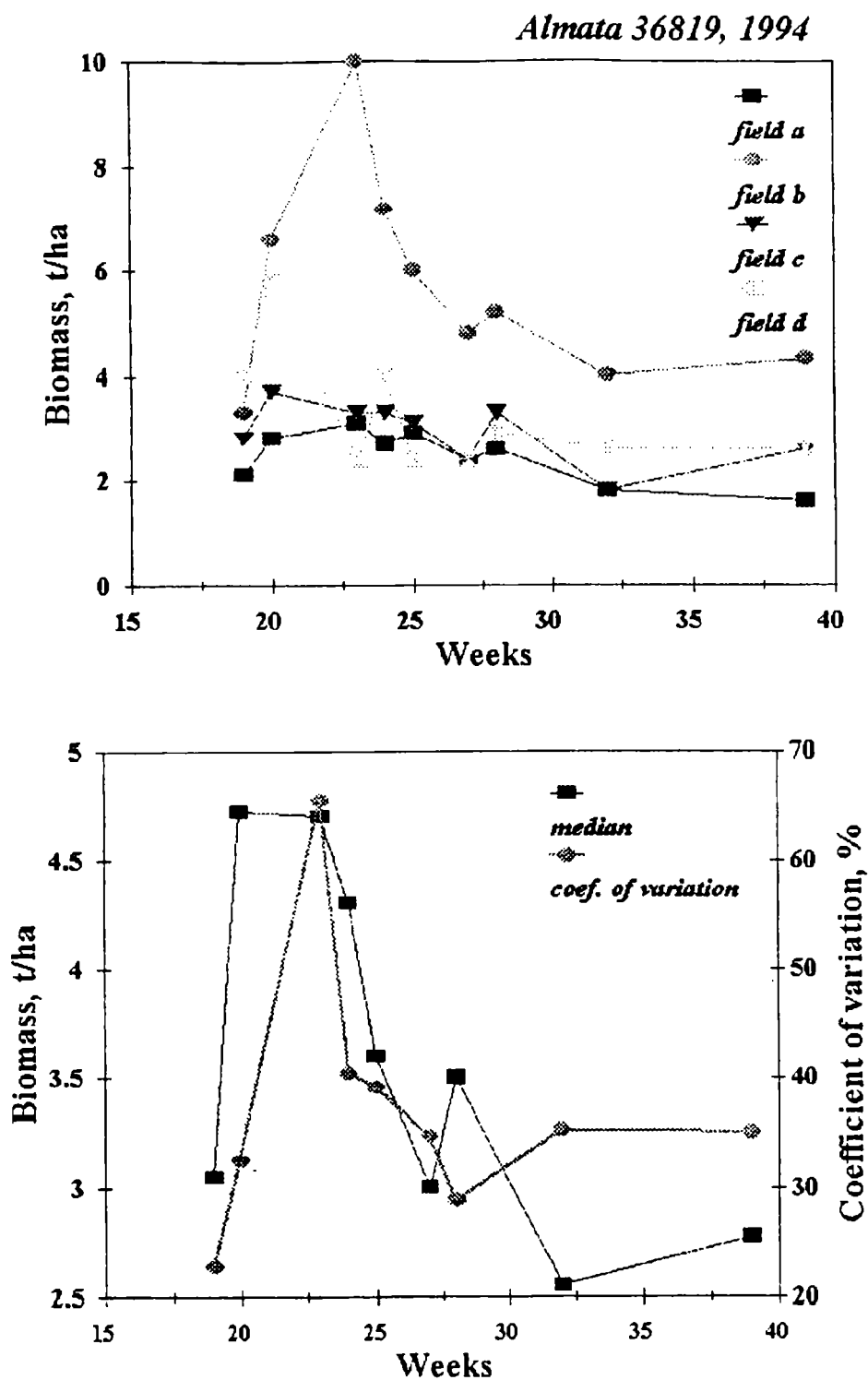


Fig. 11. Seasonal dynamics of biomass measured at experimental plots (100 by 100 m) of four fields (a,b,c,d) for station 36819, pasture, (A), and three fields (a,b,c) for station 36874, spring barley (B) in the Almaty region in 1994. For each plot, biomass was derived as an average from four measurements.

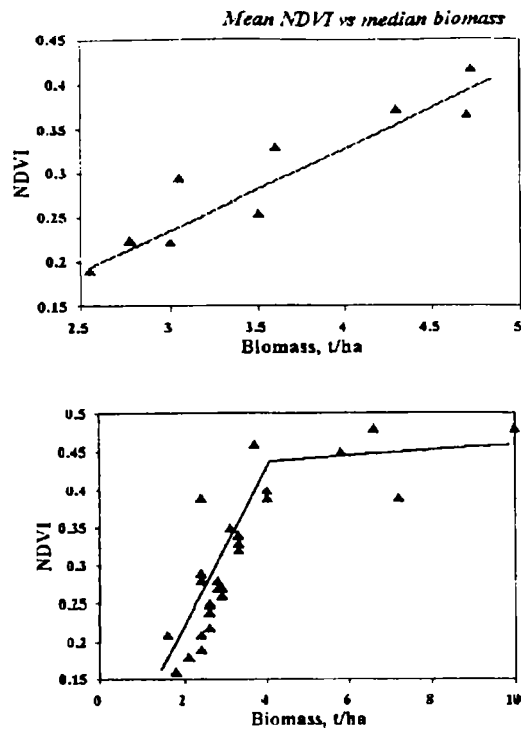


Fig. 12. NDVI versus biomass for four pasture plots of station 36819 in 1994. (A) NDVI was derived from hand-held radiometer measurements, and biomass was averaged from four measurements at each plot; (B) median NDVI and median biomass calculated for four plots of fields (a,b,c,d).

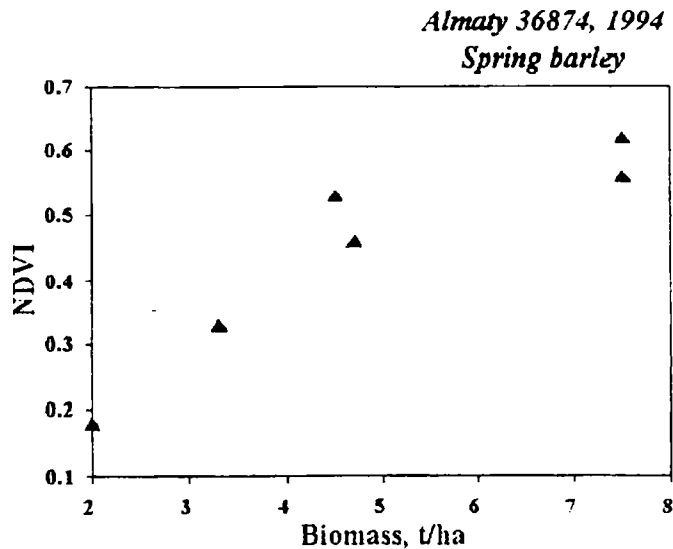


Fig. 13. Median NDVI versus median biomass for three spring barley plots of station 36874 in 1994. (A) NDVI was derived from hand-held radiometer measurements, and biomass was averaged from four measurements at each plot.

(Akmola) Kazakhstan. Analysis was done for two years with different weather conditions, 1991 dry and 1992 wet. As a result of these conditions, agricultural crops production was lower in 1991 (total grain 11,992 million metric tons, Table 2) and higher in 1992 (29,772).

In addition to satellite data, data on density of vegetation (number of plants per m²) were collected for the growing season several times (5 to 11) from 1985 to 1993. Since the VCI characterizes both spatial distribution of vegetation and fluctuation of vegetation between the years, the ground measurements of density were also expressed in terms of multi-year variation. Therefore, minimum, maximum, and median values of the density were calculated from the 1985-1993 data base. Each measurement, D_i , was expressed as a deviation either from minimal, $D_{\min}$, or median, D_{med} , values and normalized to the range of multi-year fluctuation of the density, $(D_{\max} - D_{\min})$:

$$\delta D,(\%) = (D_i - D_x)/(D_{\max} - D_{\min})$$

The VCI was compared with the density characteristic δD .

5.5.2. Ground and satellite data comparison

Since vegetation density measurements were carried out at a single point in a field, there is a chance that these measurements might not have been representative for the entire field. Therefore, we tested two possibilities: which of two criteria, the multi-year minimum (similar to the VCI, which is an aerial index) or multi-year median, is more suitable for estimating density deviation. Figure 14 shows seasonal dynamics of density deviation from (A) the minimum criterion and (B) the median criterion at station 36819 (Almaty). As can be seen, both estimates show that the selected two years were extremely different. The 1991 dry year had very low density of vegetation throughout the entire season, while the 1992 wet year had low density of vegetation only at the very beginning (up to week 23) and density had increased considerably by the end of the growing season (weeks 33 to 40). In relation to the selected criteria (minimum and median) we should emphasize that the variation of density for the driest period (weeks 18 to 26) was larger for the median (-20 to -50) rather than for the minimum (near zero).

These findings are supported by the correspondence between deviation density (DD) and VCI dynamics in 1991 (Fig. 15 a). The VCI and median-derived DD had a similar decreasing tendency during weeks 18-22 and an increasing tendency during weeks 23-26, while the minimum-derived DD did not show this similarity. This is natural, since the sensitivity at extreme values is higher for median rather than minimum criteria. It is important to indicate that there is a good match between VCI derived conditions and DD throughout the whole season, for the two extremely different years, especially for the median-derived

Table 2. Area, yield and production of selected grain crops, sunflower, and sugar beets in Kazakhstan (after USDA, 1994).

ai Kazakhstan: Area , yield, and production of selected grain crops (cleanweight), sunflowerseed and sugarbeets

Year	Wheat			Barley			Rye	Oats	Millet	Corn	Buck- wheat	Rice	Pulses	Total grain	sunflower- seed	sugar- beets
	Winter	Spring	Total	Winter	Spring	Total										
Area																
1,000 hectares																
1981-85 avg.	1,089	15,246	16,335	na	na	6,737	354	446	802	123	198	137	169	25,352	101	68
1986-90 avg.	1,086	13,764	14,849	38	6,774	6,819	598	415	725	128	193	131	172	24,109	118	50
1988-92 avg.	1,127	13,006	14,134	47	6,519	6,566	651	422	821	129	275	126	161	23,361	176	49
1986/87	1,062	14,538	15,600	46	6,643	6,727	432	450	692	119	177	129	164	24,563	96	62
1987/88	1,155	14,156	15,311	30	6,841	6,871	489	483	677	119	179	133	184	24,525	104	58
1988/89	915	13,961	14,876	30	7,033	7,063	577	350	699	137	177	135	183	24,290	122	42
1989/90	1,097	13,293	14,390	29	6,744	6,773	723	408	774	134	215	133	172	23,812	131	45
1990/91	1,199	12,871	14,070	53	6,607	6,660	769	382	781	129	218	124	159	23,356	137	44
1991/92	1,206	12,250	13,456	60	6,554	6,614	562	512	847	121	318	118	152	22,753	190	45
1992/93	1,220	12,657	13,877	61	5,657	5,718	623	456	1,003	126	447	121	140	22,596	298	68
1993/94	1,313	11,437	12,750	63	6,938	7,001	na	549	527	117	409	112	119	22,250	271	65
Yield																
tons per hectare																
1981-85 avg.	0.92	0.75	0.75	0.99	0.79	0.79	0.60	0.97	0.47	4.14	0.40	4.38	0.62	0.79	0.94	25.6
1986-90 avg.	1.53	0.92	0.97	1.78	0.99	0.99	0.92	1.10	0.80	3.88	0.51	4.51	0.80	1.00	0.99	28.9
1988-92 avg.	1.38	0.87	0.91	1.86	0.96	0.97	0.95	1.05	0.67	3.35	0.53	4.34	0.72	0.94	0.79	20.2
1986/87	1.25	1.06	1.07	1.08	1.06	1.06	0.85	1.37	0.56	4.25	0.42	4.55	0.91	1.08	0.87	27.9
1987/88	1.95	0.98	1.05	1.96	1.00	1.00	0.69	0.95	0.82	4.03	0.40	4.54	0.79	1.05	1.12	32.0
1988/89	1.48	0.77	0.82	2.00	0.83	0.83	0.95	0.98	0.82	4.09	0.66	4.65	0.72	0.86	1.14	31.8
1989/90	1.32	0.70	0.75	1.72	0.78	0.78	1.03	0.61	0.59	3.58	0.25	4.16	0.62	0.79	0.80	26.7
1990/91	1.64	1.11	1.15	2.12	1.27	1.28	1.09	1.60	1.20	3.44	0.80	4.65	0.97	1.22	1.03	26.0
1991/92	1.02	0.46	0.51	1.52	0.46	0.47	0.85	0.45	0.28	2.72	0.43	4.40	0.43	0.53	0.57	16.1
1992/93	1.43	1.31	1.32	1.95	1.48	1.49	0.85	1.59	0.45	2.91	0.51	3.86	0.88	1.32	0.41	17.2
1993/94	1.47	0.84	0.91	1.78	1.01	1.02	na	1.46	0.44	3.03	0.32	3.61	0.79	0.97	0.40	13.8
Production																
1,000 tons																
1981-85 avg.	1,018	11,380	12,398	103	5,261	5,364	217	420	374	503	80	597	105	20,082	94	1,785
1986-90 avg.	1,671	12,728	14,399	92	6,645	6,737	568	456	583	493	98	590	138	24,108	117	1,434
1988-92 avg.	1,562	11,301	12,863	93	6,159	6,251	627	433	532	436	142	550	116	22,004	123	1,108
1986/87	1,328	15,415	16,743	91	7,004	7,095	369	616	391	505	74	586	150	26,562	83	1,724
1987/88	2,255	13,853	16,108	122	6,807	6,929	338	459	549	477	72	606	145	25,721	117	1,804
1988/89	1,354	10,808	12,162	84	5,766	5,850	548	345	577	561	117	626	132	20,970	139	1,321
1989/90	1,451	9,332	10,783	50	5,260	5,310	745	251	459	479	53	555	107	18,797	105	1,188
1990/91	1,966	14,231	16,197	112	8,389	8,500	839	610	940	442	174	579	154	28,488	141	1,134
1991/92	1,298	5,591	6,889	100	2,985	3,085	480	231	235	330	136	521	66	11,992	108	726
1992/93	1,743	16,542	18,285	118	8,393	8,511	525	727	447	368	230	467	123	29,772	122	1,170
1993/94	1,934	9,651	11,585	112	7,037	7,149	na	802	232	355	130	403	94	21,631	107	900
na = not available.																
Sources: USDA; Goskomstat Kazakhstan.																
JOINT AGRICULTURAL WEATHER FACILITY (NOAA/USDA)																

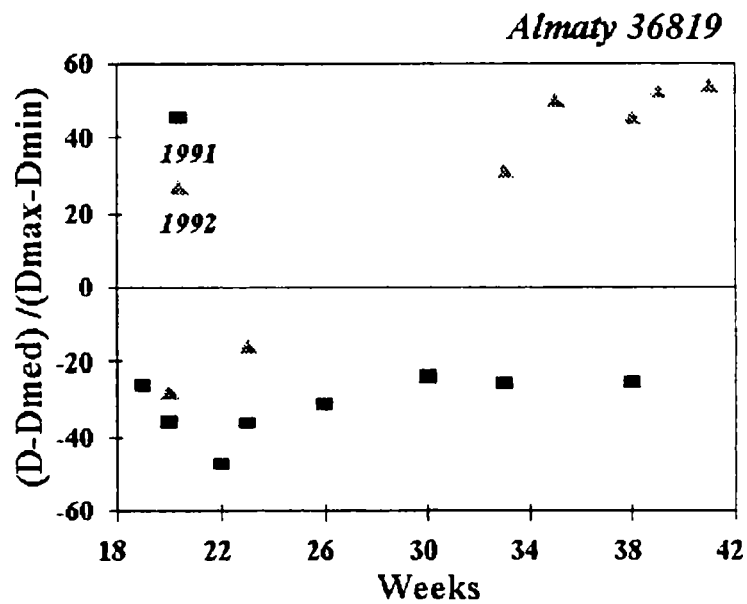
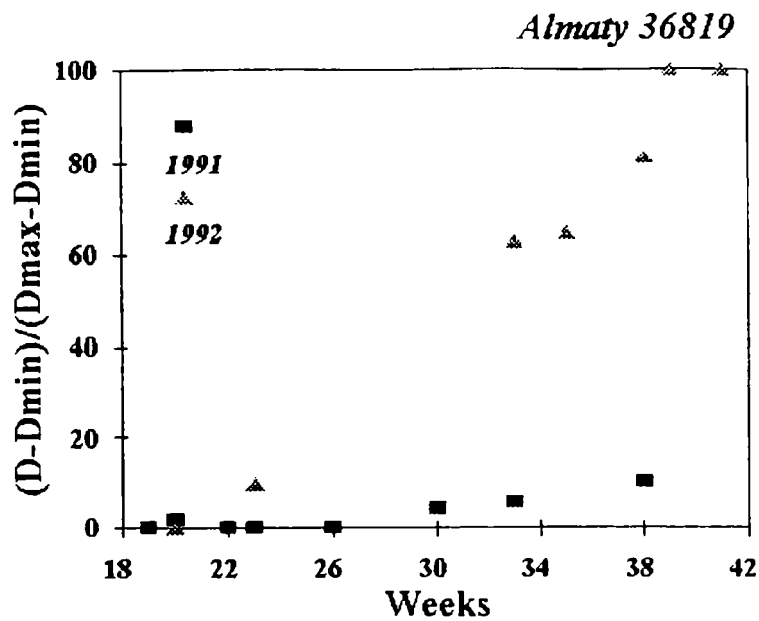


Fig. 14. Seasonal dynamics of density deviation (DD) from multi-year minimum (A) and median (B) values, normalized to the 1985-1993 density fluctuation ($D_{\max}-D_{\min}$). Almaty region, station 36819.

DD (Fig. 15 and 16). In the further discussion we will concentrate on the median-derived DD.

The Figures 17 through 21 show VCI and median-derived DD dynamics in 1991-1992 for the rest of the experimental sites. Analysis of these figures clearly indicate that for very different ecological zones, extremely different years, throughout the entire season and for different types of vegetation there is a very good match between satellite- and ground-derived estimates of vegetation conditions. The ecological zones of the discussed data changed from dry in Jeskazgan (Fig. 20 and 21) to wetter in Almaty (Fig. 15b, 16b, 17) regions. Conditions for vegetation growth were very dry in 1991 and wet in 1992. The most interesting fact is that the very beginning of the 1991 season was quite favorable (Fig. 18a, 19a, 20a, 21a). In 1992 the situation was opposite, conditions at the beginning of the growing season were unfavorable and in the second part were favorable (Fig. 18b, 19b, 20b, 21b). All stations had pasture-type of vegetation except for Akmola, 28978 which had spring wheat (Fig. 18).

The good match between VCI- and density-derived conditions shown in Figs. 17-21 allows us to correlate these characteristics. The correlation for individual stations is shown in Figs. 22 to 24. The correlation is strong ($r^2=0.72-0.92$) with an estimating error of density between 10 to 15 percent. Only one station 35744 (Almaty), Fig. 22, had a lower correlation ($r^2=0.47$) because weather conditions were more favorable and the variation of the VCI was smaller.

We should again point out that the higher values of correlation are partially explained by the fact that we are discussing two years with very different weather conditions. However, it is important to emphasize that for some of these stations 36819 (Fig. 22a), 28987 (Fig. 23a), 35376 (Fig. 23b), and 35478 (Fig. 24a) there is an overlap of the points for the two different years. We should also indicate that there is some saturation of the VCI for extreme values of median-derived DD (Figs. 23b, 24a,b). This saturation of VCI for high vegetation density can be explain by the saturation of NDVI for chlorophyll content above $3-5 \mu\text{g}/\text{cm}^2$ (Buschmann and Nagel, 1993, Gitelson and Merzlyak, 1994a,b) and for Leaf Area Index above 4-5 (Baret and Guyot, 1991; Danson and Plummer, 1995).

Despite of the fact that the selected stations were located in very different climatic and ecological zones, with elevation changing from 300 to 700 m and a large range of NDVI variation (over space and season) from 0.05 to 0.47, all station points were located around the same correlation line (Fig. 25). Although there are some local differences, correlation was high $r^2 = 0.76$ with an estimating error of less than 16 percent. This error is less for low density, indicating that in cases of very unfavorable weather (such as drought) the accuracy of VCI-derived estimates is higher. This corresponds to our conclusions in Kogan, 1995a. One of the main causes for scattering of the VCI/DD relationship is the difference

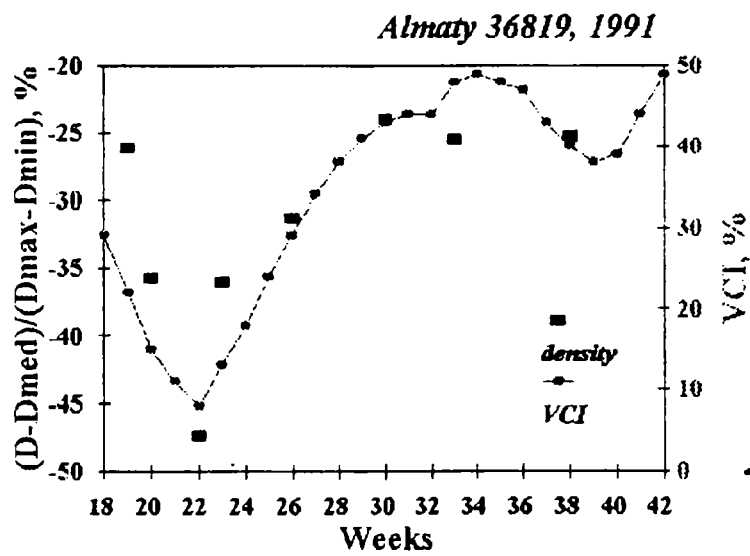
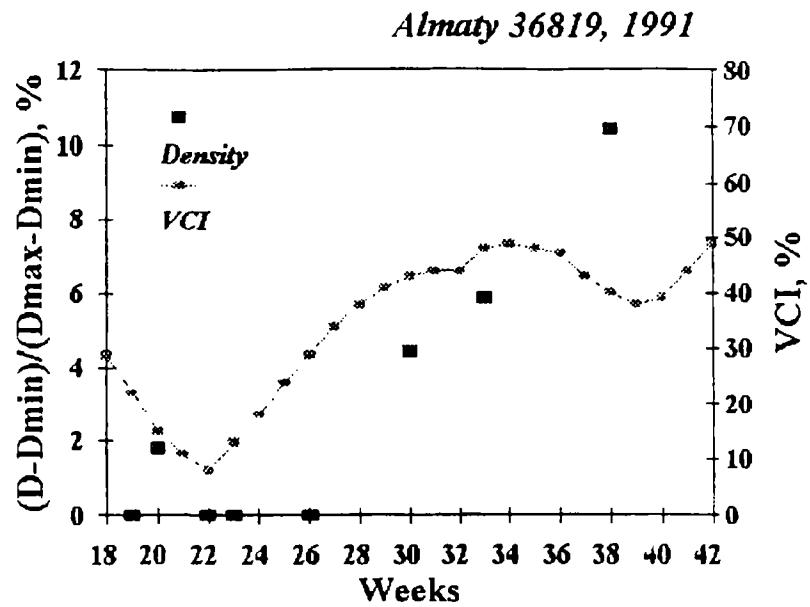


Fig. 15. Comparison of the VCI and multi-year density deviation (A) from minimal, and (B) median. Almaty region, station 36819, 1991.

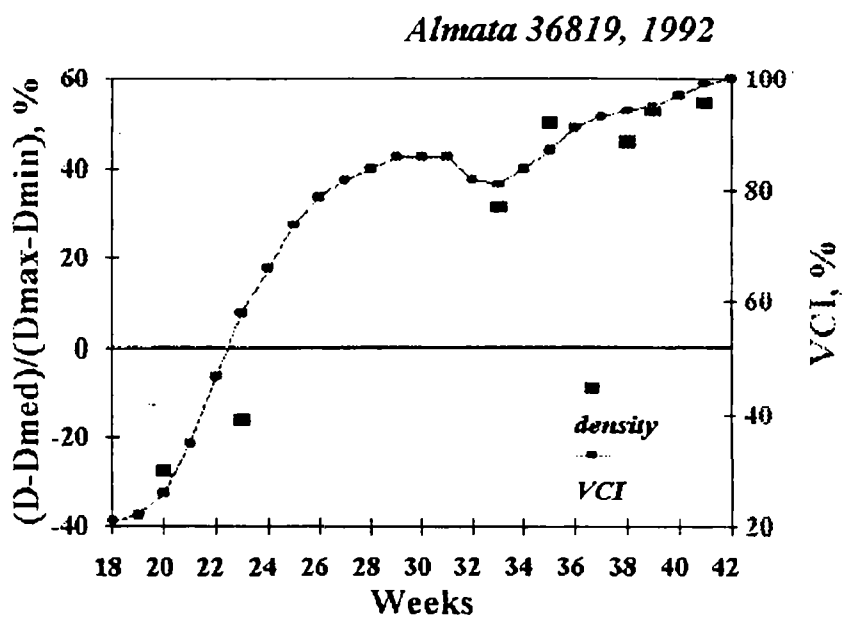
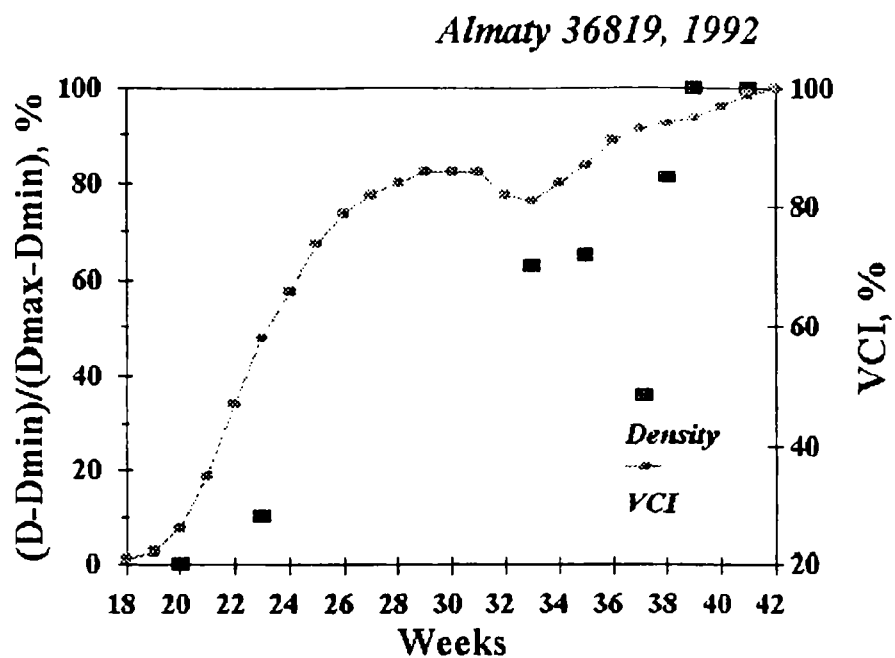


Fig. 16. Comparison of the VCI and multi-year density deviation (A) from minimal, and (B) median. Almaty region, station 36819, 1992.

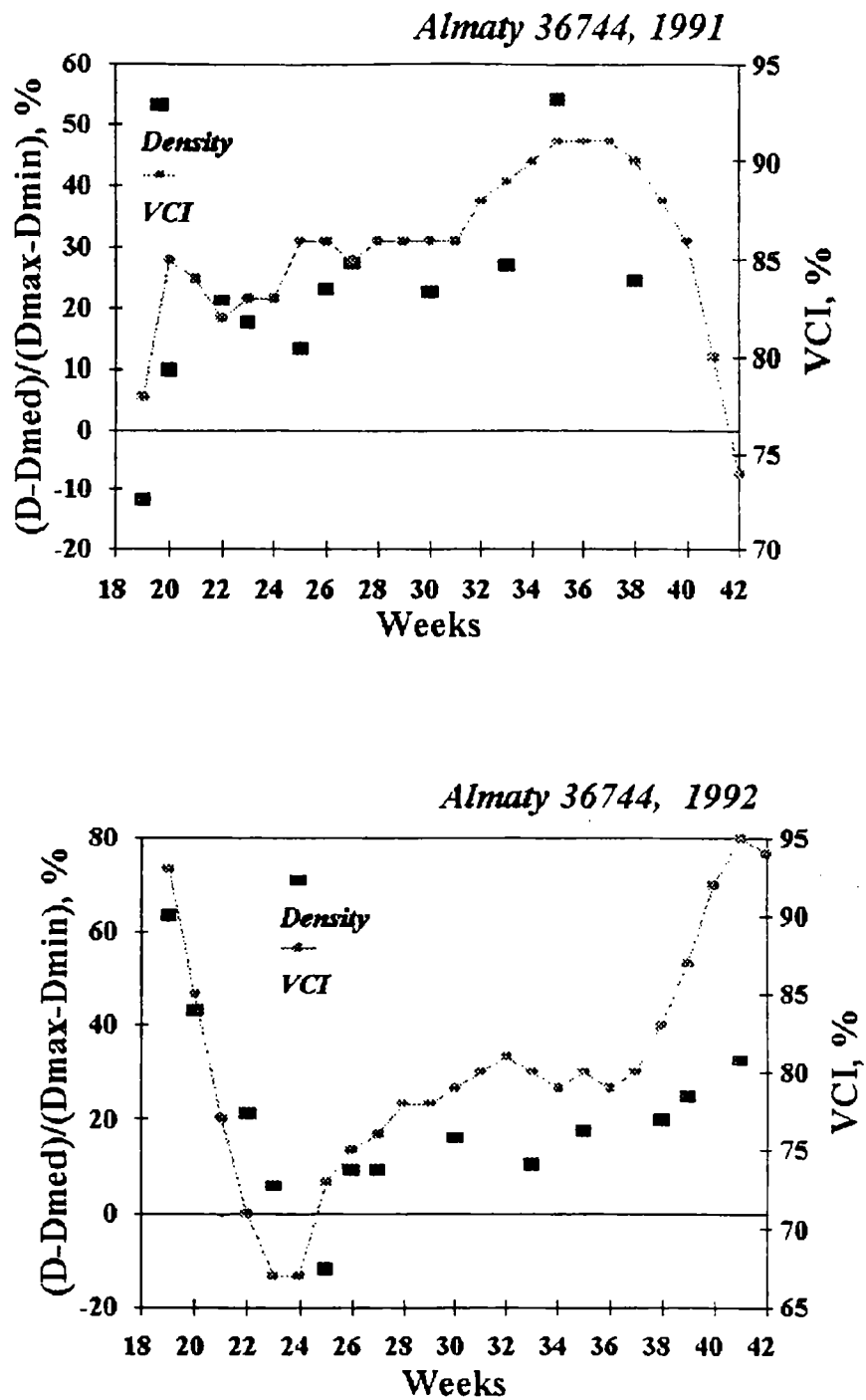


Fig. 17. Comparison of the VCI and multi-year density deviation from median (A) 1991, and (B) 1992. Almaty region, station 36744.

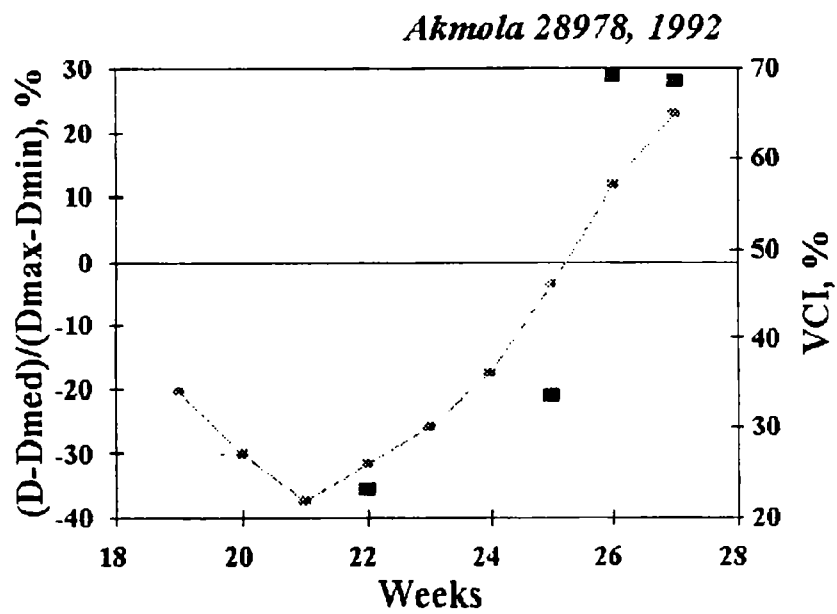
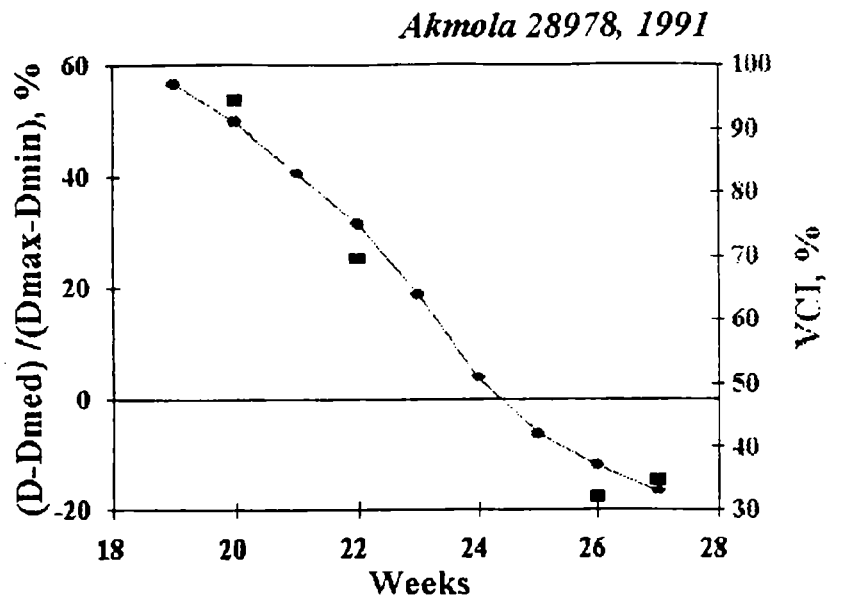


Fig. 18. Comparison of the VCI and multi-year density deviation from median (A) 1991, and (B) 1992. Akmola region, station 28978.

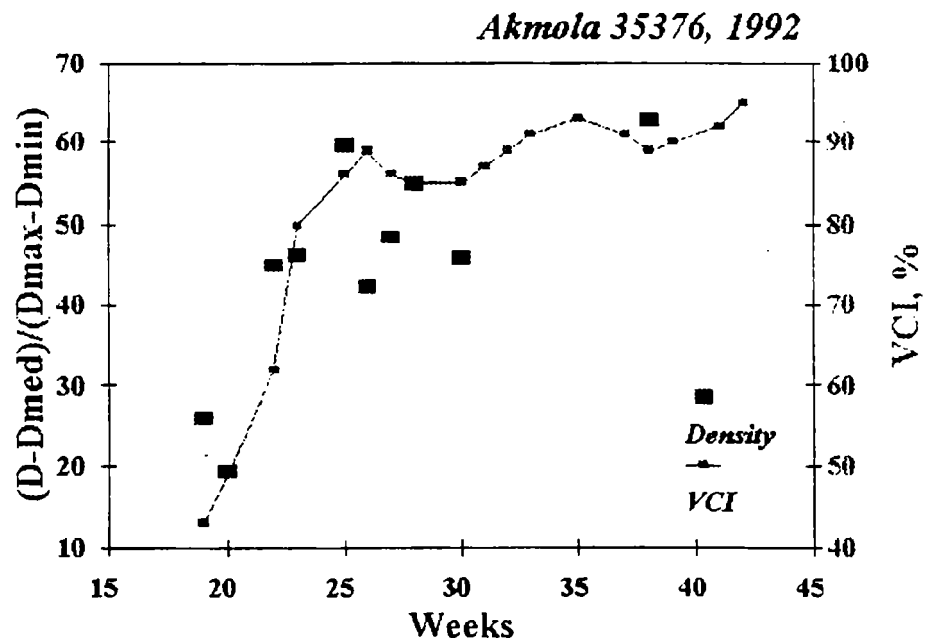
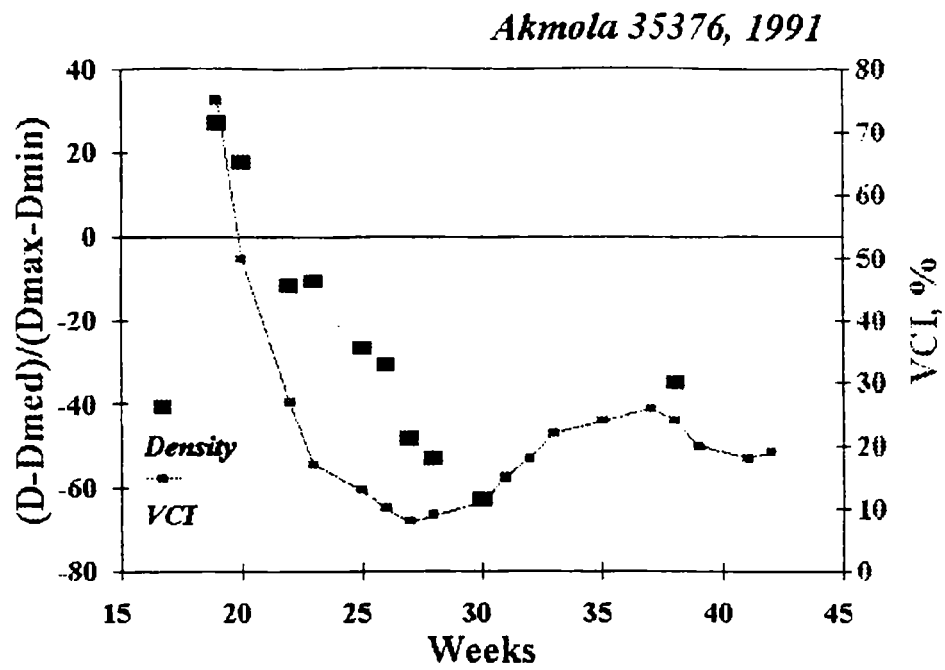


Fig. 19. Comparison of the VCI and multi-year density deviation from median (A) 1991, and (B) 1992. Akmola region, station 35376.

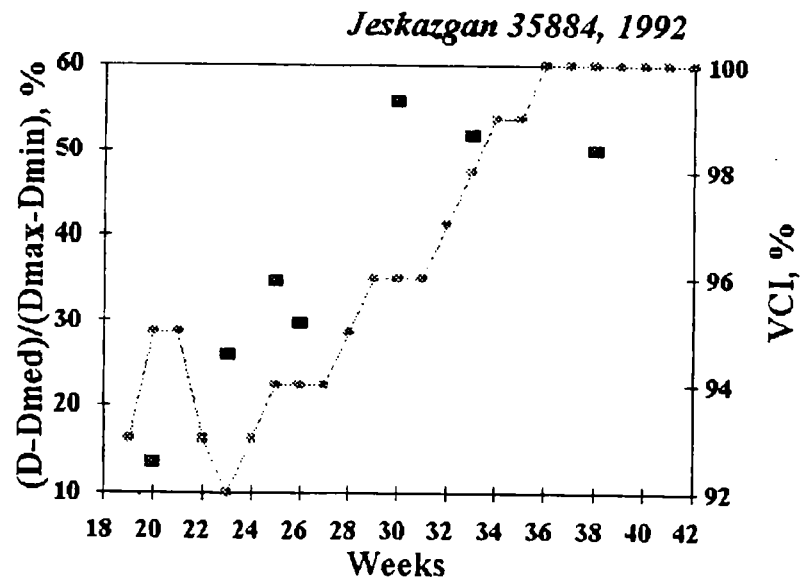
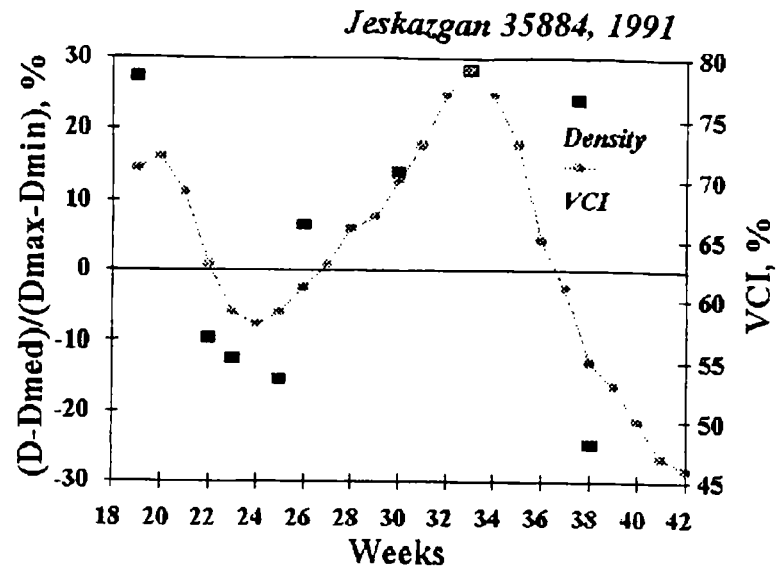


Fig. 20. Comparison of the VCI and multi-year density deviation from median (A) 1991, and (B) 1992. Jeskazgan region, station 35884.

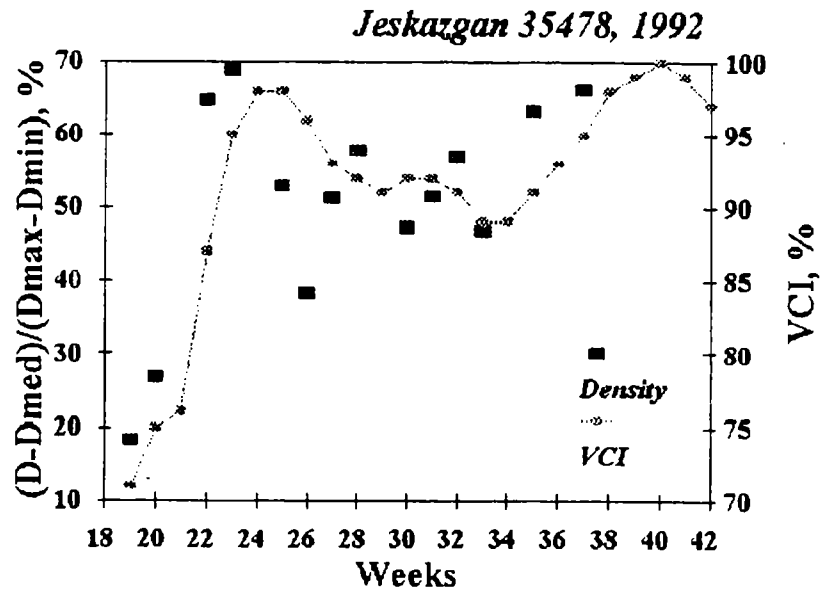
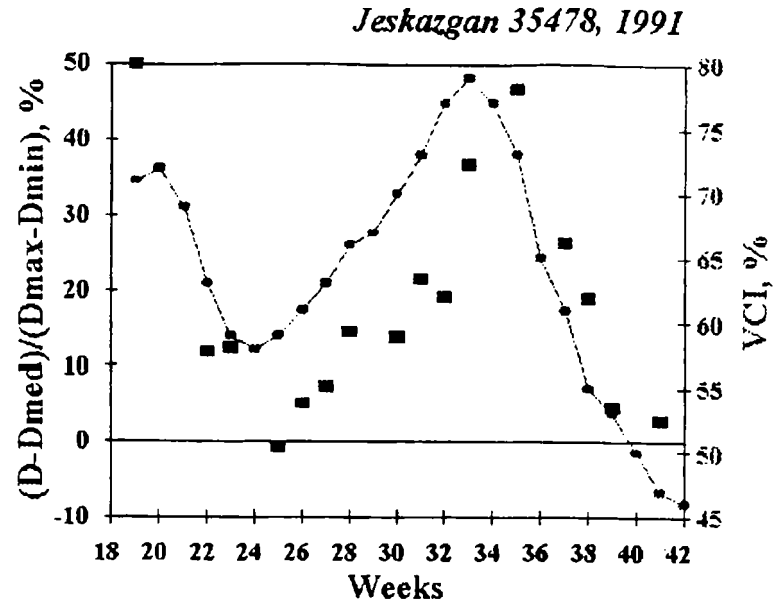


Fig. 21. Comparison of the VCI and multi-year density deviation from median (A) 1991, and (B) 1992. Jeskazgan region, station 35478.

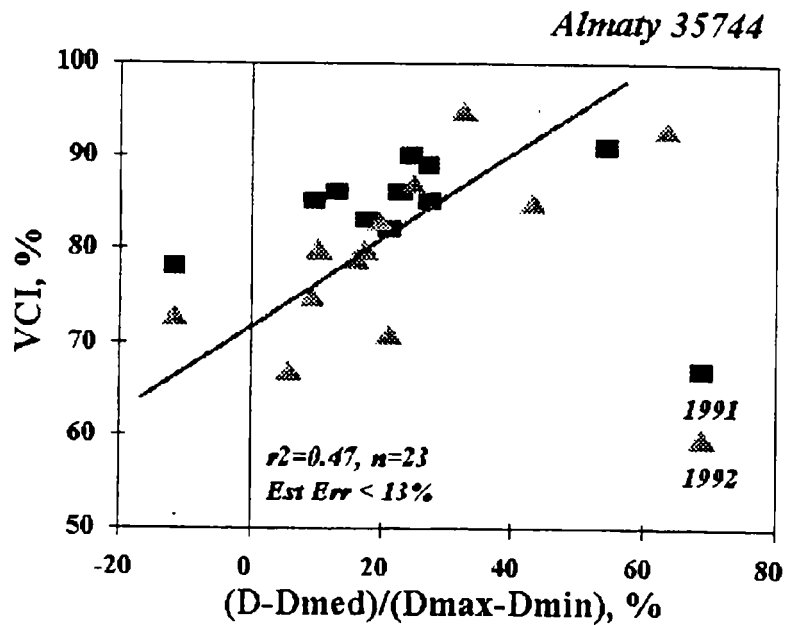
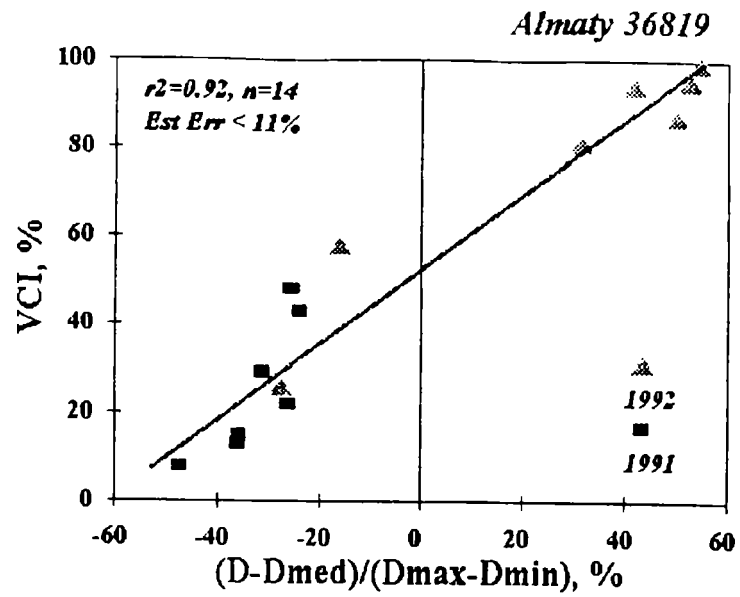


Fig. 22. Correlation between the VCI and median-derived density deviation for Almaty 36819 (A) and 35744 (B).

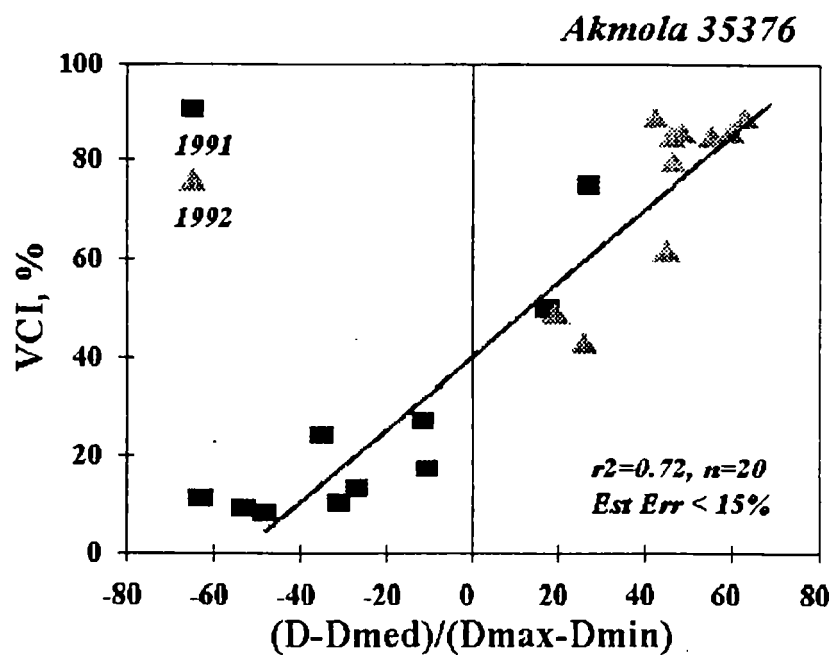
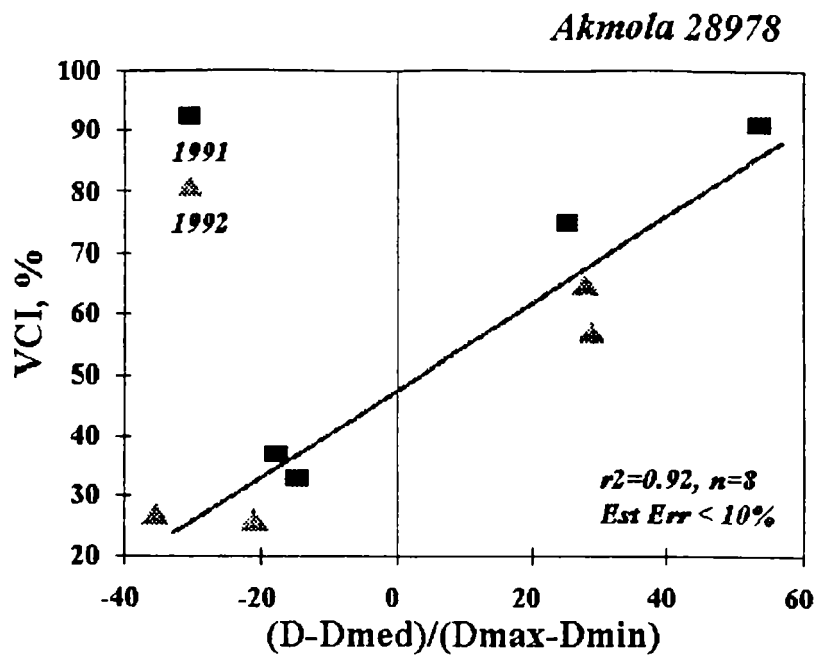


Fig. 23. Correlation between the VCI and median-derived density deviation for Akmola 35376 (A) and 28978 (B).

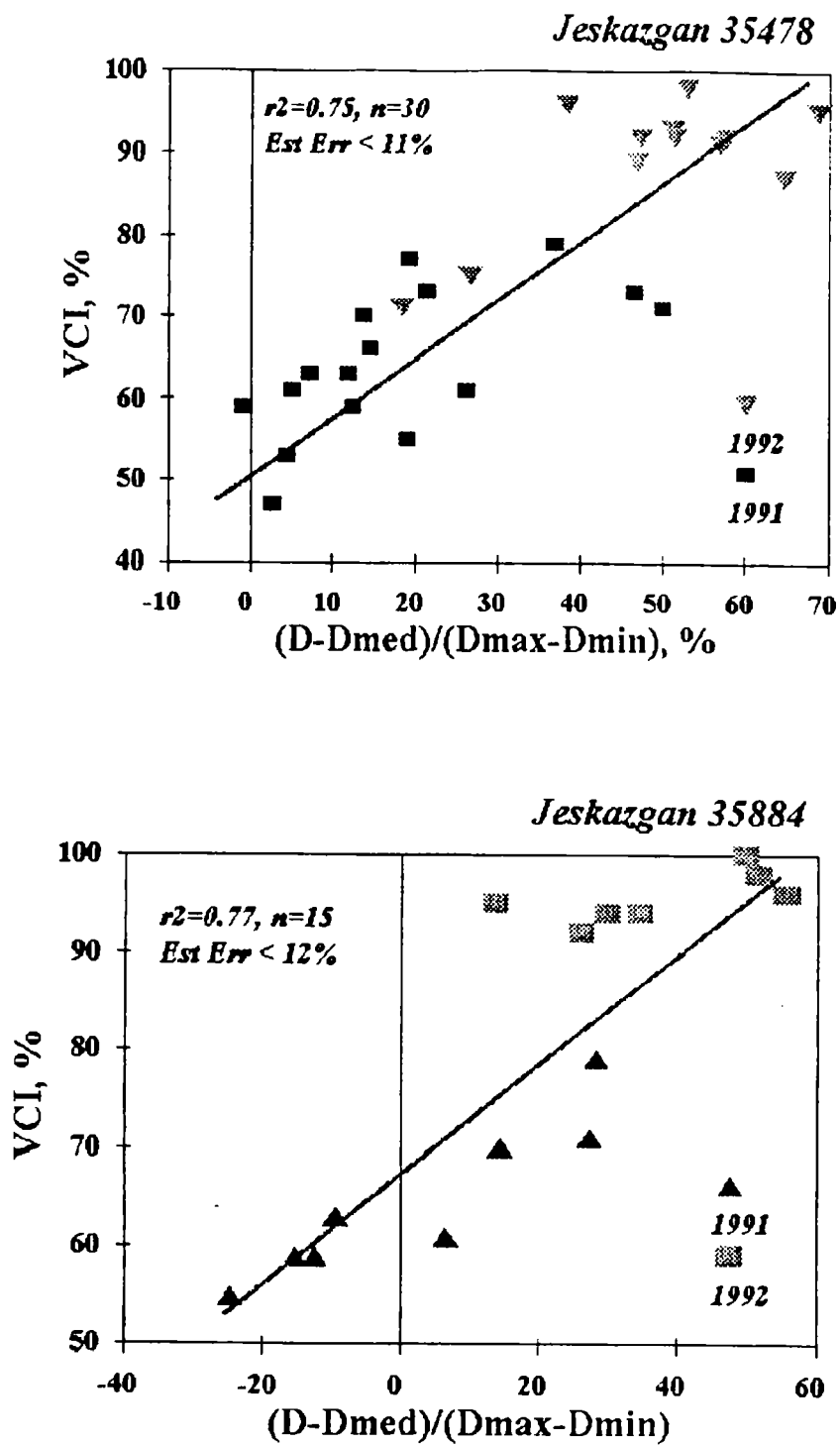


Fig. 24. Correlation between the VCI and median-derived density deviation for Jeskazgan 35478 (A) and 35884 (B).

between aerial estimates from satellite data and point measurements of ground density which was discussed in chapter 5.4.1 and 5.4.2.

These findings are the first step in validating the VCI in Kazakhstan. First time it was shown that the VCI-derived vegetation condition data can be effectively used for quantitative assessments of both vegetation state and productivity (density and biomass) over large areas. The second step should include quantitative calibration of the VCI against large area biomass, yield and production measurements of various crops and pastures with different vegetation types.

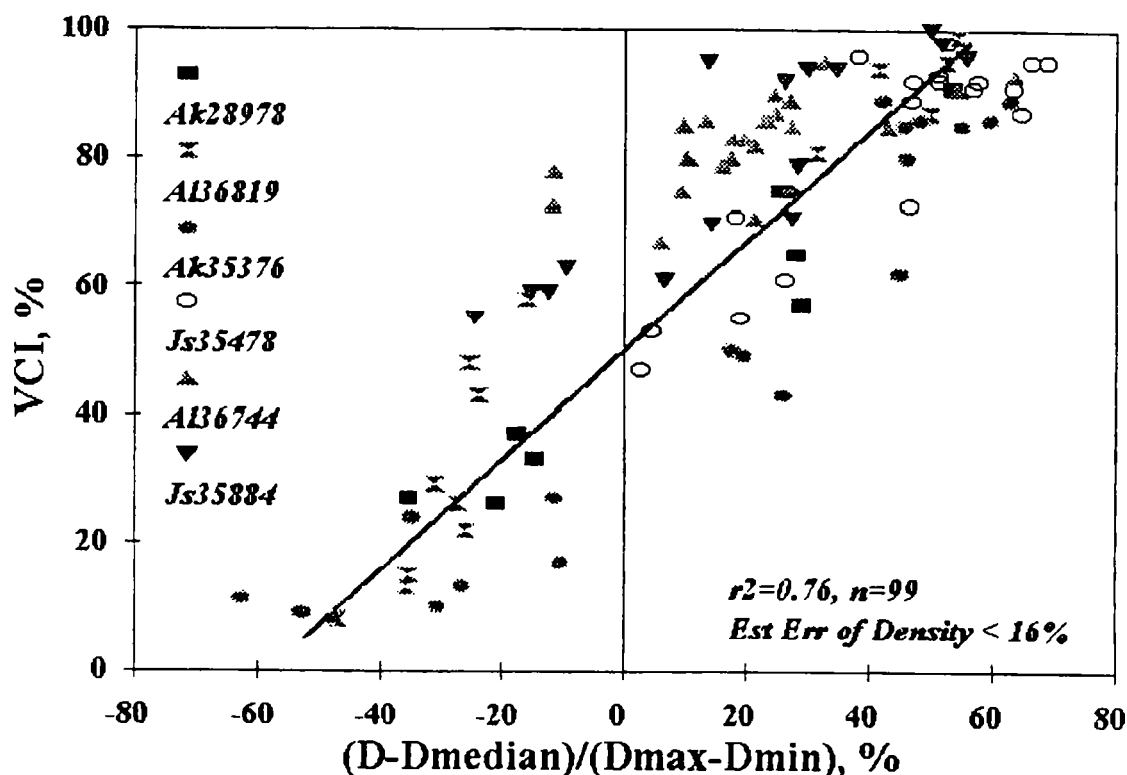


Fig. 25. Correlation between the VCI and median-derived density deviation for all six stations and two years (1991 and 1992).

5.6. VCI data for drought monitoring

Drought is a typical phenomenon in the Kazakhstani climate. Almost all of the Kazakhstan area is located in a zone where annual consumption of water, estimated from potential evapotranspiration, is greater than the annual amount of precipitation (Gol'tsberg, 1972). Kazakhstan experiences both atmospheric and soil droughts; quite often they can be accompanied by a dry wind (dessicative wind). The extreme droughts occur every 5-6 years, while severe and moderate droughts occur once in 3 years and mild droughts occurred almost every year somewhere around the Kazakhstan area. Drought normally affects from 30 to

100 percent of the entire area of Kazakhstan (Kogan, 1985). In the past 100 years, nearly 40 years experienced extreme, severe, or moderate droughts. In the past 10 years above, severe and moderate droughts were observed in 1985, 1989, 1991, and 1993. The last two droughts can be classified as a very severe.

5.6.1. Drought as weather hazard

Drought is the most complex but least understood of all natural disasters. Therefore, a universally accepted definition of drought does not exist (Wilhite 1993). The major cause of drought is lack of precipitation. However, the same precipitation deficit may have different impacts depending on other meteorological elements, types of ecosystem, and economic activities. The many definitions of drought reflect these impacts (Wilhite et al. 1985). They might also identify specific climatic conditions, regional differences, physiological characteristics, economic development, and even traditions. Presently, scientific literature classifies drought into four types: meteorological, agricultural, hydrological, and socioeconomic (WMO 1975; Wilhite et al. 1985). Droughts in Kazakhstan belong to the first two types.

Droughts have some specific features that distinguish them from other natural hazards and make them difficult to identify (Wilhite 1993). Drought development is cumulative and builds up slowly over a period of time. The impacts of drought on the environment and/or economic activity is also cumulative. Therefore, the losses from drought are not immediately detectable, i.e., there is a lag time. In addition, the absence of a distinctive criterion for drought creates difficulties in identifying drought, assessing its onset, duration, aerial extent, and severity. Drought spreads over a large area, making it difficult to identify its impact. In sum, drought is not easily identifiable, especially at the very beginning, even if the appropriate weather observations are available.

Lack of biophysical drought criteria and difficulties in estimating drought impact on vegetation and the environment make vegetation indices, especially VCI, very attractive as tools for drought detection and monitoring. In recent years, the VCI has found applications for drought monitoring in areas with very different ecological and economic resources (Kogan, 1994, 1995a).

5.6.2. Large-area 1991 drought in Kazakhstan

In this section, we discuss application of VCI for monitoring of the 1991 drought for the entire area of Kazakhstan. This drought was the most intensive and widespread of the recent years. The VCI-derived 1991 drought data were compared with VCI assessments of the 1992 favorable year.

The image in Fig. 26 shows the VCI for the two indicated years at the end of June (week 26). As seen in 1991, the vegetation in the majority of Kazakhstan regions was under severe stress, while in 1992, stress vegetation was observed

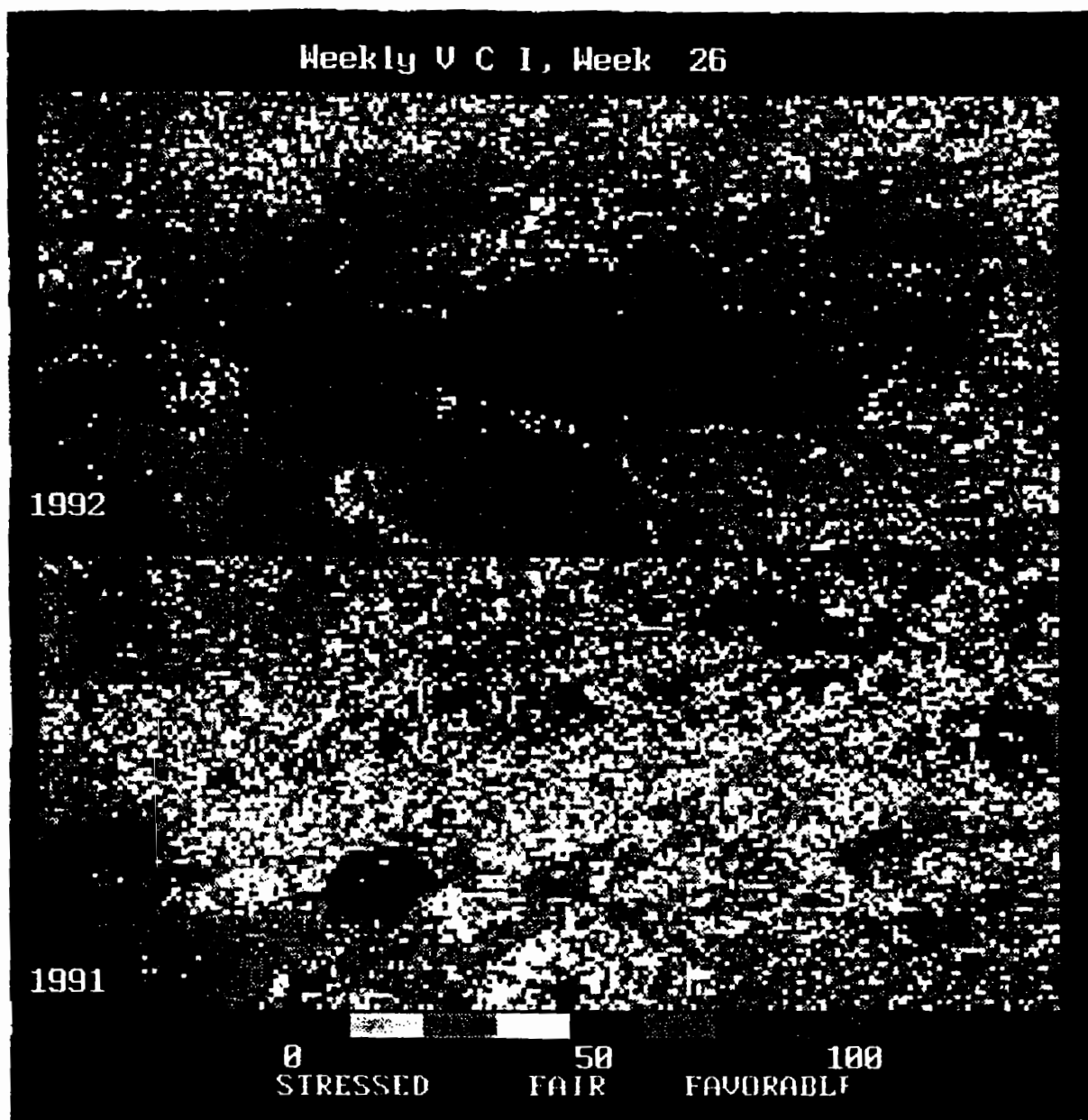


Fig. 26. Vegetation Condition Index for the end of June (week 26) 1991 and 1992 for each 16x16 km pixel.

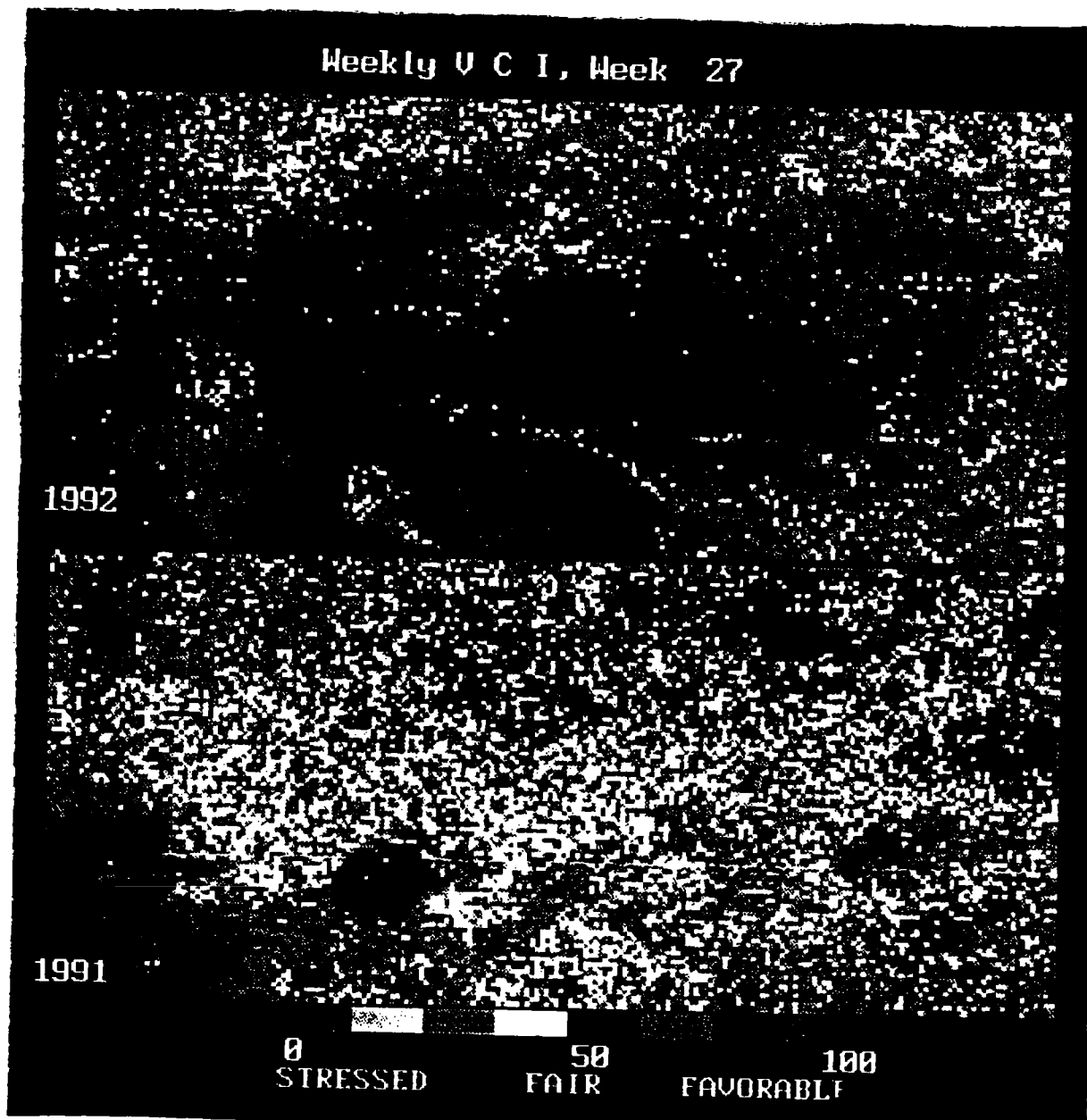


Fig. 27. Vegetation Condition Index for the beginning of July (week 27) 1991 and 1992 for each 16x16 km pixel.

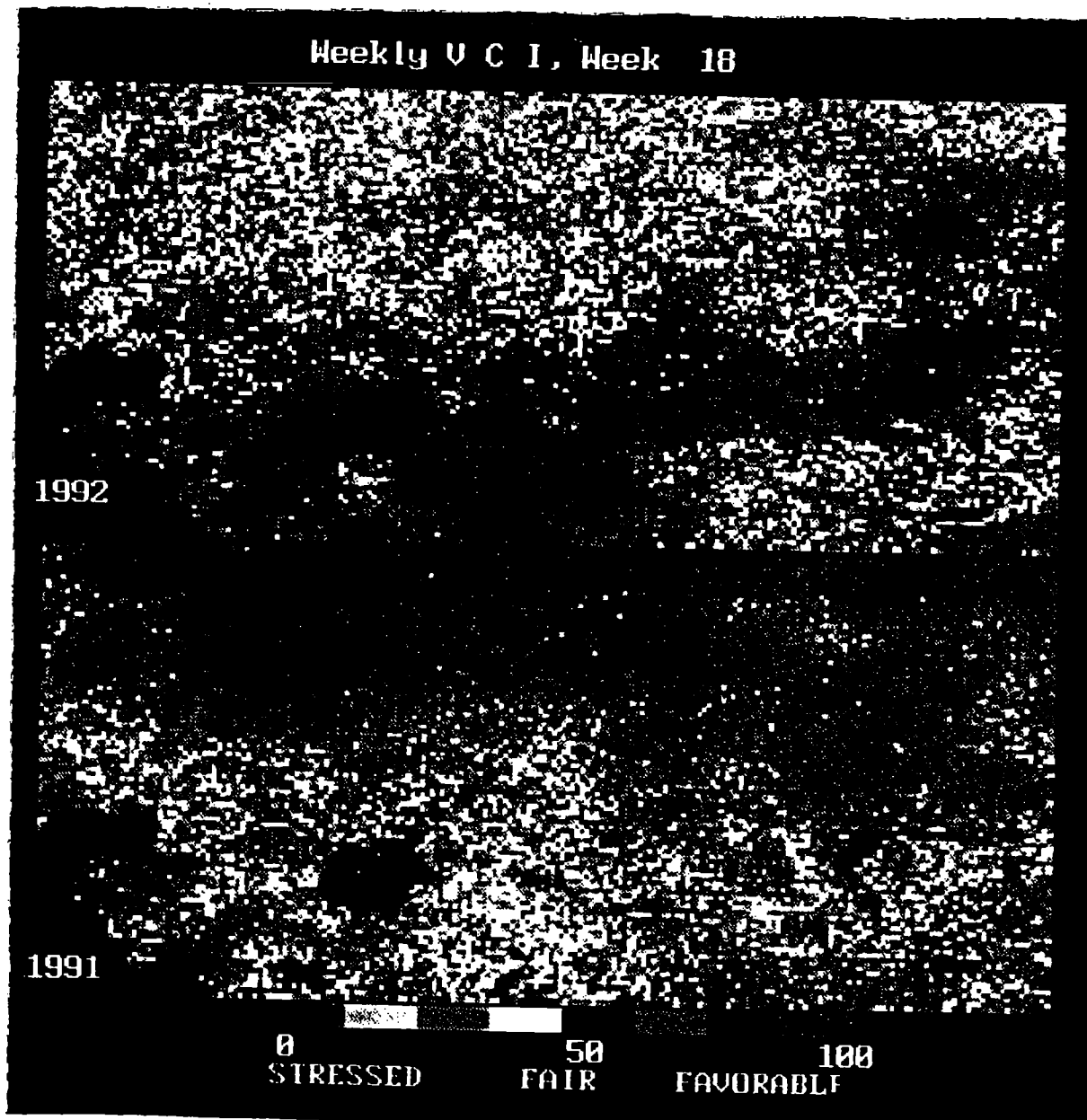


Fig. 28. Vegetation Condition Index for the beginning of May (week 18) 1991 and 1992 for each 16x16 km pixel.

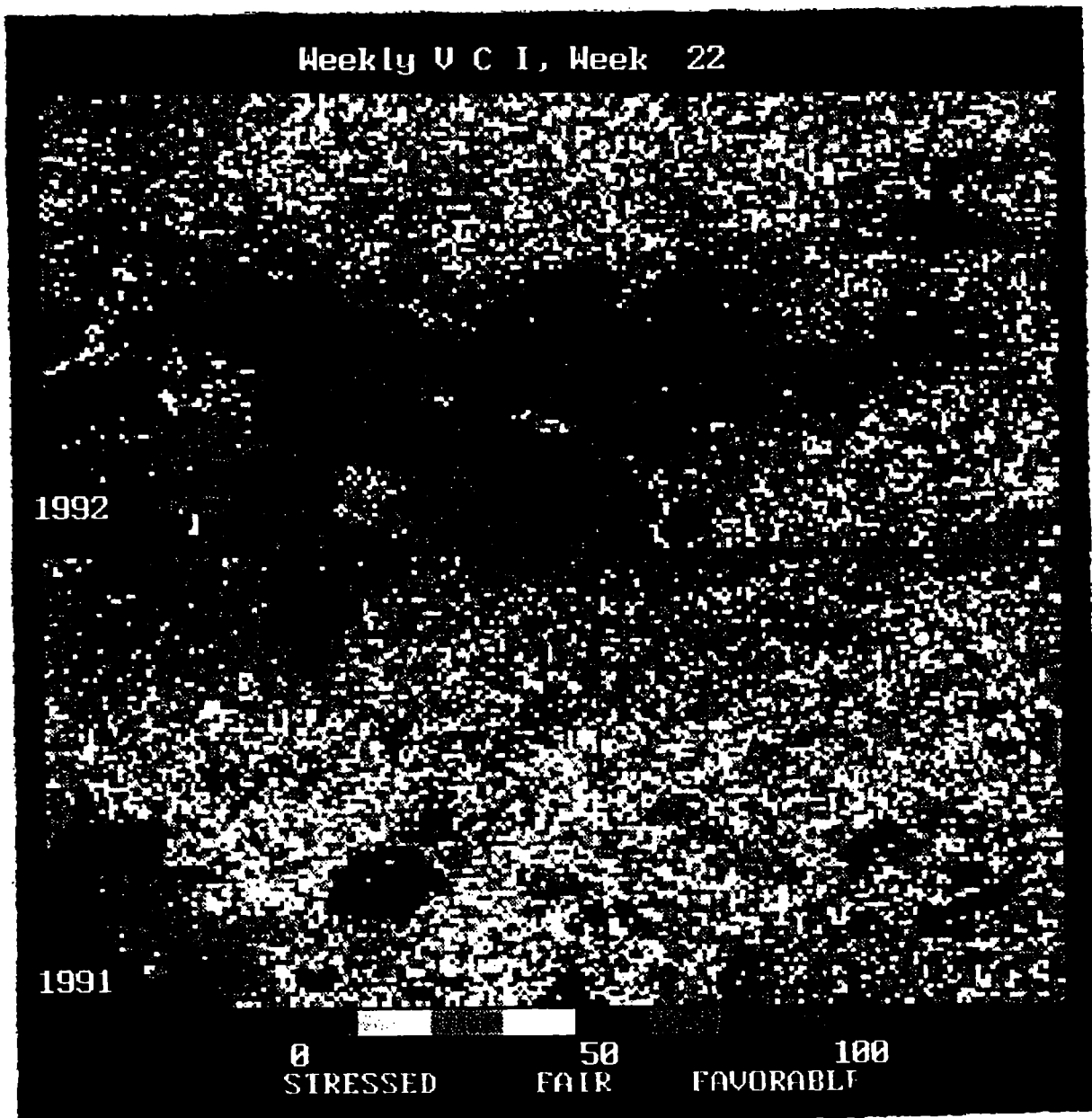


Fig. 29. Vegetation Condition Index for the end of May through the beginning of June (week 22) 1991 and 1992 for each 16x16 km pixel.

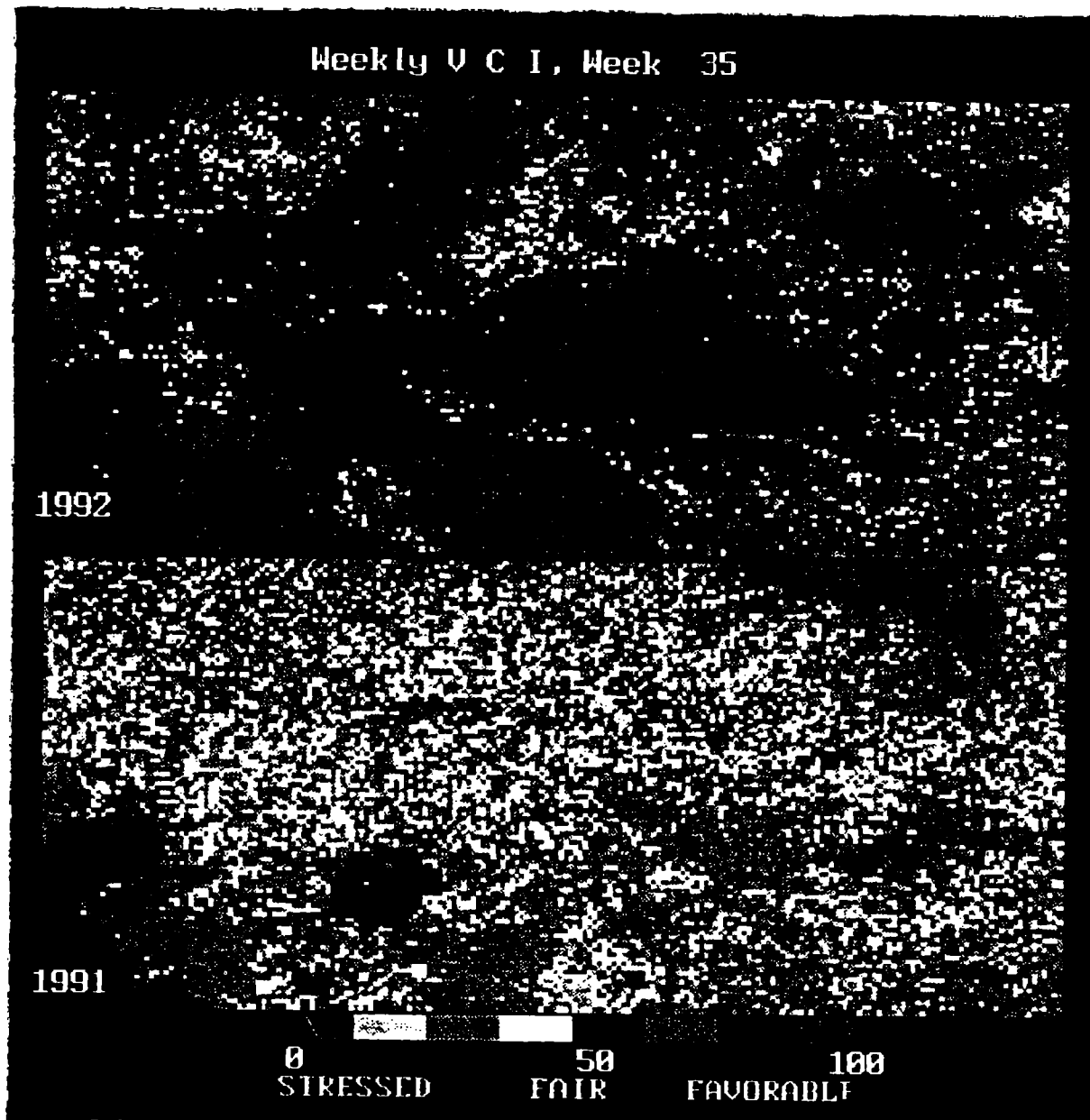


Fig. 30. Vegetation Condition Index for the end of August (week 35) 1991 and 1992 for each 16x16 km pixel.

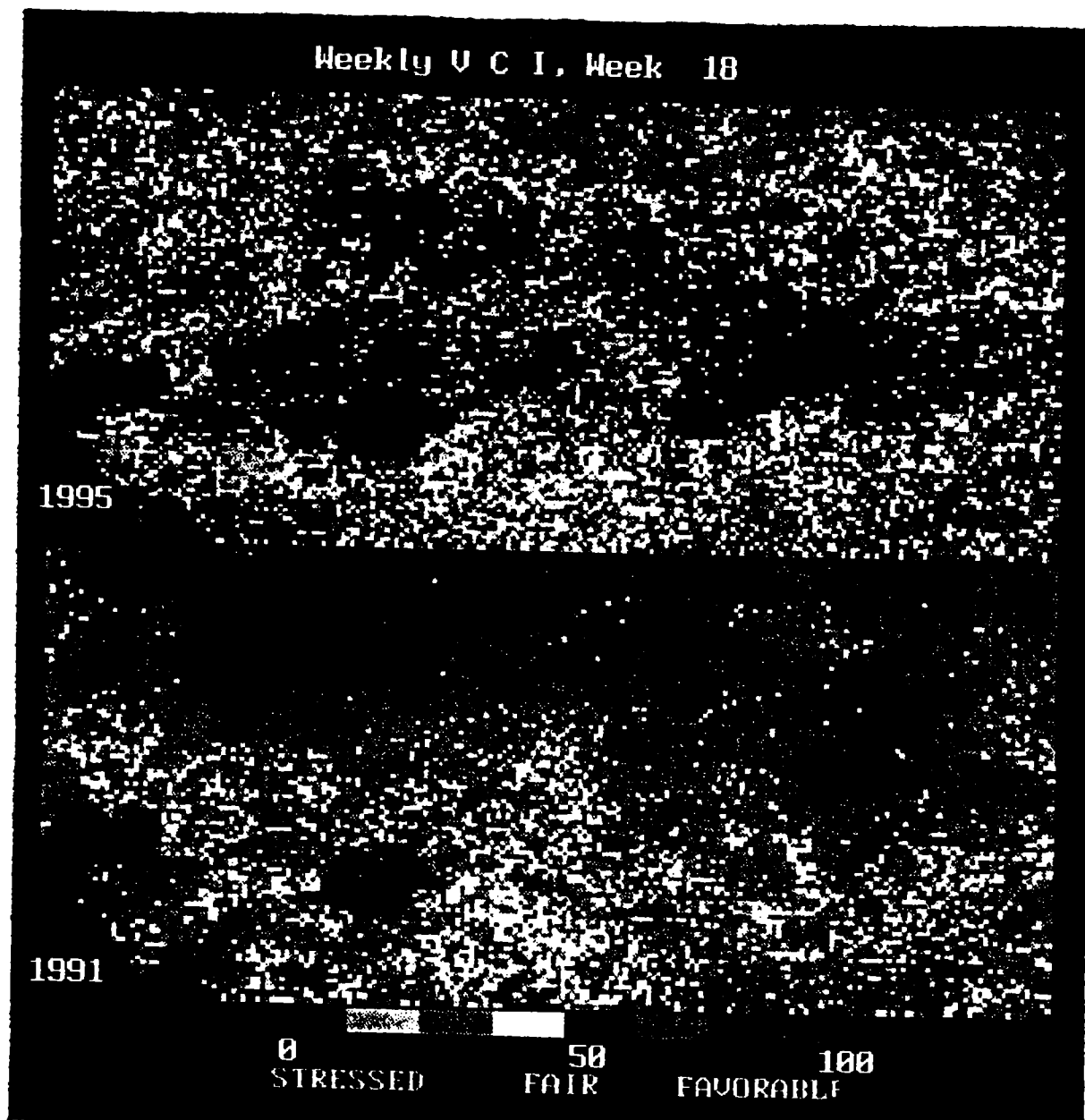


Fig. 31. Vegetation Condition Index for May 1-7 (week 18) 1995 and 1991 for each 16x16 km pixel.

1991 for each 16x16 km pixel.

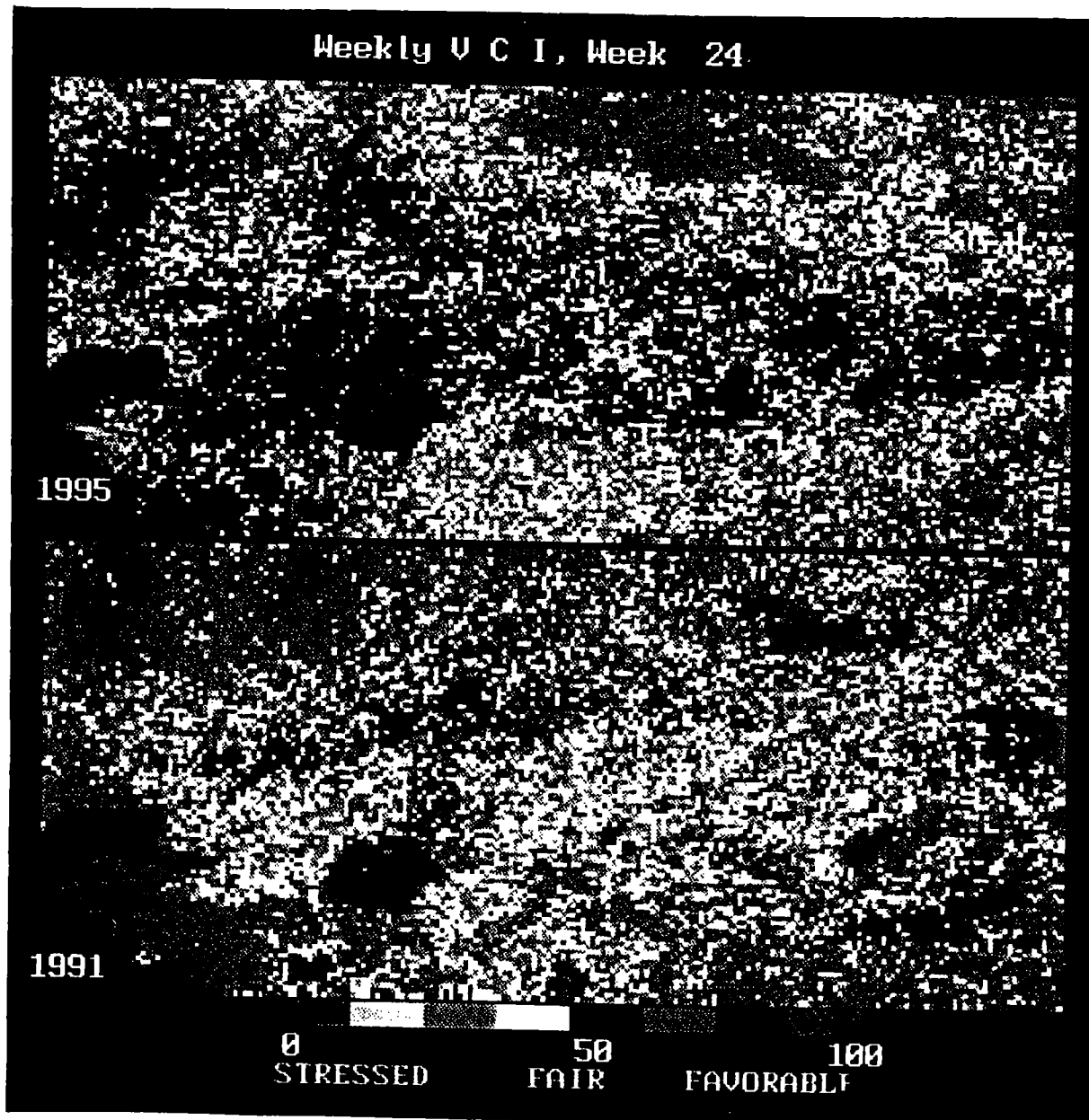


Fig. 32. Vegetation Condition Index for June 13-18 (week 24) 1995 and 1991 for each 16x16 km pixel.

and 1991 for each 16x16 km pixel.

only in a few locations. We should emphasize that June is a most critical month in terms of water requirement for development and productivity of vegetation. These conditions were quite stable if we compare the VCI estimate for the end of June (Fig. 26) with the beginning of July (Fig. 27). There is very little difference between VCI-derived drought intensity and extent.

It is interesting to note that the vegetation conditions at the beginning of the 1991 (unfavorable year) growing season were better than in the 1992 (favorable year). Figure 28 shows that in early May (week 18) 1992 vegetation over a large area of Kazakhstan was under severe stress, while in 1991, vegetation conditions were favorable. However, during May and June, vegetation conditions deteriorated considerably in 1991 and improved in 1992 (Fig. 29). For most of Kazakhstan agricultural areas, vegetation conditions remained unfavorable until the end of the 1991 growing season and favorable for the 1992 season (Fig. 30). These resulted in very low crop production in 1991 and high production in 1992 (Table 2).

5.6.3. The 1995 large-area vegetation conditions

In 1995, we have been monitoring vegetation conditions of Kazakhstan in near real-time. Every Monday, satellite data were extracted for the Kazakhstan region from the Global Vegetation Index Product, were processed and the VCI was calculated. These VCI data were used for assessment of vegetation conditions. It is important to note that the 1995 data have been collected from the new NOAA-14 satellite which became operational in mid-February. Additional procedures have been applied for data calibration.

From the beginning of the 1995 growing season (week 18, beginning of May) vegetation in majority of Kazakhstan region was under stress (Fig. 31). These conditions remained unfavorable until the time of our report completion in mid-June (Figs. 32 and 33).

We handed out these data regularly to collaborators in Kazakhstan, and also reported the 1995 test assessments at the AID office in Kazakhstan (on May 25) and gave them to the decision and policy makers at the Ministries of Agriculture, Economics, Environment, Science and Technology (on May 26). During our meeting in Jerusalem on July 3 with the Kazakh Minister of Environment Mr. Svatoslav Medvedev, we reported our assessments of vegetation conditions in Kazakhstan up to mid-June 1995. We also gave him a PC diskette with the relevant data files, for use in Kazakhstan.

6. Impact, Relevance and Technology Transfer

The results of this project will help Kazakhstan to start using new remote sensing technology for drought monitoring. The delivered hardware, software, proposed concept and methods, will lay the foundation for a new, complete and efficient drought-watch system. This system will be the main contributor to a program of early warning crop and hazardous pasture condition assessment and prediction of agricultural production. The findings of this project will also help to increase the accuracy of agricultural production estimates, spatial distribution of production and timeliness of delivery of these estimates to customers. These improvements, in turn, will help to develop a more efficient system for management of water resources and to improve agricultural planning. Since satellite data has global coverage, this system will serve as a prototype for similar systems in other parts of the developing world where ground observations are limited or not available at all.

The main beneficiary institutions in Kazakhstan will be, first, our collaborators, the Institute for Space Research, and the National Meteorological Administration; the other institutions to benefit include the Ministries of Agriculture, Environment, Water Resources and Kazah Government in general.

The findings of this project were tested on large areas located in various ecological zones with different climates and with different level of economic development.

The resulting new capacity of Kazakhstan includes:

High Resolution Picture Transmission (HRPT) receiving station, tracking antenna, positioner and receiver/demodulator/sectorizing subsystems for receiving NOAA polar-orbiting satellite signal; on-line PC IBM 486 for data collection and initial processing; image processing hardware and software for data processing, storage and distribution; algorithms for converting satellite radiances into the new Vegetation Condition Index (VCI); algorithms for converting the VCI into ground-derived environmental and agricultural characteristics (seasonal dynamic of pasture and crop conditions, and productivity) at test sites; drought detection and monitoring; expertise for data receiving, processing and interpretation.

7. Project Activities/Outputs

Dr. A. Gitelson (Israel) visited Russia (Moscow) on November 5-20, 1993 to meet with collaborators Prof. E. Zakarin and Dr. L. Spivak (Kazakhstan) at the Institute for Space Research of Russian Academy of Sciences. The goal of this meeting was to initiate the project, to select hardware and software appropriate for Kazakhstan.

Prof. E. Zakarin and Dr. L. Spivak (Kazakhstan) visited Israel (Beer-Sheva and Sede-Boker) on April 6-20, 1994 to meet with Principal Investigator Dr. A. Gitelson at the J. Blaustein Institute for Desert Research of Ben-Gurion University of the Negev. The goal of this meeting was to introduce the receiving station TELONICS and hand-held radiometers to our Kazakh collaborators and to train them to use the hardware.

Dr. Kogan (USA) visited Russia (Moscow) on August 5-20, 1994 to meet with our collaborator Dr. L. Spivak (Kazakhstan) at the Institute for Space Research of the Russian Academy of Sciences. The goal of this meeting was to discuss and exchange the results obtained during the 1994 field experiments in Kazakhstan and to provide the training and processing of images at the Institute for Space Research.

Dr. A. Gitelson (Israel) visited Kazakhstan (Almaty) on May 20-30, 1995 to meet with entire Kazah team at the Kazah Institute for Space Research. The goal of this meeting was to control the quality of the 1994 field experiments data; to process and analyze them together with the team; to train team members to work with radiometers; to control the results and to process them; to transfer the expertise of working with HRPT station, receiving images and preliminary interpretation of the results. Also, the 1995 near real-time GVI data were transferred for the assessment of pasture and crop conditions, analysis of drought situation and delivery of these data to users. We also informed the AID officer in Kazakhstan (on May 25) and the decision and policy makers at the Ministries of Agriculture, Economics, Environment, Science and Technology (on May 26) on the result of the project and the current drought situation in Kazakhstan.

Dr. Kogan (USA) visited Israel (Beer-Sheva and Sede-Boker) on June 25-July 9, 1995 to meet with Dr. A. Gitelson at the Institute for Desert Research of Ben-Gurion University of the Negev. The goal of this meeting was to analyze the 1994 experimental data, historical and current satellite and ground data, and to discuss the final results, and to write the final report for this project. During this visit we also met with the Kazah Minister of Environment Mr. Svatoslav Medvedev in Jerusalem on July 3, where we reported the main results of this project, presented the current assessments of vegetation condition in Kazakhstan up to mid-June 1995 and handed over a PC diskette with the data files for use in Kazakhstan.

8. Project Productivity

All project goals were accomplished. Scientific principles, hardware and software of non-conventional system which will use NOAA operational polar-orbiting satellites for quantitative assessments of pasture and crop conditions and productivity in Kazakhstan were developed.

In addition to the project goals several other important tasks were accomplished:

- * calibration of satellite-derived indices versus ground data at experimental sites;
- * aircraft remote sensing measurements together with ground observations (despite of the fact that the current economic situation in K is very difficult, our collaborators found it possible to carry out these experiments).
- * near real-time monitoring of drought and vegetation conditions in 1995.

9. Future work

This project suggests several immediate tasks for:

- * launching a system for receiving and real-time monitoring of drought, and monitoring of crop and pasture conditions and their productivity;
- * developing a satellite data base for the entire region of Kazakhstan.
- * validating the algorithms for the major crop- and pasture-producing regions of Kazakhstan.

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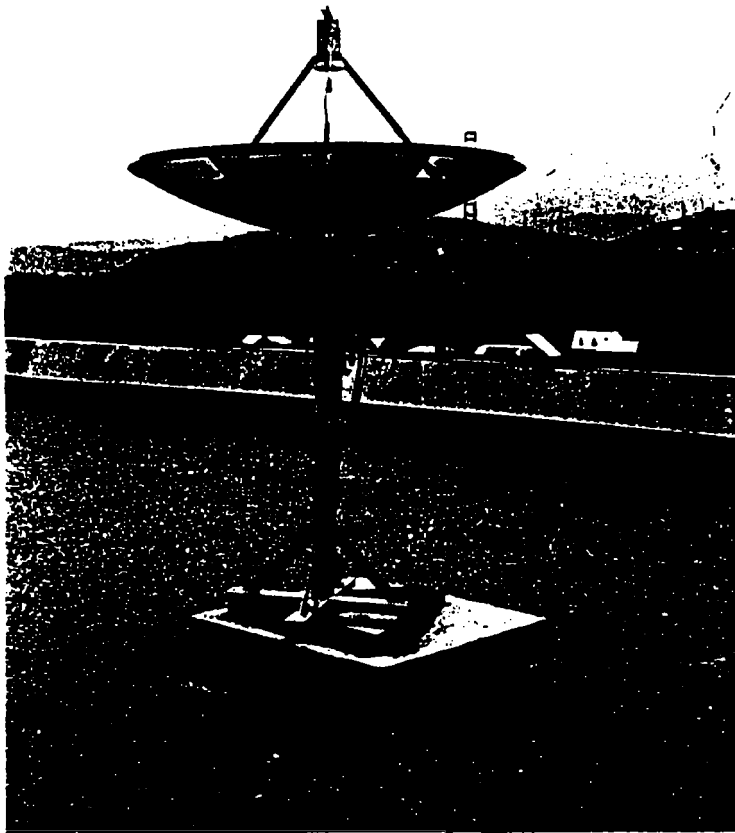
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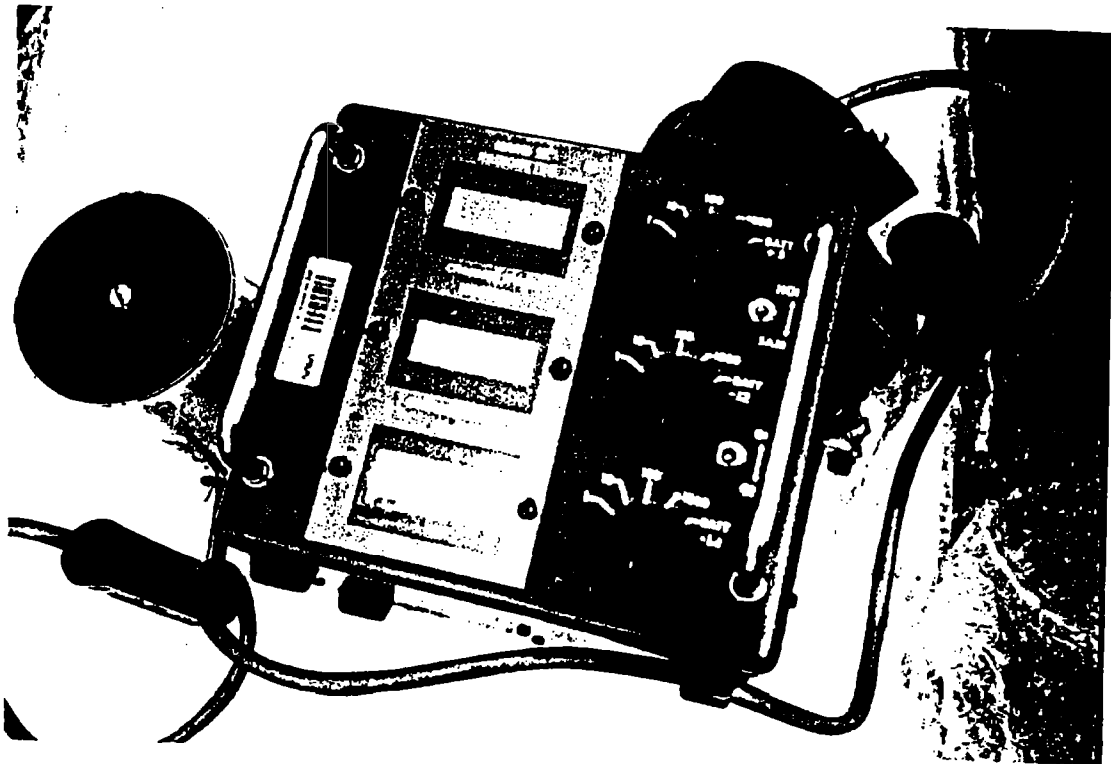
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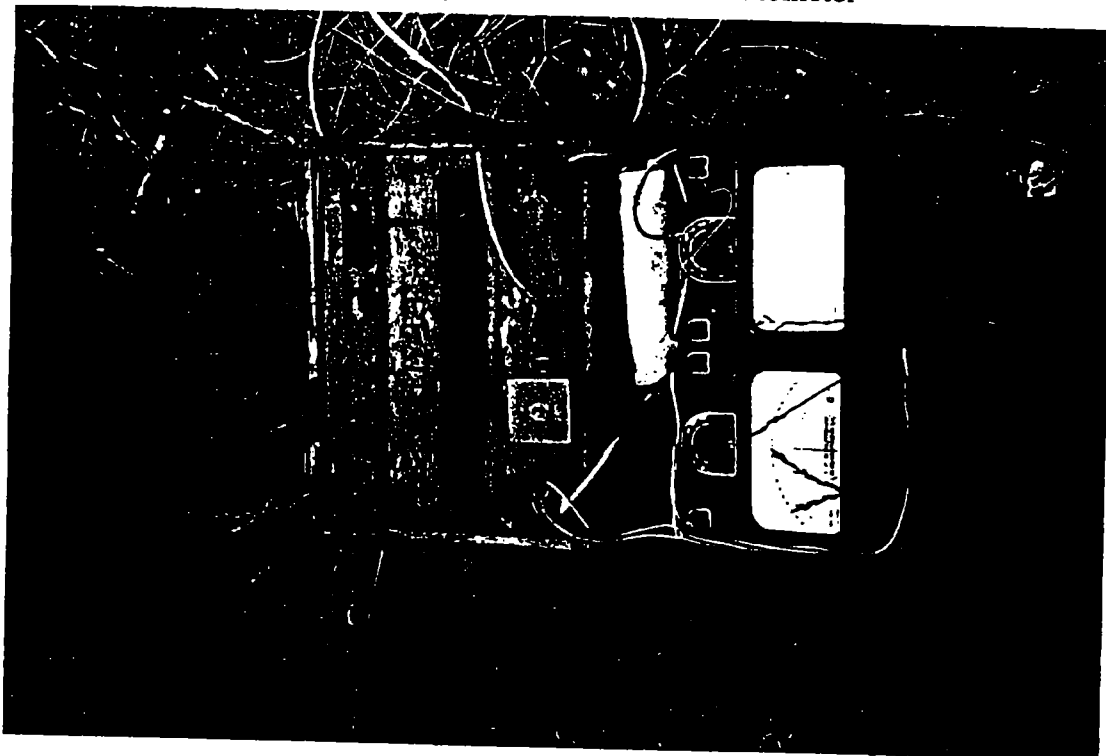


TELONIX receiving station installed at the roof of the Institute for Space Research, Academy of Sciences of Kazakhstan in Almaty. Antenna for receiving high resolution NOAA/AVHRR data (HRPT format).





NASA designed field hand-held radiometer



Airborne radiometer DPF



Image processing laboratory. Institute for Space Research, Academy of Sciences of Kazakhstan, Almaty.



Kazakhi and Israeli team members. Almaty, May 1995

Research proposal submitted to AID/CDR for the Central Asian Republics

Estimation of seasonal dynamics of arid zone pasture and crop productivity using NOAA/AVHRR data.

Request for extension

Phase II: Launching the Remote Sensing System

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Phase I has been granted by
US-Israel AID/CDR/CAD program
Grant No. TA-MOU-CA13-056

Beer-Sheva
July 1995

Scientific summary and relevance to development

Kazakhstan agriculture is highly dependent on climate and weather. Only in recent years weather-related variation in total grain production changed from 12 (1991) to 30 (1992) million metric tons. Unfortunately, weather-watch system does not provide enough information about crop and pasture conditions and productivity. The current economic situation in Kazakhstan put additional constraints on conventional observation system for monitoring the environment because the number of weather stations is sharply decreasing and quality of environmental observations is deteriorating.

In 1993 the Agency for International Development (AID) funded the two-year project "Estimation of pasture and crop productivity using NOAA/AVHRR data". During these two years (1993-1995) we developed scientific principles and hardware and software background of non-conventional system which will use NOAA operational polar-orbiting satellites for quantitative assessments of pasture and crop conditions and estimating their productivity in Kazakhstan.

The HRPT station and PC hardware is able to collect, process and store NOAA polar-orbiting satellite data over Kazakhstan region. The developed algorithms will convert these data into the VCI and into crop and pasture characteristics. However, the created data bases were developed and the algorithms were validated only in principal ecological zones and for test sites.

We suggest to extend the project for one more year in order to:

- * launch a system for receiving NOAA/AVHRR data and real-time monitoring drought and crop and pasture conditions and productivity;*
- * develop satellite data base for the entire Kazakhstan.*
- * validate the algorithms for major crop- and pasture-producing regions of Kazakhstan.*
- * use NOAA/AVHRR thermal channels for improvement of the reliability of the developed algorithms.*

Strengthening Scientific and Technical Capacity of Kazakhstan

The results of this one-year extension will help Kazakhstan to start using new complete remote sensing system for real-time drought-watch and monitoring crop/pasture conditions and productivity. This system will be the main contributor to an early warning crop and pasture hazardous condition assessments and prediction of agricultural production. The finding of this extension will also help to increase the accuracy of agricultural production estimates, spatial distribution of production and timeliness of delivery of these estimates to customers. These improvements, in turn, will help to develop more efficient system for management of water resources and to improve agricultural planning. Since satellite data has global coverage, this system

will serve as a prototype for similar systems in other parts of the developing world where ground observations are limited or not available at all.

Description of the research plan

For a period of one year the project team plans

1. To launch a system for receiving NOAA/AVHRR data and real-time monitoring drought and crop and pasture conditions and productivity.

The signal obtained from NOAA-14 satellite will be mapped, geometrically corrected, sampled from 1 to 16 km and 1 to 7-day composite. The data will be used together with data base for calculating the Vegetation Condition Index which in turn will be used for detecting droughts and monitoring its development, extend, duration and impact on vegetation. The final results will be weekly maps of this product provided to policy and decision makers.

2. To develop satellite data base for the entire Kazakhstan.

This data base includes

- * real time observed radiances in visible and near infra-red channels and NDVI;
- * historical NDVI and VCI data for each 16 by 16 km pixels and real time VCI data.

3. To validate the algorithms for major crop- and pasture-producing regions of Kazakhstan.

The attempt will be made to calibrate the VCI data against crop/pasture yield and production for main administrative regions (oblast).

4. To use NOAA/AVHRR thermal channels for improvement of the reliability of the developed algorithms.

These channels are known to improve the accuracy of estimating of earth surface characteristics especially the productivity of vegetation.



KAZAKHSTAN COUNTRY STUDIES PROGRAM

INVENTORY OF KAZAKHSTAN GREENHOUSE GAS EMISSIONS

COOPERATIVE AGREEMENT BETWEEN
THE GOVERNMENT OF THE UNITED STATES OF AMERICA
AND THE GOVERNMENT OF THE REPUBLIC OF KAZAKHSTAN

KAZAKH SCIENTIFIC AND RESEARCH
HYDROMETEOROLOGICAL INSTITUTE (KAZNIGMI)
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SEPTEMBER 1995

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ACKNOWLEDGMENTS

The Republic of Kazakhstan started the emissions inventory process in October 1993 under the framework of the Country Studies Program with financial and technical support of the Governments of Kazakhstan and the United States of America.

In Kazakhstan, under the leadership of Main Administration for Hydrometeorology at the Cabinet of Ministry of the Republic of Kazakhstan, experts and officers of various ministries and departments contributed to data collection and review. The authors express their gratitude to Georgy Papafanasopulo (Ministry of Energy and Coal Industry), Boris Akimov (Ministry of Industry), Oleg Semenov (KazNIGMI), Asiya Fisher (Environmental Pollution Center), Maira Amirkhanova (Governmental Statistical Committee), Vakhit Kerimkulov (Ministry of Ecobioresources), Yury Noarov (Ministry of Industry) for the submitted data and help in the analysis.

The authors also would like to thank those American organizations and personnel who consulted and helped in the working out of the Kazakhstan Inventory, in particular, Alexei Sankovski and Craig Ebert of ICF Consulting Group and Norman Willard and Jack Fitzgerald of the U.S. Country Studies Management Team.

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

BOD₅	Biochemical Oxygen Demand
C	Carbon
CH₄	Methane
CO	Carbon Monoxide
CO₂	Carbon Dioxide
dm	dry matter
FCCC	Framework Convention on Climate Change
Gg	Gigagrams
GHG	Greenhouse Gas
GWP	Global Warming Potential
ha	hectare
ICE	Internal Combustion Engines
IPCC	International Panel on Climate Change
ktdm	kilotonne of dry matter
LPG	Liquefied Petroleum Gas
mln	million
MMTCE	Million Metric Tons of Carbon Equivalent
N₂O	Nitrous Oxide
NCV	Net Calorific Value
NMVOC	Non-Methane Volatile Organic Compound
NO_x	Nitrogen Oxides
t	tonne
ths	thousand

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SUMMARY

As part of obligations under the UN Framework Convention on Climate Change (FCCC), the Republic of Kazakhstan conducted an inventory of greenhouse gas (GHG) emissions. The objective of this report is to provide the results of the estimation of emissions by sources and removals by sinks in Kazakhstan. The emission estimates were calculated using the IPCC Guidelines for National Greenhouse Gas Inventories as well as some additions and differences from this method. The estimates are provided for the 1990 base year defined by the FCCC for which countries are to submit inventories of GHG emissions. The main sources of data for emission calculations were the official statistical information and information provided by the Ministry of Energy of Kazakhstan.

The emissions of six greenhouse and photochemical active gases - carbon dioxide (CO₂), carbon monoxide (CO), nitrogen oxides (NO_x), nitrous oxide (N₂O), methane (CH₄) and non-methane volatile organic compounds (NMVOC) - from the territory of Kazakhstan in 1990 have been determined as the result of the GHG inventory.

According to IPCC, the GHG emissions estimates are presented in Gigagrams (Gg). Besides, the emissions estimates are also presented on carbon-equivalent basis (Million Metric Tons of Carbon Equivalent, MMTCE) in order to show the relative contribution of each gas and sector to total Kazakhstan GHG emissions. Following recommendations of IPCC we used a Global Warming Potential (GWP) of 24.5 for methane, GWP of 320 for nitrous oxide and GWP of 1 for carbon dioxide.

Total Kazakhstan emissions were 65.764 MMTCE. The most important emissions source is the energy sector which is responsible for 58.172 MMTCE or about 90 percent of all GHG emissions. The most important emission source in non-energy sector in Kazakhstan is the agriculture. The GHG emissions from this sector are about 5.564 MMTCE or 8 percent of total emissions.

CO₂ emissions accounted for the largest share of Kazakhstan emissions -- 53.039 MMTCE or 80.8 percent of total emissions. In molecular basis its emission accounted for 194,477.0 Gg. Thus, in 1990 CO₂ emissions accounted for more than 11 tonne per each person of Kazakhstan. Methane emissions accounted for 12.435 MMTCE or 18.9 percent of total emissions, including contributions from landfills and agricultural activities, among others. N₂O emissions equaled 0.2 MMTCE or 0.3 percent of total Kazakhstan emissions. The emissions of the photochemical important gases CO, NO_x and NMVOCs are 3,108; 1,197; and 260 Gg (molecular basis) respectively.

The largest sources of CO₂ emissions were the thermal power plants and large boilers which contributed 48 percent of the total CO₂ emissions. Internal combustion engines (ICE), residential boilers and stoves, light and food industries contributed 17, 16, 8 percent of the total CO₂ emissions respectively. The major sources of CH₄ emissions were fugitive fuel emissions (49 percent) and agriculture (45 percent). The other sources, including wastes accounted for 6 percent. The largest proportion of N₂O emissions comes from coal combustion, accounted for about 94 percent of total N₂O emissions in 1990. N₂O was emitted first of all from thermal power plants and large boilers (51 percent), from ICEs (27 percent). N₂O emissions from the other sources, including industry, residential, etc., accounted for 22 percent. The largest sources of NO_x emissions were ICEs (40 percent), residential boilers and stoves (36 percent), thermal power plants and large boilers (21 percent). The largest sources of CO emissions were ICEs (65 percent), ferrous and non-ferrous metallurgy (17 percent), residential boilers

and stoves (9 percent). Data are presented in percentage of the total emissions of the respective gas.

The results obtained in some of main sectors are described further below. It should be noted that the main reason of missing data about emissions in the some categories (such as N₂O emissions from application of fertilizers and emissions from solvent use) is the lack of data and the lack of the concrete activities, emitted GHGs.

Power Generation Sector

For estimating of carbon dioxide emissions from fossil energy consumption we used the methodology, which is similar to approach provided by IPCC. However, according to this methodology we estimated the emissions for individual sectors, not for economy in general. To evaluate total emission we simply added the emissions from different sectors. So, such approach conceptually similar to so-called "bottom-up" methodology although the algorithm of calculation is similar to "top-down" approach, provided by IPCC. We did not use "top-down" itself, because there was a lack of data about import and export of fuel, while the data about fuel consumption were available and sufficiently accurate. To check and to compare the results we calculated CO₂ emissions from fossil fuel combustion at the thermal power plants and large boilers using another approach also. The major difference between two methods lies in the energy data used to derive carbon emissions (actual reported consumption is used for the second approach and apparent consumption is used for the IPCC, first approach).

CO₂ emissions from fuel combustion from the power generation sector by the first IPCC approach accounted for 93,159 Gg or 25.407 MMTCE. CO₂ emissions from fuel combustion in power engineering by the second approach are total 93,574 Gg or 25.520 MMTCE. These two alternative methods can both produce closely related estimates that are comparable within a few percent. We included in reporting IPCC Tables the total CO₂ emissions from energy and transformation industries according to first approach -- 25.407 MMTCE.

Nitrous oxide emissions from stationary sources were 0.147 MMTCE, and 0.101 MMTCE from its value contribute the thermal power plants and large boilers. It is important to note, however, that this gas is currently not regulated in Kazakhstan. The estimates of nitrous oxide emissions presented here are based on rate per amount of fuel used (*IPCC/OECD, Vol. 2, 1994*).

Internal Combustion Engines and Residential Sector

Utilization of energy for ICEs and domestic purposes was a significant source of GHGs. The ICEs also greatly contribute to CO₂ emissions, accounted for about 17 percent of Kazakhstan emissions. Virtually all of the energy consumed in this sector comes from petroleum-based products.

Emissions from ICEs were estimated by transport fuel consumption, where several major fuel types, including diesel fuel, motor gasoline, aircraft gasoline, and kerosene were considered. Nearly 41 percent of the GHG emissions was the result from gasoline consumption in automobiles and other vehicles, with other uses, including diesel fuel.

Fuel consumption at ICEs produces the majority of the CO, NO_x and NMVOC emissions. In fact, motor vehicles that burned fossil fuel were the largest source of CO emissions in Kazakhstan, contributing approximately two-thirds of all Kazakhstan CO emissions in 1990. Motor vehicles also emitted more than half of total Kazakhstan NO_x emissions and all NMVOC emissions according to our calculations based on available input data. N₂O emissions from ICEs accounted for 0.053 MMTCE or about 27 percent of total N₂O emissions.

The residential sector accounted for about 16 percent of total CO₂ emissions. Stationary combustion in residential sector is believed to be a small source of methane and nitrous oxide. Methane emissions from residential sector in 1990 accounted for 0.044 MMTCE including 0.043 MMTCE from biomass combustion, while nitrous oxide emissions from residential sector accounted for 0.012 MMTCE. Practically all these emissions were from biomass combustion. Stationary combustion in residential sector is a large source of oxides of nitrogen and carbon monoxide emissions. In 1990 emissions of NO_x from residential sector represented 36 percent of national NO_x emissions, and CO emissions from residential sector contributed 9 percent to the national CO total.

Carbon dioxide emissions from biomass have been estimated separately from fossil fuel-based emissions and are not included into Kazakhstan totals. For 1990, CO₂ emissions from woody biomass were about 0.9 MMTCE, and the Kazakhstan residential sector was responsible for all these emissions.

Industrial Processes

The carbon dioxide emissions proportion from industrial processes amounted for 4,349 Gg or 1.186 MMTCE per year or approximately 2 percent of total CO₂ Kazakhstan emissions. The cement and carbide plants are the main sources of industrial CO₂ emissions in Kazakhstan. Taking into account that the total output of cement in 1990 was 8,301,200 tonnes, the total CO₂ emissions from cement production in Kazakhstan were 4,138 Gg. In 1990 the calcium carbide output was 306,700 tonnes. Respective CO₂ emissions were 210.5 Gg, CO emissions equaled 134.0 Gg.

Agriculture

The agricultural activities are responsible for emissions of 5.564 MMTCE, or approximately 8 percent of total Kazakhstan emissions. The most significant gas emitted by agricultural activities is methane (CH₄). The Agriculture sector produces more than 45 percent of total methane emissions in Kazakhstan. Domestic livestock, manure management and rice cultivation are all sources of methane in Kazakhstan.

The total methane emissions from all animal types were 774.5 Gg. In 1990, domestic livestock and manure management together were responsible for 93 percent of methane emissions from agricultural activities. In domestic livestock, methane produced by enteric fermentation accounted for 89 percent of the total CH₄ emissions from livestock and share of methane from the management of animal manure was 11 percent. Methane emissions from rice cultivation were a small fraction of total CH₄ agricultural emissions - only 7 percent. The annual methane emissions from flooded rice fields were 58.2 Gg. Total methane emissions from agriculture in 1990 were 832.7 Gg.

Kazakhstan specialists used locally available data to account for NO_x emissions from agricultural soils. This approach was adopted by determination of NO_x emissions from fertilizer use.

Waste

The residential solid waste and wastewater treatment were the large methane emission sources. The procedure of the calculation was completed according to IPCC. Net annual methane emissions from waste accounted for 108.2 Gg from residential solid waste and 3.3 Gg from wastewater treatment. In total 111.5 Gg or 0.745 MMTCE of methane was emitted from waste in Kazakhstan in 1990.

Land Use Change and Forestry

The spontaneous and prescribed forest fires lead to significant emissions of greenhouse gases. In Kazakhstan this source was described by applying the IPCC methodology, originally developed for estimating emissions from biomass burning. Emissions caused

by fire in Kazakhstan were estimated separately for different forest types (fir, larch) and different types of post-fire regeneration (birch, aspen).

The carbon emissions from burning aboveground biomass or the immediate release as a result of fires estimated to be 55.3 Gg. The carbon emissions from decomposition of aboveground biomass were accounted to be 112.6 Gg. So, the total emissions from fire are estimated to be 168 Gg carbon or 616 Gg (0.168 MMTCE) CO₂ per year. Besides, non-CO₂ trace gases emissions from forest fire have been estimated such as follows: CO emissions are 7.74 Gg; CH₄ emissions were 0.88 Gg (0.006 MMTCE); NO_x emissions were 0.143 Gg and N₂O emissions were 0.006 Gg (0.0005 MMTCE).

The average annual carbon dioxide uptake from forest exploitation was calculated using the IPCC methodology; it was estimated to be 4,627 Gg or 1.262 MMTCE of CO₂. Taking into account the CO₂ emissions from forest fires, the net carbon dioxide flux in 1990 due to land-use change and forest management activities was estimation to have been an uptake (sequestration) of 4,011 Gg of CO₂ or 1.094 MMTCE. It is accounted for approximately 2 percent of total CO₂ emissions or about 1 percent of total GHG emissions in Kazakhstan.

Uncertainties of the Results

Many of the categories of GHG emissions can be estimated only with large ranges of uncertainty. We provide the following level of uncertainties yield by national activity (statistical) data. Some of the current estimates, such as those for CO₂ emissions from energy and transformation industries, are considered rather accurate: possible error is not more than 5 percent. For other categories of emissions, however, a lack of data or an incomplete understanding of how emissions are generated limit the scope or accuracy of the inventory: possible error is about 20 percent. The largest uncertainty of emission estimations (more than 20 percent) was in subsector of ICEs. The uncertainty, connected with activity data in agricultural was about ± 10 percent of the emissions estimate.

The Expert Judgments of Future CO₂ Emissions till 2000

It is important to know how the CO₂ emissions will develop in the future, without any mitigation options, i.e., so-called reference or baseline emission scenario. The problem of preparing this scenario is very difficult. It is clear that the scenario for Kazakhstan as a country with the economy in transition will differ from the historical pattern. While during more than 60 years starting 1927 the planning and development of the economy were guided by five-year or seven-year plans approved by the Government of the USSR. Now there are no such plans in ministries and departments, the share of the private sector increases and the share of the state sector decreases; thus, it turned out impossible to receive any official plans from the relevant governmental bodies. Therefore, the reference scenario was developed by experts judgments. Ten experts were questioned including the leading authorities and scientists in the energy sector, industry, transport, agriculture as well as scientists in economics. The experts took into account, first, the results of the last 4 years (official statistics) and, second, the actual status of production in their respective branches of the economy.

As we only have the calculation of the emissions for 1990 (the base year), the first step was to determine the production ratio among 1991 and 1990. The comparison of data showed that in both production volumes (including fuel) and the consumption of fuel 1991 characteristics are practically the same as for 1990. 1991 was the year of stagnation, when the production growth already stopped while the decline had not yet started. Since 1992, there has been a decline: first in industry and then also in the other branches of the economy.

All experts noted the following four reasons for the decline:

- Interruptions or cancellation of the supplies from the countries -- members of the former Soviet Union due to severing economic and financial links;
- High degree of equipment worn-out and moral depreciation of the equipment, decrease in efficiency, available capacity and as the result, increase in energy consumption;
- Difficulties in selling the major items of Kazakhstan exports (non-ferrous metals, mineral fertilizers for example phosphates, etc.). Kazakhstan consumes only 8-20 percent of such products while the former consumers (the countries -- members of the former Soviet Union) either can not buy it due to economic difficulties or prefer other suppliers;
- Movement of human resources from the country and from the state industrial enterprises to other activities (retail stores, cooperatives, etc.).

Due to these and other reasons the decline in production as compared to 1991 was 10 percent in 1992, 25 percent in 1993, and the expected decline in 1994 is 40 percent. For 1995 the experts prognosticate further decline in production: 45 percent for the optimistic scenario and 50 percent for the pessimistic scenario. Stabilization is expected in 1997 only; after that, some slow growth is expected up to the level of 75-80 percent to the end of the decade.

One should emphasize that the forecast for the production volumes in industry for the second half of the decade is especially unreliable in comparison with similar forecasts for the other branches of the economy. The mentioned high degree of depreciation, being a highly negative factor, will nevertheless become a stimulus for the restructuring of the industry.

Another important factor - a high growth of the prices for energy sources - can also have an essential impact. As the energy consumption in the industry of Kazakhstan is high, the cost of industrial products will be also high, which will deteriorate the problem of selling the products.

The decline in the energy sector is somewhat less than the discussed general decline in industry due to an increase in energy consumption because of the worn-out (depreciation) of equipment. In addition, residential consumption in cities, towns and villages, which is the second main consumer of electricity, almost did not change. As the result, the consumption of energy in 1993 was 85 percent of the 1991 level, i.e., the decline was 15 percent as compared with 25 percent in industry. The stabilization of the electricity generation is expected in 1996; after that, a growth is expected with reaching the level of 90 percent of the 1991 generation in 2000.

In agriculture, the total amount of the cultivated land decreased by 2 million ha during the last three years. In the near future, a reduction by 1-2 million ha can be expected, with the total reduction of about 15 percent in comparison to the 1991 level. The specific energy consumption per 1 ha will increase by 10-20 percent due to a progress in the cultivation technique: at present, many operations such as cultivation, water retention, snow retention, etc., are not implemented in full due to shortages in fuel and equipment.

On the basis of the received expert assessments and data on specific fuel consumption in the major branches of the economy we developed a reference (baseline) scenario of the CO₂ emissions for the period 1991-2000. It was received that the reduction of the GHG emissions by 1996 will reach 26 percent of the 1991 level, with subsequent stabilization and gradual growth reaching the base level right after 2010.

INTRODUCTION

The Republic of Kazakhstan is situated in Asia and has a territory of more than 2.7 million km² and a population of more than 16 million. There are 19 administrative provinces and more than 80 cities and towns in the country. There are large industrial facilities for the extraction of minerals and fossil fuels, thermal power plants, factories of ferrous metallurgy, chemical industry and refineries, machinery manufacturing, an industry of construction materials etc. Kazakhstan has a high proportion of energy-intensive industry because of its strong natural resource base.

The extraction of coal in the country is more than 100 million tonnes per year, while the deposits of coal are assessed to be 64 billion tonnes. The extraction of oil in 1990 was 26.6 million tonnes, and the deposits of oil are assessed to be 2,357 million tonnes. There are also some deposits of natural gas.

The land available for harvesting is more than 35 million hectares (ha), including about 3 million ha of irrigated land. The harvest of cereal crops amounts for 25-30 million tonnes per year; some amount of corn is exported. The total number of livestock is 9 million; in addition to dairy-cattle and beef-cattle there are horses, camels, and pigs.

The forests in Kazakhstan are small: they occupy only 3.7 percent of the territory (9,648 thousand ha). On the majority of this territory, there are saksaul trees, trees capable of surviving without much water that are often found in deserts.

Kazakhstan is concerned about the undesirable consequences of climate change as a result of the growth in the concentration of greenhouse gases (GHG) in the atmosphere. Kazakhstan is one of the countries that signed and recently ratified the UN Framework Convention on Climate Change (FCCC). In accordance with Article 4, one of the commitments of the FCCC is to develop, update and publish national inventories of anthropogenic emissions by sources and removals by sinks of greenhouse gases.

As part of obligations under the UN Framework Convention on Climate Change, the Republic of Kazakhstan conducted an inventory of greenhouse gas emissions.

This report provides the estimates of Kazakhstan greenhouse gas emissions and sinks, as well as the methods used to calculate these estimates, and the uncertainties associated with them. The emissions of six greenhouse and photochemical active gases - carbon dioxide, carbon monoxide, nitrogen oxides, nitrous oxide, methane and non-methane volatile organic compounds - from the territory of Kazakhstan in 1990 have been determined as the result of the GHG inventory.

The estimates are provided for the 1990 base year defined by the FCCC for which countries are to submit inventories of GHG emissions. The expert judgments of future CO₂ emissions till 2000 are represented as well.

According to IPCC, the GHG emissions estimates are presented in gigagrams. Besides, the emissions estimates are also presented on carbon-equivalent basis (Million Metric Tons of Carbon Equivalent, MMTCE) in order to show the relative contribution of each gas and sector to total Kazakhstan GHG emissions. Following the recommendations of IPCC we used a GWP of 24.5 for methane and GWP of 320 for nitrous oxide (*IPCC Working Group I*, 1994). Obviously, GWP for carbon dioxide is 1.

According to the IPCC Guidelines for National Greenhouse Gas Inventories (*IPCC/OECD, Vol. 1*, 1995) every national inventory should consist six major parts. This Inventory consists five parts because of lack of data on Solvent Use source.

The main sources of data, presented here, were the official statistical information and information provided by the Ministry of Energy of Kazakhstan.

Emissions of greenhouse gases from different sources and removals by sinks were estimated using the IPCC methodologies, that are consistent with volumes 1-3 of IPCC Guidelines for National Greenhouse Gas Inventories (*IPCC/OECD*, 1995). Also, for some emissions sources the IPCC default methodologies were amended by our methods. These instances, including energy production, industry sector and forest sink are documented in the text below, along with the estimations of the differences between the results obtained by IPCC and by other methods.

PART I. EMISSIONS FROM ENERGY

A. GHG EMISSIONS FROM FOSSIL FUEL COMBUSTION

Inventory emissions estimates were based primarily on the official statistical information and information provided by the Ministry of Energy of Kazakhstan (*Ministry of Energy of Kazakhstan*, 1991). As a result the largest stationary sources included 46 cogeneration and condensed power plants (further simply "thermal power plants") and central heat systems (further simply "large boilers"); 23 enterprises of ferrous and non-ferrous metallurgy; 11 enterprises of oil and gas industry, 8 enterprises of chemical industry, 5 the largest machine-building plants; 10 cement and asbestos plants. The emissions from other great fuel consuming enterprises (i.e. food and light industries, municipal economy, agriculture and cattle-breeding) were also taken into account in the whole. The emissions from the internal-combustion engines (ICEs) on automobiles, locomotives, air-crafts and river-boats, on agricultural and constructional machines were defined as from separate plural source.

The major fuel source categories considered in this report included: coal, fuel oil, natural gas, diesel fuel, gasoline, condensed and liquefied gas (LPG according to IPCC), fuel for residential stoves (fuel oil according to IPCC), wood, straw, dry stalks and bolls of cotton plant, or guzapay. However, emissions from last three fuels originating from the biomass sector were not included in the national CO₂ balance (*IPCC/OECD*, Vol. 1, 1995).

CO₂ Emissions

For estimating of carbon dioxide emissions from fossil fuel consumption we used the methodology, which is similar to approach provided by IPCC (*IPCC/OECD*, Vol. 2, 1995). However, we estimated the emissions for individual sectors, not for economy in general. To evaluate total emission we simply added the emissions from different sectors. So, such approach conceptually similar to so-called "bottom-up" methodology although the algorithm of calculation is similar to "top-down" approach, provided by IPCC. We did not use "top-down" itself, because there was a lack of data about import and export of fuel, while the data about fuel consumption were available and sufficiently accurate. These data were given in Worksheet 1-1, Sheets 1-1, 1-2, 1-3 (*IPCC/OECD*, Vol. 2, 1995) of Appendix 2.

According to IPCC, the calculation procedure can be represented by the following equation:

$$M(\text{CO}_2) = AC \cdot CF \cdot CC \cdot Fco \cdot 3.67 \cdot 10^{-6} \quad (1)$$

$\text{tonne} \left(\frac{\text{kcal}}{\text{kg}} / \frac{\text{kcal}}{\text{kg}} \right)$
 Gg CO_2

where:

$M(\text{CO}_2)$ = mass of CO₂ emissions (Gg);

AC = apparent consumption of fuels (standardized tonnes);

$$AC = B_{tar} \cdot (Q'_h / 7,000) \quad (2)$$

B_{tar} = mass of fuel (actual tonnes);

Q'_h = net calorific value (NCV) of fuels (kcal/kg). These data about B_{tar} and Q'_h were taken from References Books (*Ministry of Energy of Kazakhstan*, 1991, and *Chokin et al.*, 1990) for each type of fuel and

sectors. Apparent consumption according to the formula (2) equaled 5,769,000 standardized tonnes of gasoline; 54,000 standardized tonnes of jet kerosene; 711,000 standardized tonnes of other kerosene; 9,000,000 standardized tonnes of diesel oil; 8,006,000 standardized tonnes of residual fuel oil; 215,000 standardized tonnes of LPG; 43,272,000 standardized tonnes of lignite; 43,000 standardized tonnes of coke; 9,798,000 standardized tonnes of dry natural gas (see Worksheet 1-1, Sheet 1-1 of Appendix 2);

- 7,000 = standard net calorific value (kcal/kg);
- CF = conversion factor from GJ to standardized tonne, which equaled 29,330 GJ/Gg or 29.33 GJ/standardized tonne or simply 29.33 GJ/tonne;
- CC = carbon content. For coals we chose CC = 27.1 kg C/GJ following recommendation our energy experts and actual data of carbon content in Kazakhstan coals (*Ministry of Energy of Kazakhstan*, 1991). For other fuels CCs equaled IPCC defaults emission factors from Table 1-2 on page 1.6 (*IPCC/OECD, Vol. 2, 1995*);
- F_{∞} = portion of carbon oxidized which ranged from 0.99 for petroleum products and coal (for the thermal power plants and large boilers only) to 0.995 for gas (*IPCC/OECD, Vol. 2, 1995*). The oxidized part of coal for industry boilers is less than at the thermal power plants and large boilers and accounted for 0.95 (*Ministry of Energy of Kazakhstan*, 1991).
- 3.67 = CO₂ and C molecular weight ratio;
- 10⁻⁶ = conversion factor from kg to Gg.

In addition, to calculate CO₂ emissions from power generation sector we have used another method, which slightly differ from IPCC approach. It is described below.

N₂O Emissions

Both mobile and stationary sources emit nitrous oxide. Nitrous oxide emissions were estimated using IPCC-recommended emissions factors and Kazakhstan fossil fuel and wood fuel consumption data. The results were obtained by multiplying the appropriate emissions factors (according to sectors and fuel types) by the appropriate Kazakhstan energy data. It was consumed 1,253 PJ of coal, 256 PJ of residual fuel oil, and 287 PJ of gas (see Standard Data Table 1, Sheet 2 of Appendix 3). The emissions factors used were: 0.1g N₂O/GJ for gas use, 0.6g N₂O/GJ for residual fuel oil use and 1.4g N₂O/GJ for coal use in all sectors. Besides, the N₂O emissions from biomass burned in ovens, cook stoves and small boilers in the residential sector were also calculated according to IPCC. The fuelwood consumption accounted for 151 thousand tonnes dry matter, and agricultural wastes (straw and guzapaya) consumption accounted for 2,077 thousand tonnes dry matter (see Worksheet 1-3, Sheet 1-1 of Appendix 2).

Emissions estimates for oxides of nitrogen and carbon monoxide were based directly on available Kazakhstan emissions data (*State Statistical Committee*, 1991).

1.1 Thermal Power Plants and Large Boilers

Thermal power plants and large district boilers were sources of CO₂, CO, NO_x and N₂O emissions. The power generation sector in Kazakhstan included the heat and electricity production at the thermal power plants and large boilers. The special feature of fuel

balance of thermal power plants and large boilers in Kazakhstan was almost stable share of coal (72-75 percent), gas and fuel oil (23 percent). The coal portion in Kazakhstan energy formed 77 percent in 1987 year, whereas in former Soviet Union coal accounted for 31 percent of the whole (*Chokin et al.*, 1990).

There were ten regional energy departments or power-grids in Kazakhstan such as Almatyenergo, Altaienergo, Atyrauenenergo, Zapkazenergo, Karagandaenergo, Kustanaenergo, Pavlodarenergo, Tselinenergo, Ekibastuzenergo and Yuzhkazenergo. Some of them embraced an area of several regions. The most powerful thermal power plants were in Ekibastuzenergo, Yuzhkazenergo, Karagandaenergo and Almatyenergo. In total we took into account 46 thermal power plants and large boilers under the jurisdiction of the Ministry of Energy. The emissions from industrial and small municipal boilers are considered in another part of the work.

Information about fuel consumption of all fuels for 1990 was the basis for calculation of GHGs from thermal power plants and large boilers. To estimate the data representative's values have been taken for five years from 1988 to 1992. Their analysis confirmed that the values of 1990 were quite typical for this file. The total consumption of all fuels and some their characteristics for this sector for 1990 are contained in Appendix 1 and in Table 1.1.

Table 1.1

Fuel Consumption by Enterprises within the Jurisdiction of the Ministry of Energy of Kazakhstan for 1990

Fuel	Fuel Consumption		Net Calorific Value, kcal/kg	Carbon Content, %
	actual tonnes	standardized tonnes (by formula 2)		
Coal				
Ekibastuz	36,946,166	19,498,261	3,620-3,924	39.6
Karaganda	5,905,551	3,531,059	4,184-4,359	48.0
Kuznetsk and Concentrate	2,062,025	1,443,032	4,745-5,246	41.0
Borlinsk	2,045,559	952,647	3,260	41.6
Kyrghyz	810,747	343,061	2,962	45.4
Maikuben	288,564	160,978	3,905	39.6
Koocheke	176,089	103,767	4,125	44.0
Shubarkol	48,561	35,380	5,100	41.6
Uzbek	20,720	8,768	2,962	39.1
Tajik	12,084	5,113	2,962	44.3
Total Coal	48,316,066	26,082,066		
Residual Fuel Oil and Crude Oil	2,960,103	4,038,425	9,550-10,400	84.8
Natural Gas (Dry)	4,626,951	5,343,921	7,322-8,200	75.0
TOTAL	55,903,120	35,464,412		

CO₂ Emissions

To check and to compare the results we calculated CO₂ emissions from fossil fuel combustion at the thermal power plants and large boilers using two approaches. First of them is the approach, described above. The ACs (see formula 2) for Ekibastuz, Karaganda, Kuznetsk, Concentrate coals, petroleum products, and gas equal sum values of all NCVs (see column "standardized tonnes", Table 1.1). The quantities of CO₂ emissions according to "approach 1" in 1990 (Gg) were:

from residual fuel oil and oil	9,080
from natural gas (dry)	8,757
from all coals	75,322
Total	93,159

Thus, CO₂ emissions from fuel combustion in the power generation sector accounted for 93,159 Gg or 25.407 MMTCE.

As to second our own approach, the basic calculation procedure for coal is represented by the following equation:

$$M(\text{CO}_2) = B_{\text{tar}} \cdot (C^p / 100) \cdot F_{\infty} \cdot 3.67 \cdot 10^{-3} \quad (3)$$

where:

$M(\text{CO}_2)$, B_{tar} , F_{∞} , 3.67 are the same values from formula (1) and (2);

C^p = portion of carbon in working mass (actual tonnes) of fuels (percent);

10^{-3} = conversion factor from tonnes to Gg.

When CO₂ emissions from coal combustion were calculated by this methodology, the carbon content in the different fuels (C^p) was taken into consideration. It is conditioned by that in Kazakhstan the coal from ten fields was used. The carbon content in working mass (actual tonnes) of fuels was changed from 39-49 percent for coals to 85 percent for residual fuel oil, and a net calorific value was changed from 2,962-5,246 to 10,400 kcal/kg. From Ekibastuz and Maikuben fields 77 percent coal came. The 19 thermal power plants of Kazakhstan, Western Siberia and Ural worked using coal from this basin. The content of carbon in this fuel was 39-40 percent, a net calorific value was 3,620-3,924 kcal/kg (*Ministry of Energy of USSR, 1979 and Ministry of Energy of Kazakhstan, 1991*).

Therefore, CO₂ emissions from fuel combustion in power engineering by the second approach were total 93,574 Gg or 25.520 MMTCE.

These two alternative methods can both produce closely related estimates that are comparable within a few percent. The major difference between these methods lies in the energy data used to derive carbon emissions (actual reported consumption is used for the second approach and apparent consumption is used for the IPCC, first approach).

The results of comparison of calculation by both approaches are given in Table 1.2

When results of calculations by both approaches were compared it was apparent, that the most discrepancy between these calculations exceeded 30 percent. However, total values are differed slightly.

We have included the total CO₂ emissions from energy and transformation industries according to first approach which equal 93.159 Gg or 25.407 MMTCE to IPCC

Standard Data Table 1, Sheet 4 (IPCC/OECD, Vol. 1, 1995) in Appendix 3 of this report and in Tables GR.1 - GR.3 of the Part "General Results".

Table 1.2

Results of Comparisons of Different Calculations

Fuel	CO ₂ Mass ("Approach 1"), Gg	CO ₂ Mass ("Approach 2"), Gg	Difference in Percentage of "Approach 2"
Coal			
Ekibastuz	56,309	53,158	+5.93
Karaganda	10,197	10,299	-0.99
Kuznetsk and Concentrate	4,167	3,072	+35.64
Borlinsk	2,751	3,092	-11.03
Kyrgyz	991	1,337	-25.88
Maikuben	465	415	+12.05
Koocheke	300	288	+4.17
Shubarkol	102	73	+39.73
Uzbek	25	29	-13.79
Tajik	15	19	-21.05
Total Coal	75,322	71,782	-14.93
Residual Fuel Oil and Oil	9,080	9,120	-0.44
Natural Gas (Dry)	8,757	12,672	-30.89
TOTAL	93,159	93,574	-0.44

CO and NO_x Emissions

Data on CO and NO_x emissions since these gases are toxic, were regularly submitted by all energy enterprises at least to statistical departments in forms "2TP-air" (*State Statistical Committee*, 1991). The total emissions from all enterprises of the Ministry of Energy for 1990 were 7.0 Gg of CO and 247.3 Gg of NO_x.

These values are cited in Table GR.1 and in Standard Data Table 1, Sheet 4 of Appendix 3.

N₂O Emissions

There were no appropriate observations of the emissions of nitrous oxide (N₂O) in Kazakhstan and therefore there was no local data. That is why we used the N₂O IPCC emission factors from Table 1-18 on page 1.50 (*IPCC/OECD, Vol. 2, 1995*). The amounts of N₂O emissions from fuel burning for 1990 were:

$$4,038.425 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 0.6 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 0.071 \text{ Gg (from fuel oil);}$$

$$26,082.066 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 1.4 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 1.071 \text{ Gg (from coal);}$$

$$5,343.921 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 0.1 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 0.016 \text{ Gg (from gas);}$$

The total N₂O emissions accounted for 1.158 Gg or 0.101 MMTCE. These values are included to Tables GR.1 - GR.3 and in Standard Data Table 1, Sheet 4 of Appendix 3.

1.2 Hydrocarbon Fuel Extraction, Processing and Transportation

CO₂ Emissions

Eleven enterprises on the whole were engaged in extraction and transportation of oil and gas and in oil processing in Kazakhstan. Pavlodar, Shimkent and Atyrau oil refineries were the largest fuel consumers at this sector. Crude petroleum refining at them in 1990 was 7,391; 5,937; and 4,526 thousand of standardized tonnes respectively (*State Statistical Committee*, 1991). According to Holding Company "Munaigas" data (*Ministry of Energy of Kazakhstan*, 1991) an average of 3 percent of total fuel consumption was used for operating of this plants facility, of which 1.6 percent was fuel oil and 1.4 percent was oil-gas or gas (a small portion of this was burned in the torches). In units of conventional fuel it accounted for 285.7 thousand standardized tonnes for fuel oil and 250.0 thousand standardized tonnes for gas. Converting energy of this fuel in GJ and using the IPCC emission factors for all fuels from Table 1-2 on page 1.6 (*IPCC/OECD*, Vol. 2, 1995) we determined that carbon emissions from fuel burning were:

$$285.7 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 21.1 \text{ kg C/GJ} \cdot 10^{-6} = 178.8 \text{ Gg C (fuel oil);}$$

$$250.0 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 15.3 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 112.2 \text{ Gg C (gas).}$$

Therefore CO₂ emissions equaled:

$$176.8 \text{ Gg} \cdot 0.990 \cdot 3.67 = 642.4 \text{ Gg CO}_2 \text{ from fuel oil combustion;}$$

$$112.2 \text{ Gg} \cdot 0.995 \cdot 3.67 = 409.7 \text{ Gg CO}_2 \text{ from gas combustion.}$$

In these calculations 0.99 and 0.995 were the portion of carbon oxidized for fuel oil and for gas respectively from page 1.33 (*IPCC/OECD*, Vol. 3, 1995), 3.67 is CO₂ and C molecular weights ratio (relative units).

Thus, the total CO₂ emissions from this sector were 1,052 Gg or 0.287 MMTCE. These values are listed in Tables GR.1 - GR.3 and in Standard Data Table 1, Sheet 5 of Appendix 3.

CO and NO_x Emissions

The main enterprises and their carbon oxide and nitrogen oxides emissions are listed in the Table 1.3. These data were provided by Holding Company "Munaigas" and included in Statistical Account (*State Statistical Committee*, 1991).

Thus, CO emissions were 31.6 Gg and NO_x emissions were 5.2 Gg from this sector. These values are included to Table GR.1 and in Standard Data Table 1, Sheet 5 of Appendix 3.

N₂O Emissions

N₂O emissions were calculated by using IPCC N₂O emission factors and data on fuel consumption mentioned above.

$$285.7 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 0.6 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 5.028 \cdot 10^{-3} \text{ Gg (fuel oil combustion);}$$

$$250.0 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 0.1 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 7.333 \cdot 10^{-4} \text{ Gg (gas combustion);}$$

The total emissions from this sector were $5.761 \cdot 10^{-3}$ Gg or 0.0005 MMTCE of N_2O . These values are included to Tables GR.1 - GR.3 and in Standard Data Table 1, Sheet 5 of Appendix 3.

GHG emissions from sectors 1.1 - 1.2 are summarized in Standard Data Table 1, Sheet 3 and in Table 7A of Appendix 3.

Table 1.3

CO and NO_x Emissions by Refinery Enterprises

№	Name of Enterprise	Emissions, tonnes	
		CO	NO _x
1	Mangistaumunaigas	5,773	1,318
2	Aktubinskpetroleum	9,288	1,643
3	Ambapetroleum	4,157	828
4	Karajabastermpetroleum	2,253	346
5	Southernkazpetroleum	8,535	188
6	Southernoilpipeline	629	220
7	Main Oil-pipelines of Kazakhstan	0.4	—
8	Pavlodar Oil Refinery	255	447
9	Atyrau Oil Refinery	250	98
10	Shimkent Oil Refinery	200	15
11	Kaztajpromarmatura	292	70
	Total	31,632	5,173

1.3 Ferrous and Non-Ferrous Metallurgy

CO₂ Emissions

The total fuel consumption for 1990 in this sector was 1,330.2 thousand standardized tonnes for fuel oil, 2,043.8 thousand standardized tonnes for coal, 796.1 thousand standardized tonnes for gas (*State Statistical Committee*, 1991). We calculated carbon emissions by default IPCC methodology, multiplying the emission factors recommended by IPCC and conversion coefficient, which equals 29,330 GJ/Gg.

Carbon emissions from fuel burning were equaled:

$$1,330.2 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 21.1 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 823 \text{ Gg (fuel oil);}$$

$$2,043.8 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 27.1 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 1,625 \text{ Gg (coal);}$$

$$796.1 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 15.3 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 357 \text{ Gg (gas).}$$

Thus, the total C emissions were 2,805 Gg.

Taking into account the portions of carbon oxidized equal 0.95 for coal, 0.99 for fuel oil, and 0.995 for gas, we calculated CO₂ emissions in this sector:

$$823.2 \text{ Gg} \cdot 0.99 \cdot 3.67 = 2,990.9 \text{ Gg from fuel oil combustion;}$$

$$1,624.5 \text{ Gg} \cdot 0.95 \cdot 3.67 = 5,663.8 \text{ Gg from coal combustion;}$$

$$357.2 \text{ Gg} \cdot 0.995 \cdot 3.67 = 1,304.4 \text{ Gg from gas combustion;}$$

So, the total CO₂ emissions from this sector were 9,959 Gg or 2.716 MMTCE. These values are listed in Table GR.1 - GR.3.

CO and NO_x Emissions

We got data on all fuel consumption and CO, NO_x emissions (Table 1.4) from 21 large enterprises (*State Statistical Committee, 1991*) for 1990. Total values of emissions equaled 535.9 Gg of CO and 21.7 Gg of NO_x. These values are cited in Table GR.1.

N₂O Emissions

The calculation of N₂O emissions from ferrous and non-ferrous metallurgy was similar to mentioned in previous sectors (1.1-1.2). We used data from Tables 1.4 and IPCC default emission factors.

Table 1.4

Fuel Consumption and Data on CO and NO_x Emissions by Enterprises of Ferrous and Non-ferrous Metallurgy

Enterprise *	Fuel Consumption, standardized tonnes			Emissions, tonnes	
	Fuel Oil	Coal	Gas	CO	NO _x
Ermak FAP	18,919	64,600	87,011	5,822	365
Eastern Kazakhstan ICCP	1,290	27,560	—	510	293
Zirianovsk ILZP	5,154	111,250	—	2,199	53
Irtish IPP	—	55,037	—	1,079	551
Leninogorsk IPP	15,593	165,307	—	3,111	163
Ust-Kamenogorsk ILZP	40,912	246,143	—	20,863	64
Ust-Kamenogorsk ITMP	—	7,626	—	1,094	22
Jerkent IMCP	9,791	19,562	—	729	397
Achisay IPP	10,588	124,930	—	2,252	295
Shimkent ILZP	—	74,422	57,184	20,939	70
Tekeli ILZP	—	16,160	—	520	58
Sokolovsko-Sarbaiski IMCP	129,281	24,849	394,473	2,407	2,080
Aktubinsk FAP	—	—	56,450	5,421	182
Aktubinsk CCP	—	—	109,000	11,000	227
Karaganda Metallurgical Plant	925,832	626,588	92,000	448,902	15,311
PA "Sary-Arka"	—	55,720	—	1,562	232
Karagaily IMCP	16,986	17,600	—	451	15
Balkhash IMMP	80,292	110,055	—	2,450	367
Akchatau IMCP	14,090	16,750	—	771	259
Djezkazgan IMMP	61,490	240,100	—	2,778	420
PA "Kazvolfram"	—	39,572	—	1,049	305
Total in Kazakhstan	1,330,218	2,043,831	796,118	535,909	21,729

*** Notes:**

(FAP)	Ferro-Alloying Plant
(ICCP)	Integrated Copper and Chemical Plant
(ILZP)	Integrated Lead and Zinc Plant
(IPP)	Integrated Polymetall Plant
(ITMP)	Integrated Titanium and Magnesium Plant
(IMCP)	Integrated Mining and Concentrating Plant
(CCP)	Chromium Compounds Plant
(PA)	Production Association
(IMMP)	Integrated Mining and Metallurgical Plant

So, we calculated N₂O emissions from fuel combustion as follows:

$$2,043.8 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 1.4 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 8.392 \cdot 10^{-2} \text{ Gg (coal);}$$

$$1,330.2 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 0.6 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 2.341 \cdot 10^{-2} \text{ Gg (fuel oil);}$$

$$796.1 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 0.1 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 2.335 \cdot 10^{-3} \text{ Gg (gas).}$$

Thus, the total N₂O emissions from this sector were $1.097 \cdot 10^{-1}$ Gg or 0.01 MMTCE. These values are included to Tables GR.1 - GR.3.

1.4 Chemical Industry

CO₂ Emissions

There were six largest chemical enterprises in Kazakhstan that belonged to Joint-stock Holding Company "Karatau" and Pavlodar Production Association "Khimprom". So, fuel consumption was 216.1 thousand standardized tonnes of fuel oil, 16.4 thousand standardized tonnes of coal, 803.5 thousand standardized tonnes of gas (*State Statistical Committee*, 1991).

The calculation of carbon emissions from ferrous and non-ferrous metallurgy is similar to mentioned in the previous sectors (1.1-1.3). So, released carbon was

from fuel oil combustion:

$$216.1 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 21.1 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 133.7 \text{ Gg C;}$$

from coal combustion:

$$16.4 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 27.1 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 13.0 \text{ Gg C;}$$

from gas combustion:

$$803.5 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 15.3 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 360.6 \text{ Gg C.}$$

The total carbon emissions were 507.3 Gg.

Thus, the CO₂ emissions from this sector accounted for:

$$133.7 \text{ Gg} \cdot 0.99 \cdot 3.67 = 485.8 \text{ Gg from fuel oil combustion;}$$

$$13.0 \text{ Gg} \cdot 0.95 \cdot 3.67 = 45.3 \text{ Gg from coal combustion;}$$

$$360.6 \text{ Gg} \cdot 0.995 \cdot 3.67 = 1,316.8 \text{ Gg from gas combustion.}$$

Thus the total CO₂ emissions in this sector were 1,848 Gg or 0.504 MMTCE. These values are listed in Table GR.1 - GR.3.

CO and NO_x Emissions

The data about all fuel consumption and toxic gases emissions from the enterprises of chemical industry for 1990 are presented in the table 1.5. These data were taken directly from the statistical documents "6-TP" and "2 TP-air" (*State Statistical Committee, 1991*).

Table 1.5

Fuel Consumption (standardized tonnes) and Toxic Gas Emissions for 1990 by Enterprises of Chemical Industry

№	Enterprise	Fuel Consumption, tonnes			Emissions, tonnes	
		Fuel Oil	Coal	Gas	CO	NO _x
1	Phosphorus	5,259	—	276,640	845	423
2	Nodfos	671	—	135,551	250	130
3	Khimprom	275	—	164,570	574	153
4	Superfosfatny Zavod	2,337	—	176,656	130	25
5	Karatau	202,293	15,899	—	1,486	497
6	Sary-Tas	2,937	532	50,080	120	278
7	Khimprom	2,294	—	—	30	7
	Total	216,066	16,431	803,497	3,435	1,513

So, the total NO_x emissions from this sector amounted for 1.5 Gg and the total CO emissions equaled 3.4 Gg. These values are included to Table GR.1.

N₂O Emissions

The calculation of N₂O emissions from ferrous and non-ferrous metallurgy was similar to mentioned in previous sectors. We used data from Tables 1.7 and IPCC default emission factors.

So, we got following values of N₂O emissions from fuel burning:

$$216.1 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 0.6 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 3.803 \cdot 10^{-3} \text{ Gg (fuel oil);}$$

$$16.4 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 1.4 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 6.734 \cdot 10^{-4} \text{ Gg (coal);}$$

$$803.5 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 0.1 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 2.357 \cdot 10^{-3} \text{ Gg (gas).}$$

The total N₂O emissions from this sector were $6.797 \cdot 10^{-3}$ Gg or 0.0006 MMTCE. These values are included to Tables GR.1 - GR.3.

1.5 Construction Materials Production

CO₂ Emissions

The enterprises producing cement and bricks consumed a large amount of fuel. Fuel consumption in this sector accounted for 1,115 standardized tonnes of coal, 655 standardized tonnes of gas, 565 standardized tonnes of fuel oil, and the total fuel consumption equaled 2,335 thousand standardized tonnes in 1990 (*State Statistical*

Committee, 1991). It should be noted that 211,000 standardized tonnes of coal were used for brickyard production and 903,800 standardized tonnes were used for other construction materials production.

Before brick firing the small coal fractions with diameters fewer than 2 millimeters are added to the brick charge. The rest coal is burned in stoves by layer manner, i.e., without preliminary grinding down. So non-oxidized part of coal accounts for 20 percent for brickyard production. 95 percent of carbon is oxidized to CO₂ and 5 percent to CO. Thus, C emissions from brickyard production accounted for:

$$211.2 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 0.80 \cdot 27.1 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 134.3 \text{ Gg};$$

CO emissions accounted for:

$$134.3 \text{ Gg} \cdot 0.05 \cdot 2.33 = 15.6 \text{ Gg};$$

CO₂ emissions accounted for:

$$134.3 \text{ Gg} \cdot 0.95 \cdot 3.67 = 468.2 \text{ Gg};$$

where 2.33 is CO and C molecular weight ratio. It should be noted that we included in the coal sum in Worksheet 1-1, Sheet 1-1 of Appendix 2 the following value:

$$211.2 \cdot 0.8 = 169.0 \text{ Gg}.$$

It was necessary because of lack of oxidized part of carbon such as 0.8 in Worksheet 1-1.

Carbon emissions from construction materials production, excluding brickyard production, accounted for:

$$903.8 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 27.1 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 718.4 \text{ Gg (coal combustion);}$$

$$655 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 15.3 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 293.9 \text{ Gg (gas combustion);}$$

$$565 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 21.1 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 349.7 \text{ Gg (fuel oil combustion).}$$

CO₂ emissions accounted for:

$$718.4 \text{ Gg} \cdot 0.95 \cdot 3.67 = 2,504.7 \text{ Gg from coal combustion;}$$

$$293.9 \text{ Gg} \cdot 0.995 \cdot 3.67 = 1,073.2 \text{ Gg from gas combustion;}$$

$$349.7 \text{ Gg} \cdot 0.99 \cdot 3.67 = 1,270.6 \text{ Gg from fuel oil combustion.}$$

Thus, CO₂ emissions accounted for 4,849 Gg, but taking into account CO₂ emissions from brickyard production, total CO₂ emissions equaled 5,317 Gg or 1.450 MMTCE. These values are listed in Tables GR.1 - GR.3.

CO and NO_x Emissions

The data about emissions of toxic gases by the enterprises of construction materials production for 1990 are presented in the table 1.6. These data were taken directly from the statistical documents "2 TP-air" (State Statistical Committee, 1991).

So, the total NO_x emissions equaled 15.7 Gg and the total CO emissions equaled 17.5 Gg. These values are included to Table GR.1.

N₂O Emissions

According to method of calculation mentioned in previous sectors, N₂O emissions from fuel combustion accounted for:

$$565 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 0.6 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 9.943 \cdot 10^{-3} \text{ Gg (fuel oil);}$$

$1,115 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 1.4 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 4.578 \cdot 10^{-2} \text{ Gg (coal);}$

$655 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 0.1 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 1.921 \cdot 10^{-3} \text{ Gg (gas).}$

The total N_2O emissions were $5.764 \cdot 10^{-2} \text{ Gg}$ or 0.005 MMTCE. These values are included to Tables GR.1 - GR.3.

Table 1.6

Product Output and Toxic Gas Emissions for 1990 by Enterprises of Construction Materials Production

№	Enterprise	Output Name	Volume of Output, 10 ³ tonnes	Emissions, tonnes	
				CO	NO _x
1	Karagandacement	Cement	2,303	5,223	600
2	Karaganda Asbestos-Cement Plant	Slate	249 million conventional (con.) tiles		
		Pipes	3,046 km con. pipes	516	179
3	Shimkentcement	Cement	1,969	33	3,025
4	Sas-Tube Cement Plant	Cement	416		
		Lime	197	15	1,317
5	Shimkent Asbestos-Cement	Slate	243.2 mln con. tiles		
		Pipes	4,500 km con. pipes		
		Brick	173,000 m ³		
		Glass Wool	120,600 m ³	204	35
6	Ust-Kamenogorsk Cement Plant	Cement	1,642	594	1,309
7	Semipalatinsk Cement Plant	Cement	1,248	480	1,199
8	Semipalatinsk Asbestoscement Plant			tracks	
9	Kustanay Asbestos Djetigara	Asbestos	500	1,685	200
10	Djambul Gypsum Plant	Gypsum	26.2	8,756	7,867
	Total (tonnes)		8,301,200 tonnes of cement products	17,506	15,731
	Total (Gg)			17.5	15.7

1.6 Mechanical Engineering

CO₂ Emissions

This branch of economy is not developed well enough in Kazakhstan. Vehicles, trolley-buses, locomotives or railroad cars, airplanes, ships, steam shovels, refrigerators, boilers and turbines, electric motors and generators, many types of machines and so on are not produced in Kazakhstan. We could not receive the whole information about toxic gas emissions and fuel consumption from some of the enterprises in this sector because

these enterprises belong to military-industry complex. We were able to get the necessary information about six enterprises only. Pavlodar tractor plant and Almaty heavy-engineering plant (AZTM) were the largest enterprises in this branch.

Fuel consumption by enterprises of mechanical engineering is listed in Table 1.5. Carbon emissions were calculated using IPCC carbon emissions factors from Table 1.3 (IPCC/OECD, Vol. 2, 1995). Thus, carbon emissions from fuel combustion accounted for:

$$58.94 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 21.1 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 36.5 \text{ Gg (fuel oil);}$$

$$10.80 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 15.3 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 4.8 \text{ Gg (gas);}$$

$$2.32 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 27.1 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 1.8 \text{ Gg (coal);}$$

$$42.86 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 29.5 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 37.1 \text{ Gg (coke).}$$

So, the total carbon emissions equaled 80.2 Gg.

The CO₂ emissions accounted for:

$$(1.8 \text{ Gg} + 37.1 \text{ Gg}) \cdot 0.95 \cdot 3.67 = 135.6 \text{ Gg (coal and coke);}$$

$$4.8 \text{ Gg} \cdot 0.995 \cdot 3.67 = 17.5 \text{ Gg (gas);}$$

$$36.5 \text{ Gg} \cdot 0.99 \cdot 3.67 = 132.6 \text{ Gg (fuel oil).}$$

The total CO₂ emissions accounted for 286 Gg or 0.078 MMTCE. These values are listed in Tables GR.1 - GR.3.

CO and NO_x Emissions

Emissions of toxic gases from mechanical engineering enterprises are presented in Table 1.7 according to State statistical data (State Statistical Committee, 1991).

Table 1.7

Fuel Consumption (standardized tonnes) and Toxic Gas Emissions by Enterprises of Mechanical Engineering for 1990

№	Enterprise	Annual Fuel Consumption				Emissions, tonnes	
		Fuel Oil	Gas	Coal	Coke	CO	NO _x
1	Pavlodartractor	39,878	10,072	—	18,132	8,683	586
2	Tselinselmash	1,885	732	2,324	4,565	389	6
3	Porshen	—	—	—	6,669	423	11
4	Aktubselmash	904	—	—	—	180	16
5	AZTM	7,209	—	—	9,175	2,876	17
6	EVRZ	9,062	—	—	4,314	2,910	2
	Total	58,938	10,804	2,324	42,855	15,461	638

Thus, the total NO_x emissions equaled 0.6 Gg and the total CO emissions equaled 15.5 Gg. These values are included to Table GR.1.

N₂O Emissions

The N₂O emissions accounted for:

$$58.94 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 0.6 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 1.037 \cdot 10^{-3} \text{ Gg (fuel oil combustion);}$$

$2.32 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 1.4 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 9.526 \cdot 10^{-5} \text{ Gg}$ (coal combustion);

$42.86 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 1.4 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 1.760 \cdot 10^{-3} \text{ Gg}$ (coke combustion);

$10.80 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 0.1 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 3.168 \cdot 10^{-5} \text{ Gg}$ (gas combustion).

The total N_2O emissions were $2.924 \cdot 10^{-3} \text{ Gg}$ or 0.0003 MMTCE. These values are included to Tables GR.1 - GR.3.

1.7 Light and Food Industry

CO₂ Emissions

Many enterprises such as bakeries, meat-packing factories, butter factories, confectioneries, canneries, breweries, textile factories, clothing and shoe factories, wood-processing plants, glassworks, furniture factories, etc., were included in this sector. These enterprises were considered in the whole. In accordance with data of the State Statistical Committee (*State Statistical Committee*, 1991) the fuel consumption accounted for 835,000 standardized tonnes of fuel oil, 4,320,900 standardized tonnes of coal, 618,500 standardized tonnes of gas in 1990.

Carbon emissions from fuel combustion equaled:

$835.0 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 21.1 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 516.8 \text{ Gg}$ (fuel oil);

$618.5 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 15.3 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 277.6 \text{ Gg}$ (gas);

$4,320.9 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 27.1 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 3,434.4 \text{ Gg}$ (coal).

The total carbon emissions accounted for 4,228.8 Gg.

CO₂ emissions from fuel combustion equaled:

$3,434.4 \text{ Gg} \cdot 0.95 \cdot 3.67 = 11,974.0 \text{ Gg}$ (coal);

$277.6 \text{ Gg} \cdot 0.995 \cdot 3.67 = 1,013.7 \text{ Gg}$ (gas);

$516.8 \text{ Gg} \cdot 0.99 \cdot 3.67 = 1,877.7 \text{ Gg}$ (fuel oil).

So, the total CO₂ emissions accounted for 14,865 Gg or 4.054 MMTCE. These values are listed in Tables GR.1 - GR.3.

The total CO₂ emissions from industry (sections 1.3 - 1.7), which equaled 32,275 Gg or 8.802 MMTCE are cited in table GR.3 and in Standard Data Table 1, Sheet 7 and in Table 7A of Appendix 3.

CO and NO_x Emissions

According to the State Statistical Committee data (*State Statistical Committee*, 1991) NO_x and CO emissions accounted for 3.1 and 35.0 Gg respectively. These values are included to Table GR.1.

The total NO_x and CO emissions from industry (sections 1.3 - 1.7) which equaled 42.6 and 622.9 Gg are cited in Standard Data Table 1, Sheet 7 and in Table 7A of Appendix 3.

N₂O Emissions

The N₂O emissions from fuel combustion equaled:

$835.0 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 0.6 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 1.469 \cdot 10^{-2} \text{ Gg}$ (fuel oil);

$4,320.9 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 1.4 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 1.774 \cdot 10^{-1} \text{ Gg (coal)};$

$618.5 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 0.1 \text{ g/GJ} \cdot 10^{-9} \text{ Gg/g} = 1.814 \cdot 10^{-3} \text{ Gg (gas)}.$

The total N_2O emissions accounted for $1.939 \cdot 10^{-1} \text{ Gg}$ or 0.017 MMTCE. These values are included to Tables GR.1 - GR.3.

The total N_2O emissions from industry (sections 1.3 - 1.7) which equaled 0.372 Gg or 0.032 MMTCE are cited in Table GR.3 and in Standard Data Table 1, Sheet 7 and in Table 7A of Appendix 3.

1.8 Internal Combustion Engines

CO₂ Emissions

This sector includes emissions from the internal combustion engines (ICE) on automobile, railroad, air and water transport, and from ICEs used in agriculture and construction as well. The data from State Statistical Committee (*State Statistical Committee*, 1991) about consumption of the petroleum products in 1990 are listed in Table 1.10.

Table 1.8

Total Petroleum Products Consumption in 1990

Fuel	Consumption	
	actual tonnes	standardized tonnes
Jet Kerosene	35,377	54,036
Gasoline	3,780,981	5,768,799
Other Kerosene	467,442	710,664
Diesel Oil	6,054,623	8,944,657

The total fuel consumption amounted for 4,283,800 tonnes of light motor fuel and 6,054,623 tonnes of diesel fuel. Averaged carbon portion accounted for 83 percent in light motor fuels and 85 percent in diesel fuel according to data of the chemical laboratories of Pavlodar and Shimkent oil refineries (*Monakrovich*, 1984). Therefore, carbon content amounted for 3,555,554 tonnes for light fuels and 5,146,430 tonnes for diesel fuel. The CO_2 emissions were calculated using second approach described in section 1.1 (see formula 3).

According to this calculation CO_2 emissions from this sector accounted for 31,588.20 Gg (12,906.66 Gg CO_2 from light motor fuel and 18,681.54 Gg CO_2 from diesel fuel). We also calculated CO_2 emissions using IPCC emission factors by the first approach (see formulas 1 and 2).

According to this approach carbon emissions from fuel combustion equaled:

$54.036 \text{ Gg} \cdot 29.33 \text{ TJ/Gg} \cdot 19.5 \text{ t C/TJ} \cdot 10^{-3} \text{ Gg/t} = 31 \text{ Gg C (jet kerosene)};$

$5,768.799 \text{ Gg} \cdot 29.33 \text{ TJ/Gg} \cdot 18.9 \text{ t C/TJ} \cdot 10^{-3} \text{ Gg/t} = 3,198 \text{ Gg C (gasoline)};$

$710.664 \text{ Gg} \cdot 29.33 \text{ TJ/Gg} \cdot 19.6 \text{ t C/TJ} \cdot 10^{-3} \text{ Gg/t} = 409 \text{ Gg C (other kerosene)};$

$8,944.657 \text{ Gg} \cdot 29.33 \text{ TJ/Gg} \cdot 20.2 \text{ t C/TJ} \cdot 10^{-3} \text{ Gg/t} = 5,299 \text{ Gg C (diesel oil)}.$

Then we calculated respective CO_2 emissions:

$$\begin{aligned}
31 \text{ Gg} \cdot 0.99 \cdot 3.67 &= 113 \text{ Gg (jet kerosene);} \\
3,198 \text{ Gg} \cdot 0.99(3.67 &= 11,619 \text{ Gg (gasoline);} \\
409 \text{ Gg} \cdot 0.99 \cdot 3.67 &= 1,486 \text{ Gg (other kerosene);} \\
5,299 \text{ Gg} \cdot 0.99 \cdot 3.67 &= 19,253 \text{ Gg (diesel oil).}
\end{aligned}$$

So, the total CO₂ emissions accounted for 32,471 Gg or 8,856 MMTCE. These values are given in Tables GR.1 - GR.3 and in Standard Data Table 1, Sheet 8 and in Table 7A of Appendix 3 as well. The difference between value of first approach and value of second approach equaled +2.8 percent of last value of CO₂ emissions.

CO and NO_x Emissions

Toxic gas emissions (in kilograms) from one tonne of fuel burning in this sector are listed below according to data of Kazakh Scientific - Research Institute of Motor Transport (*Monakrovich*, 1984):

Fuel	CO	NO _x
Gasoline, Kerosene	400	40
Diesel Fuel	50	50

Taking into account the amount of fuel consumed in 1990 (Table 1.8), we got the following amount of the toxic gas emissions:

474.08 Gg NO_x (171.35 Gg from light motor fuel and 302.73 Gg from diesel fuel);

2,016.25 Gg CO (1,713.52 Gg from light motor fuel and 302.73 Gg from diesel fuel).

The total values are listed in Table GR.1 and in Standard Data Table 1, Sheet 8 and in Table 7A of Appendix 3.

CH₄, NMVOC and N₂O Emissions

To calculate CH₄, NMVOC and N₂O emissions we used corresponding IPCC emissions factors. We used mean value of listed in Part 1 on pages 1.65-1.68 (*IPCC/OECD, Vol. 3, 1995*) emission factors for each gas. So, we used the following values of emissions factors: 1.1 g CH₄ per 1 kg of light fuel; 53.79 g NMVOC per 1 kg of light fuel, and 0.03 g N₂O per 1 kg for light fuel from Tables 1-21 and 1-22, "Uncontrolled" (*IPCC/OECD, Vol. 3, 1995*). These factors for diesel fuel equaled 0.14 g CH₄ per 1 kg; 4.94 g NMVOC per 1 kg; 0.08 g N₂O per 1 kg from Tables 1-23, 1-24 and 1-25, "Uncontrolled" (*IPCC/OECD, Vol. 3, 1995*).

The results of calculations of CH₄, NMVOC and N₂O emissions from ICEs are listed in Table 1.9.

Table 1.9

Total GHG Emissions from ICEs for 1990, Gg

Fuel Type	CH ₄	N ₂ O	NMVOC
Light Motor	4.71	0.13	230.43
Diesel	0.85	0.48	29.91
Total	5.56	0.61	260.34

These total values are listed in Tables GR.1 - GR.3 and in Standard Data Table 1, Sheet 8 and in Table 7A of Appendix 3.

1.9 Residential Boilers and Stoves

A significant part of urban population and almost all rural population in Kazakhstan use autonomous heat sources for houses heating and preparation of hot water. Other part of urban population use hot water from centralized heat-supply systems where heat is produced by boilers. These boilers are not under the jurisdiction of the Ministry of Energy that is why they were not considered in part 1.1. Almost all population use gas stoves or stoves consuming other fuels for cooking. Some people use electric stoves for the same needs in Kazakhstan.

State Statistical Committee data (*State Statistical Committee*, 1991) of fuel consumption in residential sector in 1990 are listed in Table 1.10.

Table 1.10

Some Fuels Consumption in Residential Sector in 1990

Fuel	thousand standardized tonnes	thousand actual tonnes
Coal	9,734	15,594
Condensed Gas	72	48
Natural Gas	1,319	1,157 mln m ³
Fuel Oil	572	413
Fuel for Residential Stoves	105	74
Liquefied Gas	143	91
Diesel	55	40

CO₂ Emissions

The procedure of calculation of CO₂ emissions from residential sector was similar to mentioned in previous sectors (1.1-1.8). Data from Tables 1.12 and IPCC default emission factors from Table 1-3 (*IPCC/OECD*, Vol. 2, 1995) were used.

Carbon emissions from fuel combustion were amounted for:

$$\begin{aligned}
 &9,734 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 27.1 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 7,737.002 \text{ Gg (coal);} \\
 &72 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 17.2 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 36.322 \text{ Gg (condensed gas);} \\
 &1,319 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 15.3 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 591.900 \text{ Gg (natural gas);} \\
 &677 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 21.1 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 418.970 \text{ Gg} \\
 &\hspace{15em} \text{(fuel oil and stove fuel);} \\
 &143 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 17.2 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 72.140 \text{ Gg (liquefied gas);} \\
 &55 \text{ Gg} \cdot 29,330 \text{ GJ/Gg} \cdot 20.2 \text{ kg C/GJ} \cdot 10^{-6} \text{ Gg/kg} = 32.586 \text{ Gg (diesel fuel).}
 \end{aligned}$$

So, total CO₂ emissions from fuel combustion in residential sector were equal:

$$\begin{aligned}
 &(7,737 \text{ Gg} \cdot 0.95 + (36 \text{ Gg} + 72 \text{ Gg} + 419 \text{ Gg} + 33 \text{ Gg}) \cdot 0.99 + \\
 &+ 592 \text{ Gg} \cdot 0.995) \cdot 3.67 = 31,171 \text{ Gg CO}_2 \text{ or } 8,501 \text{ MMTCE.}
 \end{aligned}$$

It should be noted that we used following values of carbon oxidized part: 0.95 for coal, 0.995 for natural gas, 0.99 for condensed and liquefied gas (LPG according IPCC), fuel oil, diesel fuel, fuel for residential stoves (fuel oil according to IPCC).

These values are listed in Tables GR.1 - GR.3 and in Standard Data Table 1, Sheets 10 and 12 and in Table 7A of Appendix 3 as well.

The rural population burnt 151 thousand tonnes of firewood, 77 thousand tonnes of guzapay (cotton stems and bolls) and about 2 millions tonnes of straw (*State Statistical Committee, 1991*).

The total amount of carbon released for each biomass fuel type was calculated by IPCC Methodology (*IPCC/OECD, Vol. 2, 1995*). The procedure of calculation was presented in Worksheet 1-3, Sheet 1 of Appendix 2 and the results of calculations were cited in Standard Data Table 1, Sheet 16 of Appendix 3. Carbon emissions from biomass fuel taking into account carbon oxidized part (see Worksheet 1-3, Sheet 1 of Appendix 2) accounted for 63 Gg and 804 Gg for fuel wood and agricultural wastes (straw and guzapaya) respectively. So, the total CO₂ emissions from biomass fuel combustion equaled:

$$867 \text{ Gg} \cdot 3.67 = 3,182 \text{ Gg CO}_2.$$

This value has not been added to the national total, but it is listed in Table GR.3 and in Worksheet 1-1, Sheet 3 of Appendix 2.

Non-CO₂ GHGs Emissions

Table 1.11

GHG Emissions from Residential Sector

Fuel	Fuel Consumption (thousand tonnes)	NCV* (TJ/Gg)	Energy Input (TJ)	Emission Factors from Table 1-10 (kg/TJ energy input)			Emissions (Gg)		
				CO	CH ₄	NO _x	CO	CH ₄	NO _x
Coal	15,594	22.0	343,068	484	—	232	166.0	—	79.6
Fuel Oil and Fuel for Residential Stoves	487	40.9	19,918	13	5	51	0.3	0.1	1.0
Diesel	40	42.9	1,716	13	5	51	0.02	0.009	0.09
Liquefied Gas	91	47.3**	4,304	10	1	47	0.04	0.004	0.2
Natural Gas	926	46.0	42,596	10	1	47	0.4	0.04	2.0
Condensed Gas	48	48.6	2,333	10	1	47	0.02	0.002	0.1
Total							166.8	0.2	83.0

Notes:

* Data from Table 1-16

** Data from Table 1-3

Emissions of non-CO₂ GHGs were calculated according to IPCC Methodology. Table 1-3 on page 1.6 (*IPCC/OECD, Vol. 2, 1995*) and Table 1-10 on page 1.40 and Table 1-16 on page 1.46 (*IPCC/OECD, Vol. 3, 1995*) were used as a basis for the calculations, which are listed in Table 1.11.

The emissions from biomass burned in ovens, cook stoves and small boilers in the residential sector are listed in Table 1.12.

Table 1.12

Emissions from Traditional Biomass Fuel Burned for Energy

Fuel	Biomass Consumed (thousand tonnes dry matter)	CH ₄ (Gg)	CO (Gg)	N ₂ O (Gg)	NO _x (Gg)
Wood (for Direct Use)	151	1.0	8.8	0.006	25.0
Agricultural Wastes (Straw and Guzapay)	2,077	5.4	112.6	0.132	319.6
Total		6.4	121.4	0.138	344.6

So, total non-CO₂ GHG emissions from the residential sector equaled:

$$166.8 \text{ Gg} + 121.4 \text{ Gg} = 288.2 \text{ Gg CO}_2;$$

$$0.2 \text{ Gg} + 6.4 \text{ Gg} = 6.6 \text{ Gg CH}_4;$$

$$83.0 \text{ Gg} + 344.6 \text{ Gg} = 427.6 \text{ Gg NO}_x; \text{ and}$$

$$0.138 \text{ Gg N}_2\text{O}.$$

These values are listed in Tables GR.1 - GR.3 and in Standard Data Table 1, Sheets 10 and 12 and in Table 7A of Appendix 3 as well.

The total GHG emissions from fossil fuel combustion are presented in Worksheet 1-1, Sheet 3 of Appendix 2 and in Standard Data Table 1, Sheet 2 and in Tables 7A and 7B of Appendix 3. It was emitted 190,128 Gg or 51.853 MMTCE of CO₂, 12.2 Gg or 0.082 MMTCE of CH₄, 2.284 Gg or 0.199 MMTCE of N₂O, 1,196.8 Gg of NO_x, 2,904.0 Gg CO, 260.3 Gg NMVOC from fuel combustion. It should be noted that total values of CO₂ emissions in different Tables are slightly differed (190,116 Gg and 190,128 Gg) because of averaging error in summation procedure.

As shown in Tables, emissions from coal combustion from all sectors of the economy accounted for about 65 percent of total Kazakhstan energy - related carbon dioxide emissions; petroleum products contributed 26 percent; and share of natural gas was 9 percent.

B. FUGITIVE FUEL EMISSIONS

1.10 Hydrocarbon Fuel Extraction, Processing and Transportation

According to State statistical data (*State Statistical Committee*, 1991) oil production was 25,820 thousand tonnes and natural gas production was 7,114 thousand tonnes in 1990. The refined oil accounted for 20,656 thousand tonnes. It was consumed 1,534 thousand tonnes of residential gas and 8,478 thousand tonnes of non-residential gas. The following NCVs were used for calculations of amount of oil and gas in energy units:

$$10,400 \text{ kcal/kg} = 43,576 \text{ kJ/kg} = 43,576 \text{ MJ/t for oil;}$$

$$8,200 \text{ kcal/kg} = 34,358 \text{ kJ/kg} = 34,358 \text{ MJ/t for gas.}$$

To calculate methane emissions we used mean value of IPCC emission factors reported in Table 1.53 on page 1.122 (*IPCC/OECD, Vol. 3, 1995*). To convert the amount of oil and gas expressed in tonnes to PJ we multiplied the oil or gas mass by respective NCV presented above.

Methane emissions from oil extraction:

$$(25,820,000 \text{ tonne} \cdot 43,576 \text{ MJ/tonne} \cdot 10^{-9} \text{ PJ/MJ}) \cdot 2,350 \text{ kg CH}_4/\text{PJ} = \\ = 2,643,750 \text{ kg CH}_4 = 2.6 \text{ Gg CH}_4.$$

Methane emissions from oil refining:

$$(20,656,000 \text{ tonne} \cdot 43,576 \text{ MJ/tonne} \cdot 10^{-9} \text{ PJ/MJ}) \cdot 745 \text{ kg CH}_4/\text{PJ} = \\ = 670,500 \text{ kg CH}_4 = 0.7 \text{ Gg CH}_4.$$

Methane emissions from gas extraction:

$$(7,114,000 \text{ tonne} \cdot 34,358 \text{ MJ/tonne} \cdot 10^{-9} \text{ PJ/MJ}) \cdot 227,000 \text{ kg CH}_4/\text{PJ} = \\ = 44,492,000 \text{ kg CH}_4 = 44.5 \text{ Gg CH}_4.$$

Methane emissions from non-residential gas consumption:

$$(8,478,000 \text{ tonne} \cdot 34,358 \text{ MJ/tonne} \cdot 10^{-9} \text{ PJ/MJ}) \cdot 280,000 \text{ kg CH}_4/\text{PJ} = \\ = 81,480,000 \text{ kg CH}_4 = 81.5 \text{ Gg CH}_4.$$

Methane emissions from residential gas consumption:

$$(1,534,000 \text{ tonne} \cdot 34,358 \text{ MJ/tonne} \cdot 10^{-9} \text{ PJ/MJ}) \cdot 140,000 \text{ kg CH}_4/\text{PJ} = \\ = 7,420,000 \text{ kg CH}_4 = 7.4 \text{ Gg CH}_4.$$

Methane emissions from venting and flaring from gas production:

$$(7,114,000 \text{ tonne} \cdot 34,358 \text{ MJ/tonne} \cdot 10^{-9} \text{ PJ/MJ}) \cdot 18,000 \text{ kg CH}_4/\text{PJ} = \\ = 4,392,000 \text{ kg CH}_4 = 4.4 \text{ Gg CH}_4.$$

Thus, the total fugitive emissions CH₄ from oil and gas equaled 152 Gg. Procedure of calculation and total amounts are presented in Table GR.3 and in Worksheet 1-5, Sheet 1 of Appendix 2 and in Standard Data Table 1, Sheet 1B2 of Appendix 3.

Besides the values of total fugitive CH₄ emissions reported above, the data about fugitive emissions from enterprises of oil and gas complex in Kazakhstan were available. These data were provided by State Statistical Committee (*State Statistical Committee*, 1991) and are given in Table 1.13.

Table 1.13

Fugitive CH₄ Emissions from Enterprises of Oil and Gas Complex in Kazakhstan for 1990

№	Name of Enterprise	CH₄ Emissions, tonnes
1	Mangistaumunaigas	69,000
2	Aktubinskpetroleum	3,321
3	Ambapetroleum	8,776
4	Karajanbastermptroleum	3,297
5	Southernkazpetroleum	8,809
6	Southernoilpipeline	7,098
7	Main Oil-pipelines of Kazakhstan	182
8	Pavlodar Oil Refinery	13,794
9	Atyrau Oil Refinery	13,418
10	Shimkent Oil Refinery	10,088
11	Kaztajpromarmatura	7
	Total	137,790

According to Table 1.13, the total methane emissions accounted for 137,8 Gg. The difference between value of IPCC calculations and value from Table 1.13 equaled + 10 percent of last value of CH₄ emissions.

1.11 Coal Enterprises

Coal enterprises were the largest source of methane emissions. Gas capacity of coal stratum depended upon the depth of their location and geologic age of the coal field. It increased with depth of coal location. So the more plentiful methane emissions were typical for Karaganda coal field for the lower stratum (maximum gas capacity is 211.3 m³/tonne coal at the Saransk mine) and the least methane emissions were typical for the surface mining in Ekibastuz, Borlinsk, Shobarkol. The data on coal extraction at the different coal fields in 1990 are given in Table 1.14. The fugitive CH₄ emissions from Karaganda coal basin mines (*Ministry of Energy of Kazakhstan*, 1991) are given in table 1.15.

Table 1.14

Coal Extraction at Kazakhstan Fields, million actual tonnes

Field	Years		
	1989	1990	1991
Underground Mining			
Karaganda	33.8	32.5	36.5
Surface Mining			
Ekibastuz	65.63	71.16	83.29
Maikuben	1.62	2.49	3.50
Shubarkol	1.64	3.70	4.95
Borlinsk	4.30	2.66	4.04
Koocheke	1.25	1.57	2.34
Total	74.44	81.58	98.12

Table 1.15

Gas Capacity Data of Mines in Karaganda Coal Field for 1990

№	Mine Name	Average Value of Coal Extraction per Day (tonnes)	Specific Gas Capacity (m ³ /tonne)		Annual CH ₄ Emissions with Taking into Account the Specific Gas Capacity (ths. m ³)
			A	B	
			Average	Maximum	$A \cdot B \cdot 365 \cdot 10^3$
1	Stakhanovskaya	3,448	49.48	51.95	62,272
2	Maikudukskaya	3,119	15.8	28.9	17,987
3	Karagandinskaya	43.78	15.32	25.32	245
4	Severnaya	3,025	22.1	61.4	24,401
5	Named Kostenko	10,674	29.84	54.78	116,257
6	Kirovskaya				
	Region 1	968	15.91	16.11	5,621
	Region 2	5,321	32.9	43.7	63,897
7	Named Gorbachev	6,553	39.8	51.64	95,195
8	Named 50 years OR	10,067	29.17	173.58	107,184
9	Named Kuzembaev	3,623	25.59	30.47	33,840
10	Named 60 years OR	44.27	25.4	36.2	410
11	Sokurskaya	3,071	31.58	62.3	35,398
12	Dubovskaya	1,690	20.2	34.66	12,460
13	Aktasskaya	2,180	44.8	40	35,647
14	Named 50 years USSR	4,560	21.6	41.2	35,951
15	Saranskaya	5,118	20.6	211.32	38,482
16	Toparskaya	1,700	26.5	95	16,443
17	Churubai-Nurinskaya	22.4	28.9	64.6	236
18	Abaiskaya	2,578	22.67	30.44	21,332
19	named Kalinin	4,477	26.19	39.95	42,797
20	Dolinskaya	5,100	45.84	80.07	85,331
21	Kazakhstanskaya	5,030	24.1	34.99	44,246
22	Named Lenin	5,765	16.75	27.6	35,246
23	Molodezhnaya	2,672	2.16	9.32	2,107
24	Stepnaya	1,820	8.2	12.72	5,447
25	Shakhtinskaya	3,979	6.5	16.6	9,440
26	Tentekskaya	7,680	12.3	12.3	34,479
	Total (10 ³ m ³)				982,355
	Total (Gg)				658,178

According to experts from company "Karaganda coal" we chose the high CH₄ emission factors from pages 1.94 - 1.100 (IPCC/OECD, Vol. 3, 1995). We took the following methane emission factors:

Underground (mining) -- 25 m³/1 tonne coal;

Underground (post-mining)	-- 4 m ³ /1 tonne coal;
Surface (mining)	-- 2.0 m ³ /1 tonne coal;
Surface (post-mining)	-- 0.2 m ³ /1 tonne coal.

We calculated the methane emissions from the underground coal extraction sector in 1990 as follows. Taking into account that the coal output in 1990 was $32.5 \cdot 10^6$ tonnes, methane emissions from underground mining were:

$$32.5 \cdot 10^6 \text{ tonnes} \cdot 25 \text{ m}^3/\text{tonnes} = 812.5 \cdot 10^6 \text{ m}^3,$$

methane emissions from underground post-mining were:

$$32.5 \cdot 10^6 \text{ tonnes} \cdot 4 \text{ m}^3/\text{tonnes} = 130.0 \cdot 10^6 \text{ m}^3.$$

Thus the total CH₄ emissions from underground coal extraction accounted for $942.5 \cdot 10^6$ m³. The CH₄ specific weight amounted for 0.67 (*IPCC/OECD, Vol. 2, 1995*), so the CH₄ emissions equaled 631.5 Gg. The difference between value of IPCC calculations and value from Table 1.15 equaled +10 percent of last value of CH₄ emissions.

We calculated the methane emissions from the surface coal extraction sector in 1990 as follows. Taking into account that the coal output in 1990 was $81.58 \cdot 10^6$ tonnes, methane emissions from surface mining were:

$$81.58 \cdot 10^6 \text{ tonnes} \cdot 2.0 \text{ m}^3/\text{tonnes} = 163.16 \cdot 10^6 \text{ m}^3,$$

methane emissions from surface post-mining were:

$$81.58 \cdot 10^6 \text{ tonnes} \cdot 0.2 \text{ m}^3/\text{tonnes} = 16.32 \cdot 10^6 \text{ m}^3.$$

Thus the total CH₄ emissions from underground coal extraction accounted for $179.5 \cdot 10^6$ m³. Taking into account the CH₄ specific weight the CH₄ emissions equaled 120.2 Gg.

So, the total methane emissions in this sector were:

$$631.5 \text{ Gg} + 120.2 \text{ Gg} = 751.7 \text{ Gg}.$$

The fugitive CH₄ emissions from coal mining are presented in Table GR.3 and in Worksheet 1-4, Sheet 1 of Appendix 2 and in Standard Data Table 1, Sheet 1B1 and the total fugitive CH₄ emissions are presented in Tables GR.1 - GR.3 and in Tables 7A and 7B of Appendix 3.

The summarized data about GHG emissions from energy in the whole (from fuel combustion and fugitive, Part I) are cited in Tables GR.1 - GR.3 and in Tables 7A and 7B of Appendix 3. It was emitted 190,128 Gg or 51.853 MMTCE of CO₂; 915.9 Gg or 6.120 MMTCE of CH₄; 2.284 Gg or 0.199 MMTCE of N₂O; 1,196.8 Gg of NO_x; 2,904.0 Gg CO; 260.3 Gg NMVOC from energy sector.

PART II. INDUSTRIAL PROCESSES

Emissions are often produced as a by-product of various non-energy related activities. According to IPCC Guidelines (*IPCC/OECD*, 1995) the cement, acids and spirits production is the most important industrial processes.

Spirits were not produced in Kazakhstan now. The sulfur acid was produced by some non-ferrous metallurgy plants. But the contribution of sulfur oxide (VI) or SO₃ production in CO₂ emissions was insignificant. Therefore the cement and carbide plants were the main industrial sources of CO₂ emissions in Kazakhstan .

The carbon dioxide emissions from industrial processes amounted for 4,349 Gg or 1.186 MMTCE or approximately 2 percent of total CO₂ Kazakhstan emissions. These values are cited in Tables GR.1 - GR.3 and in Tables 7A and 7B of Appendix 3.

2.1 Cement Production

Carbon dioxide emissions from cement production were estimated using IPCC default emission factors (*IPCC/OECD*, Vol. 2, 1995). Since the lime percentage in the cement produced in Kazakhstan is not more that 60-67 percent, we used CO₂ emissions factor, which equals 0.4985 tonnes CO₂ per tonne of cement produced.

The enumeration and location of the cement and asbestos enterprises in Kazakhstan and output for 1990 were shown in Table 1.6. So, taking into account that the total output of cement and cement products was 8,301,200 tonnes in 1990 (*State Statistical Committee*, 1991), the total CO₂ emissions from cement production in Kazakhstan were:

$$8,301,200 \text{ tonnes} \cdot 0.4985 \text{ tonnes CO}_2/\text{tonne} = 4,138,148 \text{ tonne or } 4,138 \text{ Gg.}$$

This value is cited in Table GR.3 and in Worksheet 2-1, Sheet 1 of Appendix 2 and in Standard Data Table 2 of Appendix 3.

2.2 Carbide Production

Calcium carbide (CaC₂) was produced by Carbide joint-stock company and its production output equaled 306,700 tonnes in 1990 (*State Statistical Committee*, 1991).

To calculate CO₂ emissions from carbide production we recommend the following method. The main technological reaction of this production is the following.



In 1990 the calcium carbide output was 306,700 tonnes. Knowing the atomic weights of elements we could write simple proportion for assessment of CO₂ emissions:

$$\frac{64.1}{44} = \frac{306,700}{X}$$

where X is CO₂ emissions as indicated above for carbide output. Solving this equation we have found X=210,500 tonnes or 210.5 Gg. This source was responsible for 5 percent only of carbon dioxide emissions in this sector, but these emissions equaled approximately CO₂ emissions from mechanical engineering in Kazakhstan. Similarly we could estimate CO emissions which equaled 134,000 tonnes or 134.0 Gg. Thus, we recommend the following values as emissions factors: 0.686 tonne CO₂ and 0.437 tonne CO per a tonne of carbide production.

The calculated values emissions from carbide production are cited in Table GR.3 and in Standard Data Table 2 of Appendix 3.

PART III. AGRICULTURE

The most significant gas emitted by agricultural activities was methane (CH₄). The Agriculture sector produced more than 45 percent of total methane emissions in Kazakhstan. Domestic livestock, manure management and rice cultivation were sources of methane in Kazakhstan.

Along with methane, agricultural activities were sources of nitrous oxide (N₂O) and nitrogen oxides (NO_x). There were no emissions from field burning of agricultural crop wastes in Kazakhstan because this type of agricultural activity did not carry out in our country. CO₂ emissions from Agriculture were result of organic substances Excluding CH₄, others emissions were not included in the totals of Inventory.

3.1 CH₄ Emissions

The Agriculture was responsible for more than 45 percent of total methane emissions in Kazakhstan. Domestic livestock, manure management and rice cultivation were sources of methane in Kazakhstan.

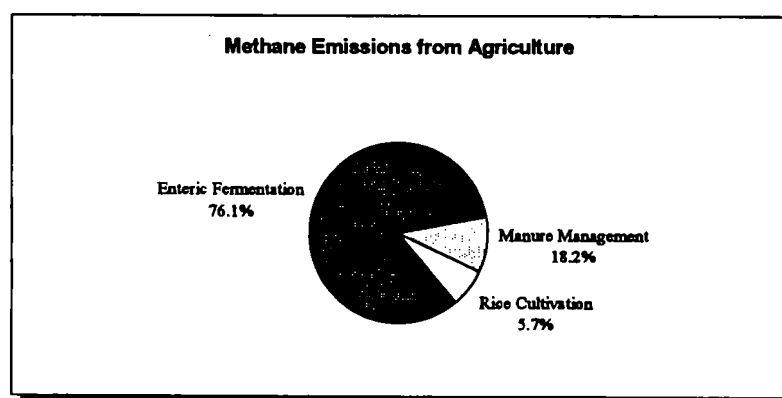


Fig. 1

Table 3.1

METHANE EMISSIONS FROM DOMESTIC LIVESTOCK: 1990

Animals	Population (1000s)	Enteric Fermentation		Manure Management		Total Emissions (Gg/year)
		Emission Factor (kg/head/year)	Emissions (Gg/year)	Emission Factor (kg/head/year)	Emissions (Gg/year)	
Non-Dairy Cattle	6,389.3	44	281.1	1	6.4	287.5
Dairy Cattle	3,368.0	56	188.6	16	53.9	242.5
Sheep and Goats	36,660.5	5	183.3	0.16	5.9	189.2
Pigs	2,976.1	1	3.0	4	11.9	14.9
Horses	1,666.4	18	30.0	1.6	2.7	32.7
Camels	143.0	46	6.6	1.9	0.3	6.8
Poultry	59,898.8	0	0.0	0.018	1.1	1.1
TOTAL			692.6		82.1	774.7

In 1990 domestic livestock and manure management together were responsible for 93 percent of methane emissions from agricultural activities (see Fig. 1). In domestic livestock methane was produced by enteric fermentation, it accounted for 83.1 percent of the total CH₄ emissions from agriculture. The amount of methane depended upon the type, age and productivity of the animals. Methane from the management of animal manure occurred as the result of its decomposition under anaerobic conditions; its share was 9.9 percent.

When calculating the CH₄ emissions we used a simplified methodology provided by the IPCC (*IPCC/OECD, Vol. 2, 1995*). According to this methodology the CH₄ emission, both for enteric fermentation and manure management were calculated by applying emission factors for the number of animals of each livestock type. The default emission factors were provided by different regions, climate regimes and for developed and developing countries. Simple multiplication of populations by emission factors produced emissions estimates. The Enteric Fermentation emission factors, emission factors for Manure Management for Kazakhstan and the results of calculation of methane emission for 1990 are given in Table 3.1.

Data on the number of animals of each livestock type were a result of an agriculture census in Kazakhstan and were included in State Statistical Accounts (*State Statistical Committee, 1991*). The emissions factors for enteric fermentation and manure management were the same as those suggested by IPCC Guidelines for developing countries and temperate regions because livestock complexes in Kazakhstan were situated at the west and north parts of the country. It should be noted, that the main livestock region is the Northern Kazakhstan, where average annual air temperatures were about 1-2 °C.

As it can be seen from the table 3.1, the total methane emissions from all animal types were 774.7 Gg or 4.6 MMTCE. These values are reported in Table GR.3 and in Worksheet 4-1, Sheet 1 of Appendix 2 and in Standard Data Table 4, Sheet 4A&B of Appendix 3.

Methane emissions from rice cultivation were the small fraction of the total CH₄ agricultural emission -- only 7 percent (Fig. 1). Anaerobic decomposition of organic material in flooded rice fields produced methane that escaped to atmosphere primary by transport through the rice plants. Methane emissions from rice cultivation in Kazakhstan were derived using the methodology recommended by the IPCC (*IPCC/OECD, Vol. 2, 1995*). This method used a daily emission factor, which was multiplied by the harvested area flooded and the number of days of flooding during the growing season.

The aggregate emission factor from Kazakhstan rice fields with consideration for average temperature of growing season (26 °C in the Southern Kazakhstan) and managed irrigation was defined as 4.22 kg/ha/day. The rice area in Kazakhstan amounted to an average of 120,000 ha, and average duration of growing season of different rice species amounted for 115 day (*State Statistical Committee, 1991*). Thus, the methane emissions from flooded rice fields per year were:

$$4.22 \text{ kg/ha/day} \cdot 120,000 \text{ ha} \cdot 115 \text{ days} = 58,236,000 \text{ kg} = 58.2 \text{ Gg}$$

This value is cited in Table GR.3 and in Worksheet 4-2, Sheet 1 of Appendix 2 and in Standard Data Table 4, Sheet 4C and in Table 7A of Appendix 3.

The total methane emissions from agriculture were 833.5 Gg or 5,001 MMTCE in 1990. These values are cited in Tables GR.1 - GR.3 and in Tables 7A and 7B of Appendix 3.

3.2 CO₂ Emissions

5-8 tonnes of CO₂ were released into the atmosphere as a result of organic substances decay from 1 ha of sowing area (*Rubenzam and Raue, 1969*). Inasmuch the cereals and other culture productivity were low in Kazakhstan we oriented ourselves on lower range. The total sowing area was 18 million ha (*State Statistical Committee, 1991*). Consequently, CO₂ emissions were 90 million tonnes or 90,000 Gg. This value is given in Table GR.1, but it is not included to the total CO₂ emissions, because all this CO₂ amount is absorbed by vegetation.

3.3 N₂O Emissions

Nitrous oxide (N₂O) emissions in agricultural soil are produced primarily by the microbial processes of nitrification and denitrification. Emission rates depend on a wide variety of natural and cultivation processes. Individual factors that control nitrification and denitrification include: soil water content; temperature; nitrate and ammonium concentrations; available organic carbon; and pH.

In our calculations N₂O emission factor was 0.01 of nitrogen amount absorbed by vegetation. Then we multiplied this value by 44/28 (molecular weights of nitrous oxide and nitrogen ratio). With taking into account the mentioned above indices of nitrogen absorption and fallow area the total N₂O emissions were 10 Gg in 1990. This value is reported in Table GR.1, but it was not included to the total N₂O emissions. Calculation was also done by 1991 and 1992. Notice, that the estimations of emission in these years are rather closely allied to each other, although for these three years there was a weak tendency for reduction of the emission due to the decreasing animal populations.

3.4 NO_x Emissions

Since emissions of nitrous oxide from agricultural soils depend on many site-specific factors, countries are encouraged to use results of local and regional studies to derive appropriate emission coefficients. Countries may also use locally available data to account for emissions of other GHG from agricultural soils. This approach was adopted by Kazakhstan specialists to determine NO_x emissions from fertilizer use.

Organic fertilizers were applied in fallow according to cereal cultivation in Kazakhstan. 800 kg ammonia or 330 kg nitrogen were released into the atmosphere as a result of organic substances decay and by the fertilization does into the soil accepted by the main grain growing farms. Nitrogen assimilation from air equaled 250 kg of nitrogen per year (*Rubenzam and Raue, 1969*). Thus, 80 kg of nitrogen or 263 kg of NO_x were released into the atmosphere from 1 ha of fallow. The total fallow was approximately 4 million ha in 1990 on Academy of Agriculture data. The NO_x emissions from this area were 1,052 million tonnes or 1,052 Gg per year. This value is reported in Table GR.1, but it was not included to the total NO_x emissions.

PART IV. WASTE

4.1 CH₄ Emissions from Landfills

The residential solid waste was the large methane emission source. The procedure of the calculation was completed according to IPCC. The solid waste generated for urban population (more than 10 million) accounted for 1,847 Gg in 1990. The fraction of the waste landfilled equaled 80 percent. This value was taken from Table 6.1 on page 6.8 (*IPCC/OECD, Vol. 2, 1995*). So, waste landfilled equaled

$$1,847 \text{ Gg} \cdot 0.8 = 1,478 \text{ Gg}.$$

Then we multiplied the annual waste landfilled by the decomposition fraction and by the fraction which actually degrades: $0.15 \cdot 0.75$ ✓

$$1,477.8 \text{ Gg} \cdot 0.15 \cdot 0.75 = 166.3 \text{ Gg of the annual carbon released as biogas.}$$

This value was multiplied by the fraction C-CH₄ to C-biogas and by the conversion ratio:

$$166.3 \text{ Gg} \cdot 0.5 \cdot 1.3 = 108.2 \text{ Gg or } 0.723 \text{ MMTCE of methane.}$$

These values are cited in Table GR.3 and in Worksheet 6-1 (Supplemental), Sheet 1 and in Worksheet 6-1, Sheet 1 of Appendix 2 and in Standard Data Table 6, Sheet 6A and in Table 7A of Appendix 3.

4.2 CH₄ Emissions from Domestic and Commercial Wastewater Treatment

The procedure of the calculation was also completed according to IPCC (*IPCC/OECD, Vol. 2, 1995*). At first we multiplied the urban population quantity by the wastewater Biochemical Oxygen Demand (BOD) value from Table 6.3 on page 6.8 (*IPCC/OECD, Vol. 2, 1995*) to get total annual BOD:

$$10,150 \cdot 10^3 \text{ people} \cdot 0.0146 \text{ Gg}/10^3 \text{ people/year} = 148.2 \text{ Gg BOD}_5.$$

Then we multiplied annual BOD by the fraction of wastewater anaerobically treated from Table 6.4 on page 6.8 (*IPCC/OECD, Vol. 2, 1995*) to get the quantity of BOD from anaerobically treated wastewater:

$$148.2 \text{ Gg BOD}_5 \cdot 0.10 = 14.8 \text{ Gg BOD}_5.$$

Further the quantity of BOD from anaerobically treated wastewater was multiplied by methane emissions factor to give total methane released from wastewater treatment:

$$14.8 \text{ Gg BOD}_5 \cdot 0.22 \text{ Gg CH}_4/\text{Gg BOD}_5 = 3.3 \text{ Gg or } 0.022 \text{ MMTCE of CH}_4.$$

This value is cited in Tables GR.3 and in Worksheet 6-2, Sheet 1 Appendix 2 and in Standard Data Table 6, Sheet 6B and in Table 7A of Appendix 3.

Net annual methane emissions from waste accounted to be:

$$108.2 \text{ Gg} + 3.3 \text{ Gg} = 111.5 \text{ Gg or } 0.745 \text{ MMTCE.}$$

These values are cited in Tables GR.1 - GR.3 and in Tables 7A, 7B of Appendix 3.

PART V. LAND USE CHANGE AND FORESTRY

Estimating GHG emissions from land use change and forestry according to the current IPCC methodology is based on two major principles: (a) fluxes of CO₂ to and from the atmosphere are assumed to be equal to changes in carbon stocks in existing biomass and soil; and (b) changes in carbon stocks can be estimated by establishing rates of change in land use and then applying basic assumptions about greenhouse gas fluxes response for a given land use.

5.1 Carbon Dioxide Absorption by Forests

There is CO₂ and water assimilation by autotrophic organisms in course of photosynthesis with formation of carbohydrates, i.e., combining of CO₂ for a long time. The particular significance here belongs to forest producing the considerable mass of primary organic substances which they use themselves in vital activity and also supply these substances to food chains of heterotrophic organisms.

In general aspect the currents of substances and energy may be presented as follows. When photosynthesis processing the trees, bushes and grasses of forest biocenose create the gross-production primary (GPP). Its value depends on closeness of canopy of leaves, the quantity of photosynthesis active radiation (PAR) and other factors.

In addition in pine and coniferous forests the canopy of trees gives near 94 percent GPP of all phytocenose. So on the Republic scale it is reasonable to considerate the forest productivity as the most investigated.

In vital activity the plants breathe and the difference between GPP and expenditure for breathing is the net-production primary (NPP). In forest phytocenose the net-production primary includes not only net growth of productivity (NEP), the actual increase of phytomass, but also the dead trees, leaves, flowers, seeds. It includes also the portion of net-production which was used for animal-phytophages feed. However the last value is small (less than 1 percent GPP) and it may not be considerate.

Thus the amounts of CO₂ accumulation in preserved order depend on two processes: the assimilation of carbon dioxide in organic remains and this organic matter decomposition (dead trees, leaves, flowers, seeds, etc.) with CO₂ emissions in atmosphere. The duration of CO₂ conservation in different forms of organic remains fluctuates from months to ten and hundred years. That is why if one considers the forests impact on CO₂ contents in atmosphere for long (more than 5-10 years) it depends on dynamics of wood amount accumulation. It is connected with that although near 30 percent total CO₂ amount absorbed by forests which are accumulated in pine-needles, leaves, grasses and underwood, its are quickly comparatively decomposed, while in the wood for economics needs carbon is preserved for tens and hundreds years.

Hence to determine the forests part in CO₂ balance in atmosphere it is necessary to know the dynamics of wood stocks in the forest and the wood amount cutting for economic needs. The dynamics of wood stocks have been determined by increase at trees growth and decrease at logging for main and intermediate use expense. That is why in that case the forests promote CO₂ outflow from atmosphere if the amount of stored up and used wood is filled in growing.

The dynamics of areas and wood stocks changes in Kazakhstan from 1961 till 1991 were provided by Kazakh Scientific Research Forestry Institute and presented in table 5.1. If to exclude the bushes biomass in which CO₂ is not preserved for a long time, the wood

stock standing timber increased from 1961 to 1991 for 66.99 million m³ or on an average for 2.48 million m³ yearly. Accepted coefficient of conversion from cubic meters to tonnes is 0.65.

Hence for last 30 years 1.61 million tonnes of biomass have been formed annually. On forming 1 tonne of living wood biomass in organic compositions 1.73 tonne of CO₂ is combined with. Thus when increasing wood stock of the Kazakhstan forests in the average 2.79 million tonnes CO₂ annually is being combined with over last 30 years.

The quantity of CO₂ being combined with increases in last years. From 1978 to 1991 an average yearly stock increase was 3.48 million cubic meters and quantity of yearly CO₂ being combined with - 3.91 million tonnes.

The amount of prolonged CO₂ preservation provided that there is the constancy or increase of total wood stock in forests equals the amount of stored up wood (excluding wood for stoves and refuse wood). The quantity of commercial wood cutting down yearly on an average over last 5 years is presented in Table 5.2. The average percent of commercial portion in coniferous trees type is 73.2, and in deciduous trees type is 26.1 of liquid stock. The commercial wood output on care and selective sanitary feelings on forestry enterprises data is 39 percent. The total wood volume used in national economy (construction, etc.) is 872.28 thousand cubic meters or 570.9 thousand tonnes. When it is forming 987.7 thousand tonnes CO₂ is absorbed from atmosphere yearly.

The total CO₂ amount being combined by Kazakhstan forests yearly is formed from its quantity absorbed when biomass of commercial cutting down wood portion generating and amount absorbed on increasing of standing timber stock. Therefore over last 30 years the Kazakhstan forests on an average absorb $3.98 + 0.99 = 4.97$ million tonnes CO₂ from atmosphere.

Table 5.1

Distribution of Areas Covered with Forests and Planting Stock
(numerator is area, thousand ha;
denominator is stock, million cubic meters).

Prevailing Sorts	Registration Periods		
	1961	1978	1988
Conifer	<u>1,510.1</u> 205.7	<u>1,593.7</u> 204.26	<u>1,737.5</u> 221.18
Hard-leaved	<u>6,485.5</u> 11.29	<u>4,647.3</u> 10.69	<u>4,815.2</u> 9.73
Soft-leaved	<u>1,011.1</u> 62.64	<u>1,211.1</u> 98.04	<u>1,303.3</u> 115.57
Total	<u>9,009.7</u> 279.64	<u>7,452.1</u> 312.99	<u>7,856.0</u> 346.48
Other Trees Soft	<u>86.5</u> 0.9	<u>45.3</u> 0.73	<u>43.9</u> 1.05
Bushes	<u>1,883.7</u> 5.77	<u>1,311.7</u> 7.57	<u>1,410.0</u> 6.5

Table 5.2

The Quantity of Annual Cutting down Commercial Wood
(thousand cubic meters / thousand tonnes)

Logging Kind	Total	Including	
		Deciduous	Coniferous
The Main Use	<u>573.2</u> 372.6	<u>169.4</u> 110.1	<u>403.8</u> 262.5
Care and Selected Sanitary Logging	<u>228.6</u> 148.6	-	-
Other Logging (Logging of Separate Trees etc.)	<u>76.48</u> 49.7	<u>7.78</u> 5.1	<u>68.7</u> 44.6
Total	<u>878.28</u> 570.9	-	-

5.2 Forest Fires

The forest clearing for converting areas in constant arable lands or pastures is not conducted in Republic Kazakhstan. However, the methodologies make no provision for registration of GHG emissions following large fires which occur once 10-25 years. The method of determination of these emissions almost coincides with the methodologies of calculations on forest clearing.

The spontaneous and prescribed forests fires lead to significant emissions of greenhouse gases. In Kazakhstan this source was described by applying the IPCC methodology, originally developed for estimating emissions from biomass burning. Emissions caused by fire in Kazakhstan were estimated separately for different forest types (fir, larch) and different types of post-fire regeneration (birch, aspen).

The conflagrations on Republic territory were registered last time in 1974 in East-Kazakhstan region when the fire covered near 230 thousand ha of forest area and near 10 million cubic meters of wood were damaged one way or another. In 1978 when there was the forest fund state registration in Kazakhstan the decrease of areas occupied by Siberian fir and larch (*Abies Sibirica*, *Larix Sibirica*) was recorded. The area portions in the next years were restored by birch, aspen (near 70 thousand ha) and bushes. The calculations were made for 27 years.

When biomass determining the actual stock of standing timber was multiplied by conversion factor 0.5 and by conversion factor from wood biomass to total mass - 1.9 (total 0.95). The distribution of biomass by fractions on site a fire was accepted as follows: 0.3 biomass was burnt down, 0.15 was cut down by hundred per cent sanitary logging (wood for stoves is considered as burnt down out of object), 0.55 was refuse wood and uncut down portion.

The biomass before fire was determined as mentioned above. After the fire the actual biomass of aspen and birch sites (10 tonnes/ha) was accepted. Its were restored on the fire places in 25 years.

The results of authorized calculations are cited in Tables 5.3-5.6.

5.3 Forest and Grassland Conversion, Abandonment of Managed Lands

The respective sheets about forest and grassland conversion are absent here, but they are included to Appendixes.

As to abandonment of managed lands the forest cultures were developed in 90 percent cases on the lands which were not occupied with forest earlier (the glades adjoining to tract of forest, unwooded areas, erosive lands) that is why 90 percent present forest area is included in the calculation.

The procedure and results of calculations according the last edition of IPCC Guidelines (*IPCC/OECD*, 1995) are reported in Tables GR.1 - GR.3 and in Worksheet 5-1, Sheets 1 - 3, Worksheet 5-2, Sheets 1 - 4 and 6, Worksheet 5-3, Sheet 3, Worksheet 5-4, Sheets 1 - 3 of Appendix 2 and in Standard Data Tables 5, Sheets 5A, 1 - 3, Sheets 5B, 1 and 2, Sheets 5C, 1 - 3 and in Tables 7A and 7B of Appendix 3.

Table 5.3

CO₂ Emissions from Forest Fires

Species	Registration Years Nominator is Area, 10³ ha; Denominator is Stock, mln m³		The Average Annual Decrease of Forest Areas as a Result of Fires for the Period from 1966 till 1993, 10³ ha mln. m³			
	1966	1993				
Abies Sibirica	485.7	384.4	2.752			
	70.92	56.67	0.528			
Larix Sibirica	187.5	175.0	0.463			
	35.8	28.79	0.233			
Module		Land Use Change and Forestry				
Submodule		Forest Fires; CO₂ Emissions as a Result of Burning of Aboveground Biomass on the Object and out of Object				
Work sheet 5.1						
Sheet A						
Step 1		Step 2				
Forest Type	A Annual Clearing Area, 10³ ha	B Biomass before Fire, tonne dry matter/ha(tdm/ha)	C Biomass after Fire, tdm/ha	D Net-changes in Biomass, tdm/ha	E Annual Biomass Losses, 10³ tdm	F Biomass Fraction Burnt on the Object
				D = B - C	E = A·D	
Boreal Climate						
Abies Sibirica	2.752	147	10	137	377	0.3
Larix Sibirica	0.463	178	10	168	78	0.3

Table 5.3 (continue)

Module			Land Use Change and Forestry		
Submodule			Forest Fires; CO ₂ Emissions as a Result of Burning of Aboveground Biomass on the Object and out of Object		
Work sheet 5.1					
Sheet B					
Step 2					
Forest Type	G Biomass Quantity Burnt down on the Object, 10 ³ tdm	H Biomass Fraction Oxidized on the Object	I Biomass Quantity Oxidized on the Object, 10 ³ tdm	J Carbon Fraction of Aboveground Biomass (Burnt down on the Object)	K The Quantity of Carbon Release, 10 ³ t C/ha
	G=E·F		I=G·H		K=I·J
Boreal Climate					
Abies Sibirica	113.1	0.9	101.8	0.45	45.8
Larix Sibirica	23.4	0.9	21.1	0.45	9.5
				Total	55.3

Table 5.3 (continue)

Module					Land Use Change and Forestry			
Submodule					Forest Fires; CO ₂ Emissions as a Result of Burning of Aboveground Biomass on the Object and out of Object			
Work sheet 5.1								
Sheet C								
Step 3					Step 4			
Forest Type	L Biomass Fraction Having Been Exposed to Burning out the Object	M Biomass Having Been Exposed to Burning out of Object, 10 ³ tdm	N Biomass Fraction Oxidized out of Object	O Biomass Quantity Oxidized out of Object, 10 ³ tdm	P Carbon Fraction of Aboveground Biomass (Burnt down out of the Object)	Q Carbon Release Quantity, 10 ³ t C	R The Total Carbon Released as CO ₂ on Object and out of Object	S The Total CO ₂ Emissions, 10 ³ t CO ₂
		M=E·L		O=M·N		Q=O·P	R=K+Q	S=R·44/12
Boreal Climate								
Abies Sibirica	0.15	56.6	0.9	50.9	0.45	22.9	68.7	251.9
Larix Sibirica	0.15	11.7	0.9	10.5	0.45	4.7	14.2	52.1
Total		68.3				27.6	82.9	304

Table 5.3 (continue)

Module					Land Use Change and Forestry				
Submodule					Forest Fires; CO ₂ Emissions as a Result of Burning of Aboveground Biomass on the Object and out of Object				
Work sheet 5.1									
Sheet D									
Step 5									
Forest Type	A Annual Area Clearing, 10 ³ ha	B Biomass before Fire, tdm/ha	C Biomass after Fire, tdm/ha	D Net-changes in Biomass, tdm/ha	E Average Annual Biomass Loss, ktdm	F The Fraction Having Been Exposed to Decay	G Biomass Quantity Having Been Exposed to Decay, ktdm	H Carbon Fraction in Above- ground Biomass	I Carbon Portion Released as CO ₂ , 10 ³ t C
				D=B-C	E=A·D		G=E·F		I=G·H
Boreal Climate									
Abies Sibirica	2.752	147	10	137	377.0	0.55	207.4	0.45	93.3
Larix Sibirica	0.463	178	10	168	77.8	0.55	42.8	0.45	19.3
Total							250.2		112.6

Table 5.3 (continue)

Module		Land Use Change and Forestry		
Submodule		Forest Fires: The Total Release		
Work sheet 5.1				
Sheet F				
Step 7				
A	B	C	D	E
The Immediate Release as a Result of Combustion, 10 ³ t C	Showed-up Release as a Result of Decomposition, 10 ³ t C	Long-term Release from Soil, 10 ³ t C	The Total Annual Carbon Release as a Result of Forest fires, 10 ³ t C	The Total CO ₂ Emissions as a Result of Forest Fires, 10 ³ t CO ₂
Boreal climate				
55.3	112.6	—	167.9	616.2

Table 5.4

Combustion on the Object in Forests (Emissions of Additional Gas Admixtures)

Module				Land Use Change and Forestry			
Submodule				Forest Fires: the Emissions of Gas Admixtures When Combusting on the Object as a Result of Fires			
Work sheet 5.2							
Sheet A							
Step 1				Step 2			
A	B	C		D	E	F	G
Carbon Emissions, 10 ³ t C	Nitrogen Carbon Ratio	Total Nitrogen Emissions, 10 ³ t N		Small Gas Admixtures Ratio	Emissions of Small Gas Admixtures, 10 ³ t C	Conversion Factors	Emissions of Small Gas Admixtures as a Result of Forest Fires, 10 ³ t CH ₄ , CO
					E=A·D		G=E·F
55.3	0.01		CH ₄	0.012	0.66	16/12	0.88
			CO	0.06	3.32	28/12	7.74
					ths. t N		10 ³ t N ₂ O, NO _x
		C=A·B			E=C·D		G=E·F
		0.55	N ₂ O	0.007	0.004	44/28	0.006
			NO _x	0.121	0.07	30/14	0.143

Table 5.5

Carbon Uptake in Soils of Forest Plantations

Module				Land Use Change and Forestry				
Submodule				Abandonment of Managed Lands				
Work sheet 5.4								
Sheet s A, B, C								
Step 2			Step 4			Step 5		
	A*	F	G	H**	M	N	O	P
Forest Type	Total Areas Planted with Forest on Neglected Lands for 20 Years, 10 ³ ha	Annual Carbon Absorption in the Soils, 10 ³ t C/ha	Total Annual Carbon Absorption in the Soils, 10 ³ t C	Total Area Planted with Forest on Neglected Lands More than 20 Years Ago, 10 ³ ha	Annual Carbon Absorption in the Soils, 10 ³ t C/ha	Total Annual Carbon Absorption in the Soils, 10 ³ t C	Total Carbon Absorption as a Result of Afforestation on Neglected Lands, 10 ³ t C	Total Carbon Dioxide Absorption, 10 ³ t CO ₂
			G=A·F			N=H·M	O=G+N	P=O·44/12
Boreal Climate	408	2.0	816	572	1.0	572	1,388	5,094***

Notes:

* The calculations on columns B-E are included in section "the exploited forests"

** The calculations on columns I-L are included in section "the exploited forests"

*** This value does not considered as CO₂ removal (see Table 5.7)

Table 5.6

The Exploited Forests

Module			Land Use Change And Forestry		
Submodule			The Exploited Forests		
Work sheet 5.5					
Sheet A					
Step 1					
	A	B*	C	D	E
	The Exploited Forests Area, 10 ³ ha	Annual Increment Extent, tdm/ha	Annual Increment in Biomass, 10 ³ tdm	Carbon Contents in Dry Matter	The Total Carbon in Biomass Increment, 10 ³ t C
			C=A·B		
Boreal Forests					
1. Conifer					
Pinus Silvestris	963	1.1	1,060	0.45	477
Picea Abovata, P. Tianschanica	168.2	1.64	276	0.45	124
Abies Sibirica	384.4	1.1	423	0.45	190
Larix Sibirica	175.0	1.45	254	0.45	114
Pinus Sibirica	43.3	1.1	48	0.45	21
Juiperus	8.4	0.32	3	0.45	1
Total					927

Table 5.6 (continue)

	A	B*	C	D	E
	The Exploited Forests Area, 10 ³ ha	Annual Increment Extent, tdm/ha	Annual Increment in Biomass, 10 ³ tdm	Carbon Contents in Dry Matter	The Total Carbon in Biomass Increment, 10 ³ t C
			C=A·B		
Boreal Forests					
2. Hard-leaved					
Quercus Robur	2.4	0.94	2	0.45	1
Ash-tree	6.2	0.7	4	0.45	2
Aser	8.2	0.5	4	0.45	2
Ulmus Laevis	78.3	0.5	39	0.45	18
Haloxylon Aphyilum	4,994.7	0.2	999	0.45	450
3. Soft-leaved					
Betula Pendula	899.6	1.4	1,259	0.45	567
Populus Tremula	298.8	1.32	394	0.45	177
Alnus	2.2	1.24	3	0.45	1
Populus	77.1	3.37	360	0.45	117
Tree-willow	46.3	2.93	136	0.45	61
Other tree types	45.4	1.0	45	0.45	20
Total					2,343

Note:

- * The data of current stock change is given since the increment only does not reflect the dynamics of biomass accumulation (not taking into account the trees falling away processes).

Annual increments in biomass were taken into account as follows. According to reference books data on Kazakhstan forests valuation the current stock change by each tree species in saplings, middle-aged, ripening and mature plantations was determined. After that with taking into account the actual average closeness of forest cover (on state forest registration data in 1993) and area occupied by each forest stand age group the increment in total tree biomass was determined. The portion of branches and roots in total increment by age groups was determined on the base of works of V.A. Usoltsev and other reference books (*Usoltsev*, 1988, *Ministry of Agriculture of Kazakhstan*, 1980, 1987, 1989).

Table 5.6 (continue)

Module				Land Use Change and Forestry				
Submodule				The Exploited Forests				
Work sheet 5.5								
Sheet B								
Step 2								
	F*	G	H	I	J	K	L	M
	Commercial Stocking up of Round Timber, 10 ³ m ³	Biomass Expansion Factor, tdm/m ³	The Total Biomass of Commercial Stocking up, 10 ³ tdm	The Total Wood Consumption, 10 ³ tdm	Other Wood Use, 10 ³ tdm	The Total Biomass Consumption, 10 ³ tdm	The Wood Removed after Forest Clearing, 10 ³ tdm	The Total Biomass Consumption from Exploited Forests, 10 ³ tdm
			H=F·G	From A, Sheet 1-2 D It goes in H		K=H+I+J	From M, Sheet 5-1	M=K - L
The Main Use	1,492	0.95	1,417.4	It goes in H				
Care and Selected Sanitary Logging	586.1	0.95	556.8					
Hundred Per cent Sanitary Logging	102.2	0.95	97.1					
Saksaul Logging	106.8	2.0	213.6					
Other Logging	123.6	0.95	117.4					
Total			2,402.3					

Note:

* In the column F the information on total logging (m³) including wood for stoves is given. That is why the rest columns (I, J) are not considered.

Table 5.6 (continue)

Module		Land Use Change and Forestry	
Submodule		The Exploited Forests	
Work sheet 5-5			
Sheet C			
Step 3			
N	O	P	Q
Carbon Fraction	Annual Carbon Emissions, 10 ³ t C	Annual Carbon Absorption or Emissions, 10 ³ t C	Annual Emissions or Removal Conversion in CO ₂ , Gg CO ₂
	O=M·N	P=E - O*	Q=P·44/12
0.45	1,081	+1,262	+4,627

GENERAL RESULTS

Inventory emissions estimates were based primarily on the official statistical information and information provided by the Ministry of Energy of Kazakhstan. As a result the largest stationary sources included 46 thermal power plants and large boilers; 23 enterprises of ferrous and non-ferrous metallurgy; 11 enterprises of oil and gas industry, 8 enterprises of chemical industry, 5 the largest machine-building plants; 10 cement and asbestos plants. The emissions from other great fuel consuming enterprises (i.e. food and light industries, municipal economy, agriculture and cattle-breeding) were also taken into account in the whole. The non-stationary sources such as internal-combustion engines (ICEs) on automobiles, locomotives, air-crafts and river-boats, on agricultural and constructional engineering were defined as separate sources.

As a result the emissions of six greenhouse and photochemical active gases - carbon dioxide, carbon monoxide, nitrogen oxides, nitrous oxide, methane and non-methane volatile organic compounds (NMVOCs) - from the territory of Kazakhstan in 1990 have been determined.

The current Kazakhstan GHG inventory for 1990 is summarized in Figure 2. The emissions estimates in this figure are presented on carbon-equivalent basis (Million Metric Tons of Carbon Equivalent, MMTCE) in order to show the relative contribution of each gas and sector to total Kazakhstan GHG emissions.

As one can see for the 1990 base year, total Kazakhstan emissions were 65.764 MMTCE. The most important emissions source is the energy sector which responsible for 58.172 MMTCE or about 90 percent of all GHG emissions. The important emissions source in Kazakhstan is the agriculture. The GHG emissions from this sector are about 5.564 MMTCE or 8 percent of total emissions

Kazakhstan emissions were slightly offset by an uptake of carbon by forests of 1.094 MMTCE or 2 percent of net Kazakhstan emissions.

The GHGs emissions on a full molecular basis (in Gg) by main sources and categories are given in Table GR.1. In Table GR.2 these values are presented in percentages of total emissions for each gas.

A summary of the estimates emissions more detailed by main source categories and subcategories for three main greenhouses gases are provided in Table GR.3. These estimates are presented on both a full molecular basis (in Gg) and on a carbon-equivalent basis (in MMTCE). The data in parentheses are not included to the total emissions.

As one can see from the Tables, CO₂ emissions accounted for the largest share of Kazakhstan emissions -- 53.039 MMTCE or 80.8 percent of total emissions. In molecular basis its emission accounted for 194,477.0 Gg. Thus, in 1990 CO₂ emissions accounted for more than 11 tonne per each person of Kazakhstan.

Methane emissions accounted for 12.435 MMTCE or 18.9 percent of total emissions, including contributions from landfills and agricultural activities, among others.

N₂O emissions equaled 0.2 MMTCE or 0.3 percent of total Kazakhstan emissions.

The emissions of the photochemical important gases CO, NO_x and NMVOCs are 3,108; 1,197; and 260 Gg (molecular basis) accordingly.

Table GR.1

GHG Emissions in Kazakhstan for 1990, Gigagrams

Nº	Emission Sources (Sectors)	CO₂	NO_x	CH₄	CO	N₂O	NMVOC
1	Energy	190,128	1,196.8	915.9	2,966.0	2.284	260.3
1.1	Thermal Power Plants and Boilers (Ministry of Energy)	93,159	247.3	—	7.0	1.158	—
1.2	Fuel Extraction, Processing and Transportation (including Fugitive)	1,052	5.2	903.7	31.6	0.006	—
1.3	Ferrous and Non-ferrous metallurgy	9,959	21.7	—	535.9	0.110	—
1.4	Chemical Industry	1,848	1.5	—	3.4	0.007	—
1.5	Construction Materials Production	5,317	15.7	—	33.1	0.058	—
1.6	Mechanical Engineering	286	0.6	—	15.5	0.003	—
1.7	Light and Food Industry	14,865	3.1	—	35.0	0.194	—
1.8	Internal Combustion Engines	32,471	474.1	5.6	2,016.3	0.610	260.3
1.9	Residential Boilers and Stoves	31,171	427.6	6.6	288.2	0.138	—
2	Industrial Processes	4,349	—	—	134.0	—	—
3	Agriculture	(90,000)	(1,052)	832.7	—	(10.000)	—
4	Waste	—	—	111.5	—	—	—
5	Land Use Change and Forestry	(-4,011)	0.1	0.9	7.7	0.006	—
	Total	194,477	1,196.9	1,861.0	3,107.7	2.290	260.3

Table GR.2

Structure GHG emissions in Kazakhstan, percent

Nº	Emission Sources (Sectors)	CO ₂	NO _x	CH ₄	CO	N ₂ O	NM VOC
1	Energy	97.76	99.99	49.21	95.44	99.74	100.00
1.1	Thermal Power Plants and Boilers (Ministry of Energy)	47.90	20.66	—	0.23	50.57	—
1.2	Fuel Extraction, Processing and Transportation (including Fugitive)	0.54	0.43	48.56	1.02	0.26	—
1.3	Ferrous and Non-ferrous metallurgy	5.12	1.81	—	17.24	4.80	—
1.4	Chemical Industry	0.95	0.13	—	0.11	0.31	—
1.5	Construction Materials Production	2.73	1.31	—	1.07	2.53	—
1.6	Mechanical Engineering	0.15	0.05	—	0.50	0.13	—
1.7	Light and Food Industry	7.64	0.26	—	1.13	8.47	—
1.8	Internal Combustion Engines	16.70	39.61	0.30	64.88	26.64	100.00
1.9	Residential Boilers and Stoves	16.03	35.73	0.35	9.27	6.03	—
2	Industrial Processes	2.24	—	—	4.31	—	—
3	Agriculture	(47.34)	(87.90)	44.75	—	(437.83)	—
4	Waste	—	—	5.99	—	—	—
5	Land Use Change and Forestry	(-2.11)	0.01	0.05	0.25	0.26	—
	Total	100	100	100	100	100	100

Table GR.3

GHG Emissions in Kazakhstan by Source: 1990

GHG Source	CO ₂	CH ₄	N ₂ O	CO ₂	CH ₄	N ₂ O	All GHGs
	(Gg)			(MMTCE)			
Total National Emissions	194,477	1,861.0	2.290	53.039	12.435	0.200	65.674
Part 1. Energy Activities	190,128	915.9	2.284	51.853	6.120	0.199	58.172
A. Fuel Combustion	190,128	12.2	2.284	51.853	0.082	0.199	52.134
1. Energy and Transformation Industries (Power engineering)	93,159	—	1.158	25.407	—	0.101	25.508
2. Hydrocarbon Fuel Extraction, Processing and Transformation	1,052	—	0.006	0.287	—	0.0005	0.288
3. Industry (ISIC)	32,275	—	0.372	8.802	—	0.032	8.834
3.1 Ferrous and Non-ferrous Metallurgy	9,959	—	0.110	2.716	—	0.01	2.726
3.2 Chemical Industry	1,848	—	0.007	0.504	—	0.0006	0.505
3.3 Construction Materials Production	5,317	—	0.058	1.450	—	0.005	1.455
3.4 Mechanical Engineering	286	—	0.003	0.078	—	0.0003	0.078
3.5 Light and Food Industries	14,865	—	0.194	4.054	—	0.017	4.071
4. Biomass Burned for Energy	(3,182)	6.4	0.138	(0.868)	0.043	0.012	0.055

Table GR.3 (continue)

GHG Source	CO ₂	CH ₄	N ₂ O	CO ₂	CH ₄	N ₂ O	All GHGs
	(Gg)			(MMTCE)			
5. Internal Combustion Engines (ICE)	32,471	5.6	0.610	8.856	0.037	0.053	8.946
6. Residential Boilers and Stoves	31,171	0.2	-	8.501	0.001	-	8.502
B. Fugitive Fuel Emissions	-	903.7	-	-	6.038	-	6.038
7. Oil and Natural Gas Systems	-	152.0	-	-	1.016	-	1.016
8. Coal Mining	-	751.7	-	-	5.023	-	5.023
Part 2. Industrial Processes	4,349	-	-	1.186	-	-	1.186
2.1 Cement Production	4,138	-	-	1.129	-	-	1.129
2.2 Carbide Production	211	-	-	0.058	-	-	0.058
Part 3. Agriculture	-	832.7	-	-	5.564	-	5.564
3.1 Enteric Fermentation	-	692.0	-	-	4.624	-	4.624
3.2 Animal Wastes	-	82.5	-	-	0.551	-	0.551
3.3 Rice Cultivation	-	58.2	-	-	0.389	-	0.389
Part 4. Land Use Change and Forestry	(- 4,011)	0.9	0.006	(-1.094)	0.006	0.0005	0.007
Part 5. Wastes	-	111.5	-	-	0.745	-	0.745
5.1 Landfills	-	108.2	-	-	0.723	-	0.723
5.2 Wastewater	-	3.3	-	-	0.022	-	0.022

Total Kazakhstan Emissions by Source: 1990
(Million Metric Ton of Carbon Equivalent)

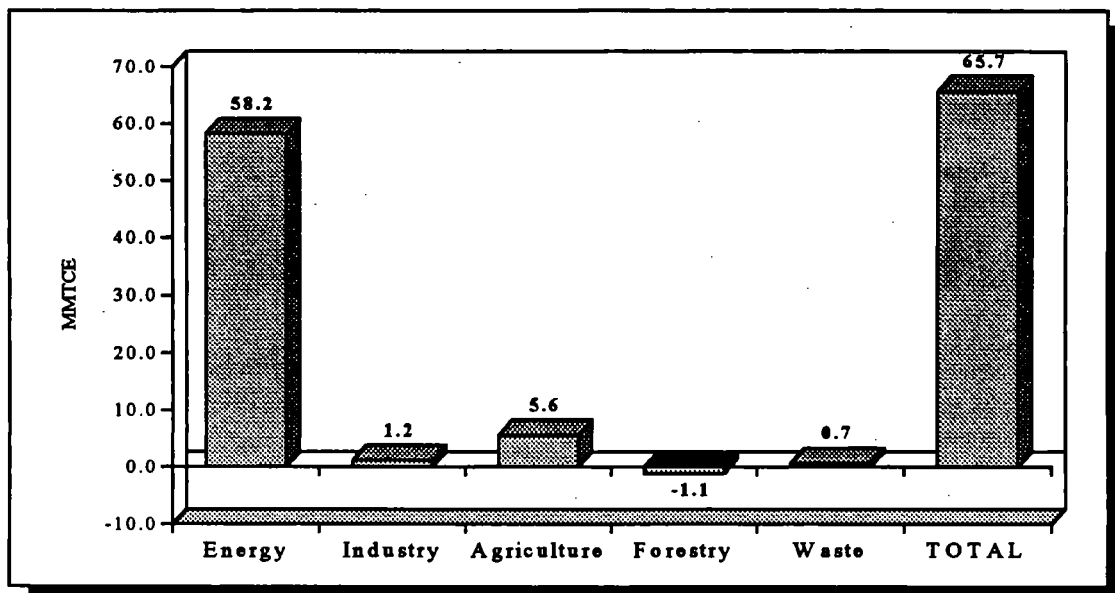


Fig. 2

The largest sources of CO₂ emissions were the thermal power plants and large boilers which contributed 48 percent of the total CO₂ emissions. ICEs, residential boilers and stoves, light and food industries contributed 17, 16, 8 percent of the total CO₂ emissions respectively (Table GR.2).

The major sources of CH₄ emissions were fugitive fuel emissions (49 percent), agriculture (45 percent), and others including wastes (6 percent).

The largest proportion of N₂O emissions comes from coal combustion, accounted for about 94 percent of total N₂O emissions in 1990. N₂O was emitted first of all from thermal power plants and large boilers (51 percent), from ICEs (27 percent). N₂O emissions from the other sources, including industry, residential, etc., accounted for 22 percent.

The largest sources of NO_x emissions were ICEs (40 percent), residential boilers and stoves (36 percent), thermal power plants and large boilers (21 percent).

The largest sources of CO emissions were ICEs (65 percent), ferrous and non-ferrous metallurgy (17 percent), residential boilers and stoves (9 percent). Data are presented in percentage of the total emissions of the respective gas (Table GR.2).

As we can see from Table GR.3, Kazakhstan emitted 52.134 MMTCE of all GHGs from fossil fuel combustion in 1990. The main energy-related activities produced these emissions were power engineering (25.508 MMTCE), petroleum products consumption in automobiles and other vehicles (8.834 MMTCE), heating and cooking in residential houses (8.502 MMTCE) and industry (8.834 MMTCE).

It should be noted, that the coal, petroleum products and natural gas from all sectors of the economy were responsible for 65, 26 and 9 percent of Kazakhstan energy - related carbon dioxide emissions respectively.

UNCERTAINTY AND LIMITATIONS OF EMISSIONS ESTIMATES

The most reliable data are those on emissions from thermal power plants which CO₂ share is 47 percent and N₂O share is 51 percent of total emissions. The possible mistake is not more than 5 percent.

In other branches of industry the power registration is not enough well as at thermal power plants so that possible mistake is within the limits of 20 percent.

The most unreliable calculation results are those connected with ICE (17 percent CO₂ emissions, 41 percent NO_x emissions and 66 percent CO emissions).

On materials of the most competent organization, Kazakh Scientific-Research Institute of Motor Transport (*Monakrovich*, 1984) the data "dispersion" and average values of gases emissions per 1 tonne fuel are shown in Table UL.1. The data dispersion is shown in numerator, and the average values in denominator.

Table UL.1

Toxic Gas	Specific Emissions, t/t		
	Gasoline	Diesel Fuel	Gas
Carbon Oxide (CO)	<u>0.250..0.800</u> 0.420	<u>0.006..0.200</u> 0.047	<u>0.040..0.310</u> 0.090
Hydrocarbons (CH ₄)	<u>0.023..0.100</u> 0.046	<u>0.004..0.050</u> 0.019	<u>0.020..0.040</u> 0.021
Nitrogen Oxides (NO _x)	<u>0.016..0.040</u> 0.027	<u>0.018..0.045</u> 0.033	<u>0.008..0.040</u> 0.016

As for the integral estimation of authenticity of initial data the comparison our obtained indices with the report data of the State Statistical Committee shown that the mistake on separate gases was within the limits of 5-20 percent. The emission indices from residential boilers and stoves are the most unreliable.

EXPERT JUDGMENTS OF FUTURE CO₂ EMISSIONS FROM 1991 TO 2000

Owing to historically established energy and fuel consumption structure of economics in Kazakhstan the amount of GHG emissions and first of all CO₂, for 1990 was large enough. For last three years economics recession caused decrease of fuel consumption. In a number of industries (for example, in cement industry) output decreased 5-7 times. The GHG emissions decreased accordingly too. But now specific fuel consumption per unit of gross national product in Kazakhstan is higher considerably than in the countries with developed industry and progressive technologies. Volume of GHG emissions for period from 1991 to 2000 will depend upon rates and scale of structural reorganization of economics which will be determined by foreign investments.

Now it is difficult to predict reliable enough volume of GHG emissions for period from 1991 to 2000. The thing is that the state authorities in Kazakhstan underwent changes after the USSR had broken down, specifically such an authority as State Planning Committee liquidated. From 1927 during more than 60 years the planning and development of national economy (in which the share of private sector was tiny) were led by government of USSR in accordance with confirmed five or seven-year plans. There are no such plans at the Ministries and Departments and the share of private sector of productive forces increases but one of state-owned sector decreases. As a result of that it is impossible to receive any information from government offices. That is why we used method of expert evaluations. We questioned 10 experts which the most authoritative leaders and specialists in fields of energy, industry, transport, agriculture and also scientists-economists. They were recommended to consider in the first place the results (official report data) for the past three years and for nine months of year 1994 and secondly the actual state of industry in familiar to them fields of economy. Since we have the results of calculation of GHG emissions for base year (1990), we should be first of all determine the volumes of output correlation for 1990 and 1991. The comparison of report data showed that the indices both of output (including the fuel) and fuel consumption for 1991 is practically equal the same for 1990. It was the stagnation period. From 1992 falling-off of production first of all in industry then in other branches has started. All experts marked four main reasons for this recession.

1. The breach or stopping supply of assembling components and some raw materials from other republics of former USSR because of their economic and financial relations breaking off.
2. High degree of equipment physical depreciation and obsolescence, decrease of its efficiency, disposed power and as a result the increase of specific power consumption of products. New producing capacity in Republic were not put into operation for five years.
3. Marketing difficulties of basic exported products such as non-ferrous metals, phosphorous fertilizers and other products. 8-20 percent of these products are consumed in Kazakhstan but ex-consumers (the Republics of USSR) refuse to buy its. They go through the industrial crisis or they prefer to buy these products from other suppliers.
4. Departure of experienced personnel out of Republic and taking up other work (retail trade, cooperatives, etc.).

Owing to these and other reasons the falling-off of production regarding 1991 level was 10 percent in 1992, 25 percent in 1993 and expected falling-off will be 40 percent in 1994. The experts predict some further falling-off of production till 45 percent according to optimistic scenario and 50 percent according to pessimistic scenario. Only in 1996 we expect stabilization and then to the end of ten years is supposed to be slow increase of volume of production to 75-80 percent of the same in 1991.

It should be emphasized that the forecast of dynamics of volumes of industrial production for second half of ten years is particularly unreliable in comparison with similar forecasts for other economics sector. Mentioned high degree of physical depreciation of fixed assets being negative factor will give impetus to reshaping the structure of production from primary production to manufacturing high-quality products, from power consumption technological processes to science-capacious production. There are no such financial resources for it in Kazakhstan now. Situation will depend upon investments to series of great projects. It will be possible that in rise in prices of energy carriers have an effect upon future development of economics. The high power consumption in Kazakhstan in this case will predetermine high product cost and aggravate the problems of marketing still more.

Power Engineering

The falling-off the production is somewhat less because of some increase of energy consumption per production unit. It is connected with bad conditions (wear and tear) of fixed assets. Besides there is not alternation in energy consumption of residential economy which is the second bulk energy consumer. As a result the energy consumption in 1993 was 85 percent as regards 1991 (i.e. the falling-off of production is 15 percent as against 25 percent in industry). Stabilization of energy production will be expected in 1995 and then will increase.

Transport

Economic recession caused the reduction of volume of goods traffic by road and by rail near 2 times. Passenger traffic by air decreased by 60 percent for three years. Rail-transport would increase volume of passenger traffic as a result of passengers outflowing from air transport to rail but their volume of traffic was 95 percent regarding 1991 because of shortage of railway cars. Volume of passenger traffic by road remained at the same level. There is the decrease of buses number and the increase of number of private vehicles here. And number of private vehicles increases by 3 percent yearly on data of State Motor Licensing and Inspection Department.

Agriculture and Forestry

The total sowing area decreased by 2 millions ha for last three years. The main reasons are population outflow, shortage of fuel and agricultural machinery. It should be expected in the next few years the croplands decrease by 1-2 million ha and altogether by 15 percent in comparison with 1991 level. It is possible that sowing area will be stabilized on this level but fuel-consumption by hectare will increase by 10-20 percent at agrotechnic improvement expense. Now because of fuel shortage such works as cultivation, retention of snow and moisture, etc., are not making fully.

The another reserve for decrease of difference between CO₂ emissions and CO₂ sink is the possibilities to increase the forest area. There are favorable soil and climatic conditions in many Kazakhstan regions and forest management ("Lespromkhoz" company) which have skill personnel and equipment. It will be possible to realize this project at the attraction of foreign investments expense particularly such companies

which need licenses to increase the output of fuel-consumption products. These licenses must be given to the companies after financing of forestry in any country.

Total Emissions

We made the prognostic graph of CO₂ emissions for period from 1991 to 2000 taking into account expert assessments and fuel-consumption of main branches of economy (Fig. 3). The area under the curve allows to calculate that the total volume of CO₂ emissions from the territory of Kazakhstan in the first decade will amount to 1,666 thousand Gg. For the same period, the CO₂ absorption by forests can be assessed as 40 thousand Gg. Thus, the difference is 1,626 thousand Gg. Thus, the reduction of the GHG emissions by 1996 will reach 26 percent of the 1990 level, with subsequent stabilization and gradual growth reaching the base level right after 2010.

Expert Estimation of CO₂ emissions from 1990 till 2000 in Kazakhstan

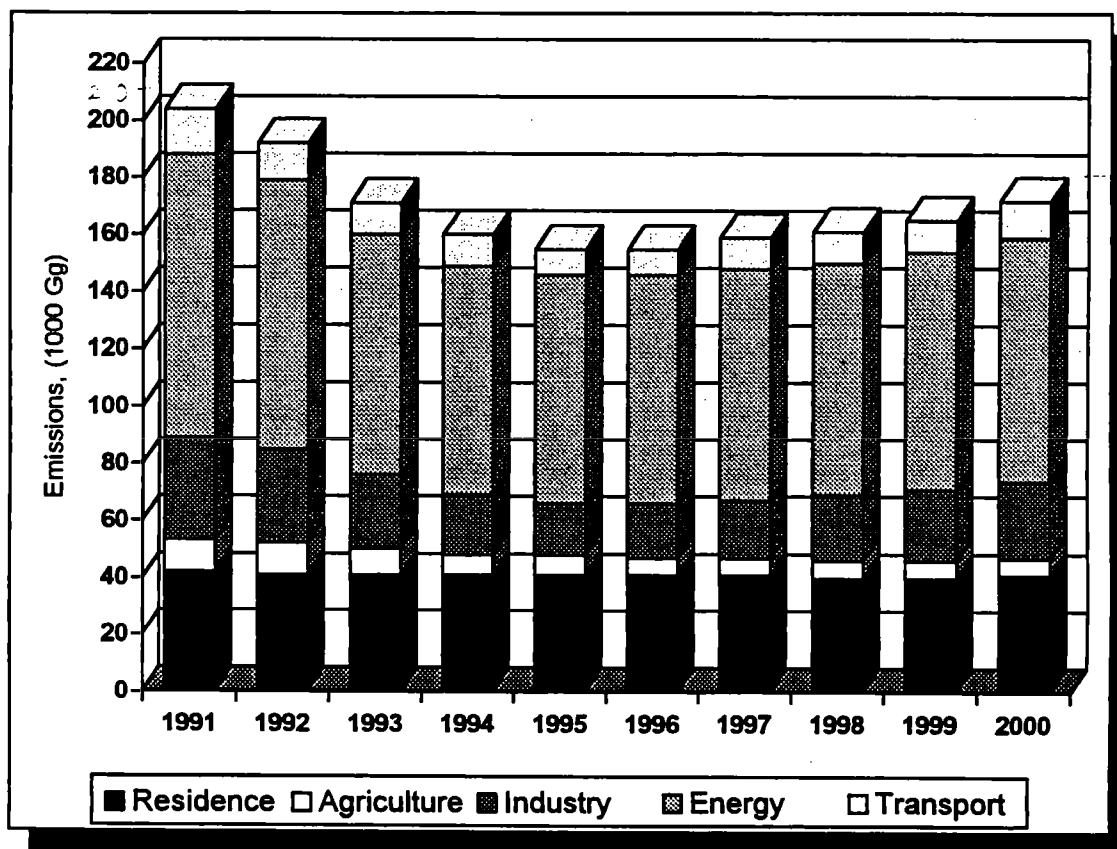


Fig. 3

CONCLUSIONS

Emissions of greenhouse gases from different sources and removals by sinks were estimated using the IPCC methodology and some of our own approaches as well. The emissions of six greenhouse and photochemical active gases - carbon dioxide, carbon monoxide, nitrogen oxides, nitrous oxide, methane and non-methane volatile organic compounds - from the territory of Kazakhstan in 1990 have been determined as the result of the GHG inventory.

Total Kazakhstan emissions were 65.764 MMTCE. The most important emissions source was the energy sector which is responsible for 58.172 MMTCE or about 90 percent of all GHG emissions. The most important emissions source in non-energy sector in Kazakhstan was the agriculture. The GHG emissions from this sector were about 5.564 MMTCE or 8 percent of total emissions

According to the 1990 inventory data obtained in Kazakhstan, carbon dioxide, methane, and nitrous oxide accounted for 80 percent, 19 percent, and 1 percent of all Kazakhstan anthropogenic emissions (in MMTCE), respectively. In molecular basis CO₂ emissions accounted for 194,477.0 Gg.

The emissions of the photochemical important gases CO, NO_x and NMVOCs were 3,108; 1,197; and 260 Gg (molecular basis) accordingly.

The average annual carbon dioxide uptake from forest exploitation was estimated to be 4,011 Gg or 1.094 MMTCE of CO₂. This amounted to approximately 2 percent of the CO₂ emissions or about 1 percent of total GHGs emissions in Kazakhstan.

To compare obtained results with other countries indices and also for computer processing of materials there are two appendices (Appendixes 2 and 3) at the end of the paper. They were made on IPCC formats. Appendix 2 is set of calculation (algorithmic) tables and Appendix 3 is set of report summing tables. We did not use IPCC "top-down" approach itself, because there was a lack of data about import and export of fuel, while the data about fuel consumption were available and sufficiently accurate.

Because of lack of concrete activities or data we did not fill in the following IPCC tables: from *IPCC/OECD*, 1995, v.2 the tables on pages 1.29, 1.31, 1.33, 1.35, 4.31, 4.33, 4.35, 4.37, 4.39, 4.41, 5.35, 6.19, 6.21; from *IPCC/OECD*, 1995 v.1 the tables on pages TABLES.1, TABLES.3 (further simply "1", "3", etc.), 5, 15, 21, 25, 29, 31, 41, 45, 51, 53, 55, 67, 69, 71, 867, 89, 93, 99, 101.

Many of the categories of GHG emissions can be estimated only with large ranges of uncertainty. We provide the following level of uncertainties yield by national activity (statistical) data. Some of the current estimates, such as those for CO₂ emissions from energy-related activities, are considered rather accurate: possible error is not more than 5 percent. For other categories of emissions, however, a lack of data or an incomplete understanding of how emissions are generated limit the scope or accuracy of the inventory: possible error is about 20 percent. The largest uncertainty of emissions estimations (more than 20 percent) was in subsector ICE of mobile sources. The uncertainty, connected with activity data in agricultural was about ± 10 percent of the emissions estimate.

According to expert judgments, we can conclude that the reduction of the GHG emissions by 1996 will reach 26 percent of the 1990 level, with subsequent stabilization and gradual growth reaching the base level right after 2010.

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APPENDIX 1. FUEL CONSUMPTION BY ENERGY ENTERPRISES

Annual Fuel Consumption by the Enterprises of Ministry of Energy for 1990
(from Forms "6-TP").

Thermal Power Plant	Fuel	Field	NCV, kcal/kg	Fuel Consumption	
				actual tonnes	standardized tonnes
Almatyenergo					
Almaty Condensed Power Plant	Fuel Oil Coal	Koocheke*	9,550	23,842	32,527
		Borlinsk*	4,125	112,967	66,570
		Shubarkol*	3,260	705,723	328,665
			5,100	10,779	7,853
		Karaganda	4,186	67,658	40,459
		Total		897,127	443,547
Almaty Cogeneration Power Plant-1	Fuel Oil Natural Gas Coal		9,550	206,362	281,537
			8,140	309,291	359,661
		Karaganda	4,186	241,266	144,277
		Koocheke	4,125	10,274	6,054
		Kuznetsk	4,838	661	457
		Total		252,201	150,788
Almaty Cogeneration Power Plant-2	Fuel Oil Coal		9,550	91,716	125,127
		Shubarkol	5,100	37,782	27,527
		Ekibastuz	3,739	492	263
		Concentrate	5,246	1,985	1,488
		Karaganda	4,184	1,612,714	963,942
		Borlinsk	3,260	495,580	230,799
Total		2,148,553	1,224,019		
Tekeli Cogeneration Power Plant	Fuel Oil Coal		9,550	780	1,064
		Kuznetsk	4,838	190,866	131,916
Almaty Central Heat System	Fuel Oil Natural Gas		9,550	135,888	185,390
			8,120	115,871	134,410
Kapchagai Central Heat System	Fuel Oil Coal		9,550	57,360	78,255
		Kuznetsk	4,838	10,276	7,102
Tekeli Power Complex	Coal	Kuznetsk	4,838	18,710	12,931
Southern	Fuel Oil		9,550	10,877	14,839

Thermal Power Plant	Fuel	Field	NCV, kcal/kg	Fuel Consumption	
				actual tonnes	standardized tonnes
Kazakhstan Condensed Power Plant					
Altaienergo					
Ust-Kamen-k Cogeneration Power Plant	Fuel Oil	Kuznetsk	9,550	20,829	28,417
	Coal		4,838	1,122,000	775,462
Leninogorsk Cogeneration Power Plant	Fuel Oil	Kuznetsk	9,550	32,210	43,944
	Coal		5,246	378,300	283,509
Sogrinsk Cogeneration Power Plant	Fuel Oil	Kuznetsk	9,550	6,748	9,206
	Coal		4,745	322,700	218,745
Semipalatinsk Cogeneration Power Plants	Fuel Oil	Karaganda	9,550	30,167	41,156
	Coal		4,186	199,200	119,122
Atyrauenergo					
Guriev Cogeneration Power Plant	Fuel Oil		9,550	438,006	597,565
	Natural Gas		8,100	353,509	409,060
	Crude Oil		10,400	444	660
Zapkazenergo					
Uralsk Cogeneration Power Plant	Fuel Oil	Orenbourg	9,550	3,879	5,292
	Natural Gas		8,054	327,716	377,061
Aktubinsk Cogeneration Power Plant	Fuel Oil	Gazly	9,550	13,642	18,612
	Natural Gas		8,200**	519,459	608,509
Karagandaenergo					
Karaganda Condensed Power Plant-1	Fuel Oil	Karaganda Koocheke Ekibastuz Total	9,550	22,231	30,329
	Coal		4,186	282	169
			4,125	3,448	2,032
			3,924	797,066	446,779
				800,736	448,980
Karaganda Condensed Power Plant-2	Fuel Oil	Ekibastuz	9,550	26,345	35,942
	Coal		3,678	3,690,889	1,939,299
Karaganda Cogeneration Power Plant-1	Fuel Oil	Karaganda	9,550	10,512	14,341
	Coal		4,186	395,642	236,594
Karaganda	Fuel Oil		9,550	46,766	63,802

Thermal Power Plant	Fuel	Field	NCV, kcal/kg	Fuel Consumption	
				actual tonnes	standardized tonnes
Cogeneration Power Plant-2	Coal	Karaganda	4,186	1,837,400	1,098,765
Karaganda Cogeneration Power Plant-3	Fuel Oil	Ekibastuz	9,550	7,369	10,053
	Coal		3,620	1,661,588	859,278
Balkhash Cogeneration Power Plant	Fuel Oil	Ekibastuz	9,550	3,267	4,457
	Coal		3,739	26,463	14,135
			3,260	627,214	292,103
			4,186	320,884	191,889
			Total	974,561	498,127
Jezkazgan Cogeneration Power Plant	Fuel Oil	Ekibastuz	9,550	49,559	67,613
	Coal		3,739	21,308	11,382
			4,186	1,029,482	615,630
			Total	1,050,790	627,012
Tenjek Cogeneration Power Plant	Fuel Oil	Karaganda	9,550	48,192	65,748
	Coal		4,186	179,369	107,263
Karajal Cogeneration Power Plant	Fuel Oil	Koocheke	9,550	1,067	1,456
	Coal		4,125	49,400	29,111
Kostanaenergo					
Rudny Cogeneration Power Plant	Fuel Oil	Ekibastuz	9,550	4,680	6,385
	Natural Gas		7,925	238,990	270,571
	Coal		3,807	375,590	204,267
Kostanai Cogeneration Power Plant	Fuel Oil		9,550	8,510	11,610
	Natural Gas		7,322	158,091	165,363
Kostanai Central Heat System	Fuel Oil		9,550	9,679	13,205
	Natural Gas		7,924	172,672	195,465
Arkalyk Cogeneration Power Plant	Fuel Oil		9,550	121,374	165,589
Pavlodarenergo					
Ermak Condensed Power Plant	Fuel Oil	Ekibastuz	9,550	64,810	88,419
	Coal		3,717	9,460,022	5,023,272
Pavlodar Cogeneration Power Plant-1	Fuel Oil	Ekibastuz	9,550	5,680	7,749
	Coal		3,703	2,747,357	1,453,352
Pavlodar Cogeneration	Fuel Oil	Ekibastuz	9,550	14,682	20,030
	Coal		3,699	752,197	397,482

Thermal Power Plant	Fuel	Field	NCV, kcal/kg	Fuel Consumption	
				actual tonnes	standardized tonnes
Power Plant-2		Maikuben*	3,905	92,566	51,639
		Total		844,763	449,121
Pavlodar Cogeneration Power Plant-3	Fuel Oil	Ekibastuz	9,550	24,894	33,963
	Coal	Kuznetsk	3,699	2,288,757	1,209,445
		Total	4,838	16,307	11,270
				2,305,064	1,220,715
Pavlodar Central Heat System	Fuel Oil		9,550	41,663	56,840
<i>Tselinenergo</i>					
Petropav-sk Cogeneration Power Plant-2	Fuel Oil	Ekibastuz	9,550	86,701	118,285
	Coal		3,739	2,599,736	1,388,630
Tselinograd Cogeneration Power Plants 1 and 2	Fuel Oil	Ekibastuz	9,550	93,327	127,325
	Coal	Borlinsk	3,860	1,377,076	759,359
		Karaganda	3,260	217,042	101,080
		Kuznetsk	4,186	21,654	12,949
		Total	4,838	220	152
				1,615,992	873,540
Kokchetav Central Heat System	Fuel Oil		9,550	72,656	99,124
<i>Ekibastuzenergo</i>					
Ekibastuz Condensed Power Plant-1	Fuel Oil	Ekibastuz	9,550	176,714	241,088
	Coal		3,631	10,573,784	5,484,773
Ekibastuz Condensed Power Plant-2	Fuel Oil		9,550	31,808	43,395
Ekibastuz Cogeneration Power Plant	Fuel Oil	Ekibastuz	9,550	5,261	7,178
	Coal		3,739	573,901	306,545
<i>Yuzhkazenergo</i>					
Jambyl Condensed Power Plant	Fuel Oil		9,550	834,642	1,138,690
	Natural Gas		8,127	1,373,354	1,594,464
Shimkent Cogeneration Power Plant-1	Fuel Oil	Bukhara	9,550	1,648	2,248
	Natural Gas		8,114	285,304	330,708
Shimkent Cogeneration	Fuel Oil	Mubarek	9,550	8,710	11,883
	Natural Gas		8,085	396,110	457,507

Thermal Power Plant	Fuel	Field	NCV, kcal/kg	Fuel Consumption	
				actual tonnes	standardized tonnes
Power Plant-3					
Jambyl	Fuel Oil		9,550	8,290	11,310
Central Heat	Natural Gas		8,200	319,717	374,526
System	Coal	Kyrghyz	2,962	684	289
Kentau	Fuel Oil		9,550	3,900	5,321
Cogeneration	Coal	Kyrghyz	2,962	310,856	131,536
Power Plant-5		Tajik	2,962	3,176	1,344
		Total		314,032	132,880
Kzyl-Orda	Fuel Oil		9,550	52,860	72,116
Cogeneration	Coal	Kyrghyz	2,962	499,207	211,236
Power Plant-6		Maikuben	3,905	195,998	109,339
		Tadjik	2,962	8,908	3,769
		Uzbek	2,962	20,720	8,768
		Total		724,833	333,112
Shimkent	Natural Gas		8,200	56,867	66,616
Central Heat					
System					
	TOTAL				
	Fuel Oil and				
	Crude Oil			2,960,103	4,038,425
	TOTAL				
	Natural Gas			4,626,951	5,343,921
	TOTAL				
	Coal			48,316,066	26,082,066
TOTAL				55,903,120	35,464,412

Notes:

* Data about NCVs for Koocheke, Borlinsk, Maikuben, Shubarkol coals, and for oil as well are taken from (*Chokin et al.*, 1990).

** Data about NCV for natural gas (dry) (8,200 kcal/kg) is our own default value (see Table 1.2)

APPENDIX 2. IPCC ALGORITHMIC TABLES



MODULE			ENERGY					
SUBMODULE			CO ₂ FROM ENERGY SOURCES (REFERENCE APPROACH)					
WORKSHEET			I-I					
SHEET			I OF 5					
			STEP 1					
			A	B	C	D	E	F
			Production	Imports	Exports	International Bunkers	Stock Change	Apparent Consumption
FUEL TYPES								F=(A+B-C-D-E), G, G
Liquid Fossil	Primary Fuels	Crude Oil						
		Natural Gas Liquids						
	Secondary Fuels	Gasoline						5,769
		Jet Kerosene						54
		Other Kerosene						711
		Gas / Diesel Oil						9,000
		Residual Fuel Oil						8,006
		LPG						215
		Ethane						
		Naphtha						
		Bitumen						
		Lubricants						
		Petroleum Coke						
		Refinery Feedstocks						
		Other Oil						
		Liquid Fossil Totals						
Solid Fossil	Primary Fuels	Anthracite ¹						
		Coking Coal						
		Other Bit. Coal						
		Sub-bit. Coal						
		Lignite					43,272	
		Peat						
	Secondary Fuels	BKB & Patent Fuel						
		Coke					43	
		Solid Fossil Totals						
Gaseous Fossil		Natural Gas (Dry)					9,798	
Total							76,868	
Biomass Total								
	Solid biomass							
	Liquid biomass							
	Gas biomass							

¹ If anthracite is not separately available, include with Other Bituminous Coal.



MODULE			ENERGY				
SUBMODULE			CO ₂ FROM ENERGY SOURCES (REFERENCE APPROACH)				
WORKSHEET			I-1				
SHEET			2 OF 5				
			STEP 2		STEP 3		
			G ¹ Conversion Factor, T ₂ / ~~(T₁Unit)⁶~~ Gg	H Apparent Consumption (TJ)	I Carbon Emission Factor (t C/TJ)	J Carbon Content (t C) K Carbon Content (Gg C)	
FUEL TYPES				H=(F×G)		J=(H×I) K=(J×10 ⁻³)	
Liquid Fossil	Primary Fuels	Crude Oil					
		Natural Gas Liquids					
	Secondary Fuels	Gasoline	29.33	169,205	18.9	3,197,975	3,198
		Jet Kerosene	29.33	1,584	19.5	30,888	31
		Other Kerosene	29.33	20,854	19.6	408,738	409
		Gas / Diesel Oil	29.33	263,970	20.2	5,332,194	5,332
		Residual Fuel Oil	29.33	234,816	21.1	4,954,618	4,955
		LPG	29.33	6,306	17.2	108,463	108
		Ethane					
		Naphtha					
		Bitumen					
		Lubricants					
		Petroleum Coke					
		Refinery Feedstocks					
		Other Oil					
		Liquid Fossil Totals					
Solid Fossil	Primary Fuels	Anthracite					
		Coking Coal					
		Other Bit. Coal ²					
		Sub-bit. Coal					
		Lignite	29.33	1,269,168	27.1	34,394,453	34,394
		Peat					
	Secondary Fuels	BKB & Patent Fuel					
		Coke	29.33	1,261	29.5	37,200	37
Solid Fossil Totals							
Gaseous Fossil		Natural Gas (Dry)	29.33	287,375	15.3	4,396,838	4,397
Total				2,254,539		52,861,367	52,861
Biomass Total							
		Solid biomass					
		Liquid biomass					
		Gas biomass					

¹ Please specify units

² If anthracite is not separately available, include with Other Bituminous Coal



MODULE			ENERGY				
SUBMODULE			CO ₂ FROM ENERGY SOURCES (REFERENCE APPROACH)				
WORKSHEET			I-1				
SHEET			3 OF 5				
			STEP 4		STEP 5		STEP 6
			L Carbon Stored (Gg C)	M Net Carbon Emissions (Gg C)	N Fraction of Carbon Oxidised	O Actual Carbon Emissions (Gg C)	P Actual CO ₂ Emissions (Gg CO ₂)
FUEL TYPES				M=(K-L)		O=(MxN)	P=(Ox[44/H2])
Liquid Fossil	Primary Fuels	Crude Oil					
		Natural Gas Liquids					
	Secondary Fuels	Gasoline		3,198	0.990	3,166	11,619
		Jet Kerosene		31	0.990	31	114
		Other Kerosene		409	0.990	405	1,486
		Gas / Diesel Oil		5,332	0.990	5,279	19,374
		Residual Fuel Oil		4,955	0.990	4,905	18,001
		LPG		108	0.990	107	393
		Ethane					
		Naphtha					
		Bitumen					
		Lubricants					
		Petroleum Coke					
		Refinery Feedstocks					
		Other Oil					
Liquid Fossil Totals							
Solid Fossil	Primary Fuels	Anthracite					
		Coking Coal					
		Other Bit. Coal ¹					
		Sub-bit. Coal			(0.6·0.99 +		
		Lignite		34,394	0.4·0.95)	33,500	122,945
		Peat					
	Secondary Fuels	BKB & Patent Fuel					
		Coke		37	0.950	35	128
Solid Fossil Totals							
Gaseous Fossil		Natural Gas (Dry)		4,397	0.995	4,375	16,056
Total				52,861		51,803	190,116
Biomass Total							3,182
		Solid biomass					3,182
		Liquid biomass					
		Gas biomass					

¹ If anthracite is not separately available, include with Other Bituminous Coal



MODULE	ENERGY							
SUBMODULE	TRADITIONAL BIOMASS BURNED FOR ENERGY							
WORKSHEET	1-3							
SHEET	1 OF 3							
	STEP 1			STEP 2			STEP 3	
	A	B	C	D	E	F	G	H
	Biomass Consumed (kt dm)	Carbon Fraction of Biomass	Carbon Content (kt dm)	Fraction Oxidised	Total Carbon Released by Biomass Fuels (kt C)	C-CH ₄ Ratio	Carbon Emitted as CH ₄ (kt C)	CH ₄ Emissions from Biomass Burned (Gg CH ₄)
			$C=(A \times B)$		$E=(C \times D)$		$G=(E \times F)$	$H=(G[16/12])$
Wood (for direct use)	151 (a)	0.475	72	0.87	63	0.012	0.756	1.0
Agricultural Wastes	2077	0.440	914	0.88	804	0.005	4.02	5.4
Dung								
Charcoal Consumption	(b)							
Charcoal Production					(c)			
Others (Specify)								
				Total	867			6.4
Charcoal Production								
Input (Wood)	(d)							
Input (Other) ^e								
Output (Charcoal)								
Carbon Released					(c)			
a Total wood consumption from column C of Worksheet 1-2 if used. b Charcoal consumption for energy use. This will be the quantity shown in column A, output (charcoal) adjusted for any charcoal used for non-energy purposes. It will also equal column E, total, of Worksheet 1-2 if used. c Carbon released from charcoal production equals carbon input (wood and other) minus carbon output (charcoal). d Total wood consumption from column G of Worksheet 1-2 if used. e E.g. coconut shells. Please specify.								



MODULE	ENERGY							
SUBMODULE	TRADITIONAL BIOMASS FUEL BURNED FOR ENERGY							
WORKSHEET	1-3							
SHEET	2 OF 3							
	STEP 4			STEP 5				
	I C-CO Trace Gas Emission Ratio	J C Emitted as CO (kt C)	K CO Emitted (Gg CO)	L Nitrogen- Carbon Fuel Ratio	M Total Nitrogen Released (kt N)	N N-N ₂ O Trace Gas Emissions Ratio	O Nitrogen Emitted as N ₂ O (kt N)	P N ₂ O Emitted (Gg N ₂ O)
		$J=(ExI)$	$K=(J \times 28/12)$		$M=(ExL)$		$O=(M \times N)$	$P=(O \times 44/28)$
Wood	0.060	3.78	8.8	0.010	0.63	0.007	0.004	0.006
Agricultural Wastes	0.060	48.24	112.6	0.015	12.06	0.007	0.084	0.132
Dung								
Charcoal Consumption								
Charcoal Production								
Others (Specify)								
		Total	121.4				Total	0.138



MODULE	ENERGY		
SUBMODULE	TRADITIONAL BIOMASS FUEL BURNED FOR ENERGY		
WORKSHEET	1-3		
SHEET	3 OF 3		
	STEP 6		
	Q N-NO _x Trace Gas Emissions Ratio	R Nitrogen Emitted as NO _x (kt N) R=(MxQ)	S NO _x Emitted (Gg of NO _x) S=(Rx46/14)
Wood	0.121	7.623	25.0
Agricultural Wastes	0.121	97.284	319.6
Dung			
Charcoal Consumption			
Charcoal Production			
Others (Specify)			
		Total	344.6



MODULE		ENERGY				
SUBMODULE		METHANE EMISSIONS FROM COAL MINING AND HANDLING				
WORKSHEET		I-4				
SHEET		I OF I				
		STEP 1			STEP 2	
		A Amount of Coal Produced (million t)	B Emission Factor (m ³ CH ₄ /t)	C Methane Emissions (million m ³)	D Conversion Factors (0.67 Gg CH ₄ /10 ⁶ m ³)	E Methane Emissions (Gg CH ₄)
				C=(AxB)		E=(Cx D)
Underground Mines	Mining	32.50	25.0	812.5	0.67	544.4
	Post-Mining	32.50	4.0	130.0	0.67	87.1
Surface Mines	Mining	81.58	2.0	163.2	0.67	109.3
	Post-Mining	81.58	0.2	16.3	0.67	10.9
					Total	751.7



MODULE		ENERGY		
SUBMODULE		METHANE EMISSIONS FROM OIL AND GAS ACTIVITIES (TIER I APPROACH)		
WORKSHEET		I-5		
SHEET		I OF I		
Category	A Activity	B Emission Factor	C CH ₄ Emissions (kg CH ₄) C=(AxB)	D Emissions CH ₄ (Gg CH ₄) D=(C/10 ⁶)
OIL				
Exploration (Optional if data is locally available) ¹	number of wells drilled	kg CH ₄ /well drilled		
Production ²	Pj oil produced 1,125	kg CH ₄ /PJ 2,350	2,643,750	2.6
Transport	Pj oil loaded in tankers	kg CH ₄ /PJ		
Refining	Pj oil refined 900	kg CH ₄ /PJ refined 745	670,500	0.7
Storage	Pj oil refined	kg CH ₄ /PJ refined		
			TOTAL CH₄ FROM OIL	3.3
GAS				
Production ² / Processing	Pj gas produced 244	kg CH ₄ /PJ 227,000	55,388,000	55.4
Transmission and Distribution	Pj gas consumed	kg CH ₄ /PJ		
Other Leakage	Pj gas consumed - non-residential gas consumed (PJ) 291 - Residential gas consumed 53	280,000 140,000	81,480,000 7,420,000	81.5 7.4
			TOTAL CH₄ FROM GAS	144.3
VENTING AND FLARING FROM OIL/GAS PRODUCTION³	Pj oil and gas produced - Oil - Gas - 244 - Combined	kg CH ₄ /PJ 18,000	4,392,000	4.4
			TOTAL CH₄ EMISSIONS FROM OIL AND GAS	152.0
¹ Emission Factors are not provided. ² If using default emission factors these categories will include emissions from production other than venting and flaring. ³ If using default emission factors, emissions from venting and flaring from all oil and production should be accounted for here.				



MODULE	INDUSTRIAL PROCESSES		
SUB MODULE	CO₂ FROM CEMENT PRODUCTION		
WORKSHEET	2-1		
SHEET	1 OF 1		
STEP 1		STEP 2	
A Amount of Clinker or Cement Produced: (t)	B Emissions Factor (t CO ₂ /t Clinker or Cement Produced)	C CO ₂ emitted: (t)	D CO ₂ emitted: (Gg)
		$C=(A \times B)$	$D=C/1000$
8,301,200	0.4985	4,138,148	4,138



MODULE		AGRICULTURE				
SUBMODULE		METHANE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC FERMENTATION AND MANURE MANAGEMENT				
WORKSHEET		4-1				
SHEET		1 OF 1				
Livestock Type	A Number of Animals (1000s)	B Emissions Factor for Enteric Fermentation (kg/head/year)	C Emissions from Enteric Fermentation (t/year)	D Emissions Factor for Manure Management (kg/head/year)	E Emissions from Manure Management (t/year)	F Total Annual Emissions from Domestic Livestock (Gg)
			$C=(A \times B)$		$E=(A \times D)$	$F=(C+E)/1000$
Dairy Cattle	3,368.0	56	188,608	16	53,888	242,496
Non-Dairy Cattle	6,389.3	44	281,129	1	6,389	287,518
Buffalo						
Sheep						
Goats	36,660.5	5	183,303	0.16	5,866	189,169
Camels	143.0	46	6,578	1.9	272	6,850
Horses	1,666.4	18	29,995	1.6	2,666	32,661
Mules & Asses						
Swine	2,976.1	1	2,976	4	11,904	14,880
Poultry	58,898.8			0.018	1,060	1,060
		Totals	692,589		82,045	774,634



MODULE	AGRICULTURE				
SUBMODULE	METHANE EMISSIONS FROM FLOODED RICE FIELDS				
WORKSHEET	4-2				
SHEET	1 OF 1				
	STEP 1			STEP 2	
Water Management Regime	A Harvested Area (Mha)	B Season Length (days)	C Megahectare-Days (Mha-days)	D Emission Factor (kg/ha-day)	E CH ₄ Emissions by Water Management (Gg)
			$C = (A \times B)$		$E = (C \times D)$
Continuously Flooded					
Intermittently Flooded	0.12	115	13.8	4.22	58.2
Totals	0.12				58.2



MODULE			LAND USE CHANGE AND FORESTRY				
SUBMODULE			CHANGES IN FOREST AND OTHER WOODY BIOMASS STOCKS				
WORKSHEET			5-1				
SHEET			1 OF 3				
			STEP 1				
			A	B	C	D	E
			Area of Forest/Biomass Stocks (kha)	Annual Growth Rate (t dm/ha)	Annual Biomass Increment (kt dm)	Carbon Fraction of Dry Matter	Total Carbon Uptake Increment (kt C)
					$C=(A \times B)$		$E=(C \times D)$
Tropical	Plantations	Acacia spp.					
		Eucalyptus spp.					
		Tectona grandis					
		Pinus spp					
		Pinus caribaea					
		Mixed Hardwoods					
		Mixed Fast- Growing Hardwoods					
		Mixed Softwoods					
		Other Forests	Moist				
	Seasonal						
	Dry						
	Other (specify)						
Temperate	Plantations	Douglas fir					
		Loblolly pine					
	Commercial	Evergreen					
		Deciduous					
	Other						
Boreal			8,199	0.6351	5,207	0.45	2,343
Non-Forest Trees (specify type)			A Number of Trees (1000s of trees)	B Annual Growth Rate (kt dm/1000 trees)			
						Total	2,343

5.23



MODULE		LAND USE AND FORESTRY	
SUBMODULE		CHANGES IN FOREST AND OTHER WOODY BIOMASS STOCKS	
WORKSHEET		5-1	
SHEET		3 OF 3	
STEP 3			
N	O	P	Q
Carbon Fraction	Annual Carbon Release	Net Annual Carbon Uptake (+) or Release (-)	Convert to CO ₂ Annual Emission (-) or Removal (+)
	(kt C)	(kt C)	(Gg CO ₂)
	$O=(M \times N)$	$P=(E-O)$	$Q=(P \times [44/12])$
0.45	1,081	+ 1,262	+ 4,627



MODULE				LAND USE CHANGE AND FORESTRY				
SUBMODULE				FOREST AND GRASSLAND CONVERSION				
WORKSHEET				5-2				
SHEET				1 OF 6				
STEP 1								
Land types				A	B	C	D	E
				Area Converted Annually (kha)	Biomass Before Conversion (t dm/ha)	Biomass After Conversion (t dm/ha)	Net Change in Biomass Density (t dm/ha)	Annual Loss of Biomass (kt dm)
							D=(B-C)	E=(AxD)
Tropical	Moist Forests	Primary						
		Secondary						
	Seasonal Forests	Primary						
		Secondary						
	Dry Forests or Woody Savannas	Primary						
		Degraded						
Temperate	Evergreen:	Primary						
		Secondary						
	Deciduous	Primary						
		Secondary						
Boreal	Primary		3,215	151.5	10.0	141.5	455	
	Secondary							
Grassland								
Other								



MODULE			LAND USE CHANGE AND FORESTRY						
SUBMODULE			FOREST AND GRASSLAND CONVERSION						
WORKSHEET			5-2						
SHEET			2 OF 6						
STEP 2									
Land types				F	G	H	I	J	K
				Fraction of Biomass Burned On Site	Quantity of Biomass Burned On Site (kt dm)	Fraction of Biomass Oxidised On Site	Quantity of Biomass Oxidised On Site (kt dm)	Carbon Fraction of Above-ground Biomass (burned on site)	Quantity of Carbon Released (from biomass burned) (kt C)
					G=(ExF)		I=(GxH)		K=(IxJ)
Tropical	Moist Forests	Primary							
		Secondary							
	Seasonal Forests	Primary							
		Secondary							
	Dry Forests or Woody Savannas	Primary							
		Degraded							
Temperate	Evergreen:	Primary							
		Secondary							
	Deciduous	Primary							
		Secondary							
Boreal	Primary		0.3	136.5	0.9	122.9	0.45	55.3	
	Secondary								
Grassland									
Other									
							Subtotal	55.3	



MODULE			LAND USE CHANGE AND FORESTRY								
SUBMODULE			FOREST AND GRASSLAND CONVERSION								
WORKSHEET			5-2								
SHEET			3 OF 6								
			STEP 3						STEP 4		
Land types			L	M	N	O	P	Q	R	S	
			Fraction of Biomass Burned Off Site	Quantity of Biomass Burned Off Site	Fraction of Biomass Oxidised Off Site	Quantity of Biomass Oxidised Off Site	Carbon Fraction of Above-ground Biomass (burned off site)	Quantity of Carbon Released (from biomass burned off site)	Total Carbon Released (from on & off site burning)	Total CO ₂ released (from on & off site burning)	
				(kt dm)		(kt dm)		(kt C)	(kt C)	(kt CO ₂)	
				M=(ExL)		O=(MxN)		Q=(OxP)	R=(K+Q)	S= Rx[44/12]	
Tropical	Moist Forests	Primary									
		Secondary									
	Seasonal Forests	Primary									
		Secondary									
	Dry Forests or Woody Savannas	Primary									
		Degraded									
Temperate	Evergreen:	Primary									
		Secondary									
	Deciduous	Primary									
		Secondary									
Boreal	Primary		0.15	68.3	0.9	61.4	0.45	27.6			
	Secondary										
Grassland											
Other											
			Subtotal	68.3			Subtotal	27.6	82.9	304	



MODULE				LAND USE CHANGE AND FORESTRY								
SUBMODULE				FOREST AND GRASSLAND CONVERSION								
WORKSHEET				5-2								
SHEET				4 OF 6								
				STEP 5								
Land types				A	B	C	D	E	F	G	H	I
				Average Area Converted (10 Year Average)	Biomass Before Conversion	Biomass After Conversion	Net Change in Biomass Density	Average Annual Loss of Biomass	Fraction Left to Decay	Quantity of Biomass Left to Decay	Carbon Fraction in Above-ground Biomass	C Released from Decay of Above-ground Biomass
				(kha)	(t dm/ha)	(t dm/ha)	(t dm/ha)	(kt dm)		(kt dm)		(kt C)
							D=(B-C)	E=(AxD)		G=(ExF)		I=(GxH)
Tropical	Moist Forests	Primary										
		Secondary										
	Seasonal Forests	Primary										
		Secondary										
	Dry Forests or Woody Savannas	Primary										
		Degraded										
Temperate	Evergreen:	Primary										
		Secondary										
	Deciduous	Primary										
		Secondary										
Boreal	Primary			3.215	151.5	10.0	141.5	455	0.55	250	0.45	112.6
	Secondary											
Grassland												
Other												
											Subtotal	112.6



MODULE		LAND USE CHANGE AND FORESTRY		
SUBMODULE		FOREST AND GRASSLAND CONVERSION		
WORKSHEET		5-2		
SHEET		6 OF 6		
STEP 7				
A Immediate Release From Burning (kt C)	B Delayed Emissions From Decay (kt C) (10-year average)	C Long Term Emissions From Soil (kt C) (25-year average)	D Total Annual Carbon Release (kt C)	E Total Annual CO ₂ Release (Gg CO ₂)
			D=(A+B+C)	E=(Dx[44/12])
55.3	112.6	—	167.9	616.2



MODULE		LAND USE CHANGE AND FORESTRY					
SUBMODULE		ON-SITE BURNING OF FORESTS					
WORKSHEET		5-3					
SHEET		1 OF 1					
STEP 1			STEP 2				
A Quantity of Carbon Released (kt C)	B Nitrogen-Carbon Ratio	C Total Nitrogen Released (kt N)		D Trace Gas Emissions Ratios	E Trace Gas Emissions (kt C)	F Conversion Ratio	G Trace Gas Emissions from Burning of Cleared Forests (Gg CH ₄ , CO)
(From column K, sheet 2, of Worksheet 5-2)		C=(AxB)			E=(AxD)		G=(ExF)
			CH ₄	0.012	0.66	16/12	0.88
			CO	0.06	3.32	28/12	7.74
					kt N		Gg N ₂ O, NO _x
55.3	0.01	0.55			E=(CxD)		G=(ExF)
			N ₂ O	0.007	0.004	44/28	0.006
			NO _x	0.121	0.07	46/14	0.143



MODULE		LAND USE CHANGE AND FORESTRY				
SUBMODULE		ABANDONMENT OF MANAGED LANDS				
WORKSHEET		5-4				
SHEET		1 OF 3				
		STEP 1				
Regrowth Land Type		A 20 Year Total Area Aban- doned and Regrowing (kha)	B Annual Rate of Above- ground Biomass Growth (t dm/ha)	C Annual Aboveground Biomass Growth (kt dm)	D Carbon Fraction of Aboveground Biomass	E Annual Carbon Uptake in Aboveground Biomass (kt C)
				$C=(A \times B)$		$E=(C \times D)$
Tropical Forests	Moist					
	Seasonal					
	Dry					
Temperate Forests	Evergreen					
	Deciduous					
Boreal Forest		408	0.6351	259	0.45	117
Grasslands						
Other						
					Subtotal	



MODULE		LAND USE CHANGE AND FORESTRY						
SUBMODULE		ABANDONMENT OF MANAGED LANDS						
WORKSHEET		5-4						
SHEET		2 OF 3						
		STEP 2			STEP 3			
Regrowth Land Type		F Annual Rate of Uptake of Carbon in Soils (t C/ha)	G Total Annual Carbon Uptake in Soils (less than 20 years) (kt C)	H Total Area Abandoned More than Twenty Years (kha)	I Annual Rate of Above- ground Biomass Growth (t dm/ha)	J Annual Above- ground Biomass Growth (kt dm)	K Carbon Fraction of Above- ground Biomass	L Annual Carbon Uptake in Aboveground Biomass (kt C)
			$G=(A \times F)$			$J=(H \times I)$		$L=(J \times K)$
Tropical Forests	Moist							
	Seasonal							
	Dry							
Temperate Forests	Evergreen							
	Deciduous							
Boreal Forest		2.0	816	572				
Grasslands								
Other								
		Subtotal					Subtotal	



MODULE		LAND USE CHANGE AND FORESTRY			
SUBMODULE		ABANDONMENT OF MANAGED LANDS			
WORKSHEET		5-4			
SHEET		3 OF 3			
		STEP 4		STEP 5	
Regrowth Land Type		M Annual Rate of Uptake of Carbon in Soils (t C/ha)	N Total Annual Carbon Uptake in Soils (kt C)	O Total Carbon Uptake from Abandoned Lands (kt C)	P Total Carbon Dioxide Uptake (Gg CO ₂)
			$N=(H \times M)$	$O=(E+G+L+N)$	$P=(O \times [44/12])$
Tropical Forests	Moist				
	Seasonal				
	Dry				
Temperate Forests	Evergreen				
	Deciduous				
Boreal Forest		1.0	572		
Grasslands					
Other					
		Subtotals	572	1505	5,523



MODULE		WASTE								
SUBMODULE		METHANE EMISSIONS FROM LANDFILLS								
WORKSHEET		6-1								
SHEET		1 OF 1								
STEP 1		STEP 2			STEP 3					
A	B	C	D	E	F	G	H	I	J	K
Annual MSW Landfilled (Specify sub-categories if any) (Gg)	Fraction DOC	Annual DOC Landfilled (Gg)	Fraction Which Actually Degrades	Annual Carbon Released as Biogas (Gg)	Fraction C-CH ₄ to C-Biogas	Annual Carbon Released as CH ₄ (Gg C)	Conversion Ratio (I6/I2)	CH ₄ Released (Gg CH ₄)	CH ₄ Recovered (Gg CH ₄)	Net CH ₄ Emissions (Gg CH ₄)
		$C=(A \times B)$		$E=(C \times D)$		$G=(E \times F)$		$I=(G \times H)$		$K=(I-J)$
1478	0.15	222	0.75	167	0.5	84	1.3	109	—	109



MODULE		WASTE		
SUBMODULE		METHANE EMISSIONS FROM LANDFILLS		
WORKSHEET		6-1 (SUPPLEMENTAL)		
SHEET		1 OF 1		
A	B	C	D	E
Population (or Urban Population) (Specify sub- categories if any) (10 ⁶ persons)	Waste Gen- eration Rate (Gg MSW/10 ⁶ persons/year)	Waste Generated (Gg MSW)	Fraction Landfilled	Annual MSW Landfilled (Gg MSW)
		$C=(A \times B)$		$E=(C \times D)$
10.150	182	1,847	0.8	1,478



MODULE		WASTE						
SUBMODULE		METHANE EMISSIONS FROM DOMESTIC AND COMMERCIAL WASTEWATER TREATMENT						
WORKSHEET		6-2						
SHEET		1 OF 1						
STEP 1			STEP 2				STEP 3	
A	B	C	D	E	F	G	H	I
Population (Specify sub-categories if any) (1,000 persons)	Wastewater BOD Value (Gg BOD ₅ / 1,000 persons / year)	Annual BOD (Gg BOD ₅)	Fraction Wastewater Anaerobically Treated	Quantity of BOD from Anaerobically Treated Wastewater (Gg BOD ₅)	Methane Emissions Factor (Gg CH ₄ / Gg BOD ₅)	Total CH ₄ Released (Gg CH ₄)	Methane Recovered (Gg CH ₄)	Net CH ₄ Emissions (Gg CH ₄)
		$C=(A \times B)$		$E=(C \times D)$		$G=(E \times F)$		$I=(G-H)$
10,150	0.0146	148.2	0.10	14.8	0.22	3.3	—	3.3

STANDARD DATA TABLE I

Energy: 1A Fuel Combustion Activities (Sheet 4) - Detailed Technology Based Calculation[illegible]

STANDARD DATA TABLE I

Energy: 1A Fuel Combustion Activities (Sheet 5) - Detailed Technology Based Calculation

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSIONS ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data by fuel	A Consumption (PJ)	B Quantities Emitted (Gg of Full Mass of Pollutant)						C Emission Factors (t Pollutant/TJ)					
		C=B/A											
		CO ₂	CH ₄	N ₂ O	NO _x	CO	NMVOC	CO ₂	CH ₄	N ₂ O	NO _x	CO	NMVOC
1A1b Petroleum Refining*	15.713	1052	—	0.006	5.2	31.6	—	66.957	—	0.0004	0.331	2.011	—
(Where appropriate, choose relevant fuels from section 1.2 of the Reporting instructions)													
Residual Fuel Oil	8.380	642		0.005				76.658		0.0006			
Natural Gas (Dry)	7.333	410		0.0007				55.871		0.0001			

* Record here the consumption and emissions resulting from the combustion of each of the fuels used in refineries.

STANDARD DATA TABLE I

Energy: 1A Fuel Combustion Activities (Sheet 7) - Detailed Technology Based Calculation[illegible]

STANDARD DATA TABLE I

Energy: 1A Fuel Combustion Activities (Sheet 8) - Detailed Technology Based Calculation

[illegible]

STANDARD DATA TABLE I

Energy: 1A Fuel Combustion Activities (Sheet 10) - Detailed Technology Based Calculation[illegible]

STANDARD DATA TABLE I

Energy: 1A Fuel Combustion Activities (Sheet 12) - Detailed Technology Based Calculation[illegible]

STANDARD DATA TABLE I

Energy: 1A Fuel Combustion Activities (Sheet 16) - Traditional Biomass Burned for Energy

SECTOR SPECIFIC DATA (UNITS)	ACTIVITY DATA	EMISSIONS ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (units)	A Apparent Consumption (kt dm)	B Quantities Emitted (Gg)						C Emission Factor (t / t dm) C=B/A					
		CO ₂	CH ₄	N ₂ O	NO _x	CO	NMVOC	CO ₂	CH ₄	N ₂ O	NO _x	CO	NMVOC
Fuelwood	151	231.2	1.0	0.006	25.0	8.8	—	1.531	0.007	0.00004	0.166	0.058	—
Agricultural Wastes	2077	2950.7	5.4	0.132	319.6	112.6	—	1.421	0.003	0.00006	0.154	0.054	
Dung													
Charcoal Consumption													
Charcoal Production													
Other (specify)													

Note: CO₂ emissions from biomass, although reported, should not be included in national total CO₂ emissions.

APPENDIX 3. IPCC REPORTING TABLES

STANDARD DATA TABLE I

Energy: 1A Fuel Combustion Activities (Sheet 2) - Detailed Technology Based Calculation[illegible]

STANDARD DATA TABLE I

Energy: 1A Fuel Combustion Activities (Sheet 3) - Detailed Technology Based Calculation[illegible]

STANDARD DATA TABLE I

Energy: I B I Fugitive Emissions from Fuels (Coal Mining)

SOURCE AND SINK CATEGORIES	A ACTIVITY DATA Production (Mt)	B METHANE EMISSIONS (Gg)	C EMISSION FACTOR (m ³ /t) C = B/A
I B I Solid Fuels	114.08	751.7	6.589
I B I a Coal Mining	114.08	751.7	6.589
I B I a i Underground Mines	32.50	631.5	19.431
Underground activities	32.50 ditto	544.4	16.751
Post-mining activities	32.50 ditto	87.1	2.680
I B I a ii Surface Mines	81.58	120.2	1.473
Surface Activities	81.58 ditto	109.3	1.340
Post-mining activities	81.58 ditto	10.9	0.134
I B I b Solid Fuel Transformation			
I B I c Other			

STANDARD DATA TABLE I

Energy: I B 2 Fugitive Emissions from Fuels (Oil and Natural Gas)

SOURCE AND SINK CATEGORIES		ACTIVITY DATA	EMISSIONS ESTIMATES			AGGREGATE EMISSION FACTORS		
		Fuel Quantity (PJ)	CH ₄ (Gg)	CO ₂ (Gg)	NMVOC (Gg)	CH ₄ (kg/GJ)	CO ₂ (kg/GJ)	NMVOC (kg/GJ)
I B 2 a Oil			3.3					
i Exploration	(no. of wells drilled)	(1)				(1)	(1)	(1)
ii Production of Crude Oil		1,125	2.6			0.002		
iii Transport of Crude Oil	(Qty. loaded on tankers)							
iv Refining/Storage	(Qty. refined)	900	0.7			0.001		
v Distribution of Oil Products ²	(Qty. consumed)							
vi Other								
I B 2 b Natural Gas			144.3					
i Production/Processing	(Qty. produced)	244	55.4			0.227		
ii Transmission/ Distribution	(Qty. consumed)							
iii Other Leakage	(Qty. consumed)	344	88.9			0.258		
I B 2 c Venting and Flaring			4.4					
i Oil	(Qty. produced)							
ii Natural Gas	(Qty. produced)	244	4.4			0.018		
iii Combined	(Qty. produced)							

¹ Activity data represents the number of wells. Emission factors are Gg/well.

² Primarily related to NMVOC emissions. See detailed Standard Data Table (I B 2 Supplement) to report data by fuel product.

STANDARD DATA TABLE 2

Industrial Processes

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES										AGGREGATE EMISSION FACTORS									
	A Production Quantity (kt)	B Full Mass of Pollutant (Gg)										C Tonne of pollutant per tonne of Product (t / t)									
		CO	CO ₂	CH ₄	N ₂ O	NO _x	NMVOC	HFCs	PFCs	SF ₆	CO	CO ₂	CH ₄	N ₂ O	NO _x	NMVOC	HFCs	PFCs	SF ₆		
A Iron and Steel																					
B Non-Ferrous Metals																					
Aluminium Production																					
Other																					
C Inorganic Chemicals (excepting solvent use)																					
Nitric Acid																					
Fertiliser Production																					
Other																					
D Organic Chemicals																					
Adipic Acid																					
Other																					
E Non-Metallic Mineral Products																					
Cement	8,301.2		4,138									0.498									
Lime																					
Other	306.7	134.0	210.5									0.437	0.686								
F Other (ISIC)																					

The IPCC Guidelines do not provide methodologies for the calculation of emissions of HFCs, PFCs or SF₆ from industrial processes. If you have reported such data, you should provide additional information (activity data and emission factors) used to make these estimates.

STANDARD DATA TABLE 4

Agriculture: 4A&B Enteric Fermentation & Manure Management

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSION ESTIMATES		AGGREGATE EMISSION FACTOR	
	A	B		C	
	Number of Animals	Enteric Fermentation	Manure Management	Enteric Fermentation	Manure Management
	(1000)	(Gg CH ₄)		(kg CH ₄ per head per year)	
				C=(B/A) X 1000	
1 Cattle					
a Dairy	3,368.0	188.608	53.888	56	16
b Non-Dairy	6,389.3	281.129	6.389	44	1
2 Buffalo					
3 Sheep					
4 Goats	36,660.5	183.303	5.866	5	0.16
5 Camels and Llamas	143.0	6.578	272	46	1.9
6 Horses	1,666.4	29.995	2.666	18	1.6
7 Mules/Asses					
8 Swine	2,976.1	2.976	11.904	1	4
9 Poultry	58,898.8		1.060		0.018
10 Other					

STANDARD DATA TABLE 4

Agriculture: 4C Rice Cultivation - Flooded Rice Fields

SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSION ESTIMATES	AGGREGATE EMISSION FACTOR
	A Area Cultivated in Megahectares (Mha)	B Megahectare- Days of Cultivation (Mha-days)	C Methane (Gg CH ₄)	D CH ₄ Average Emission Factor (kg CH ₄ per ha-day) D=C/B
1 Continuously Flooded				
2 Intermittently Flooded	0.12	13.8	58.2	4.22
3 Other				

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5A (Sheet 1) Changes in Forest and Other Woody Biomass Stocks - Annual Growth Increment

SOURCE AND SINK CATEGORIES			ACTIVITY DATA	UPTAKE ESTIMATES	AGGREGATE UPTAKE FACTOR
Sector Specific Data (units) Land Type			A Area of Forest/Biomass Stocks (kha)	B Total Carbon Uptake Increment (Gg C)	C Carbon Uptake Factor (t C/ha) C=B/A
Tropical Forests	Plantations (specify type)				
	Other Managed Forests	Moist			
		Seasonal			
		Dry (or Woody Savannas)			
Other					
Temperate Forests	Plantations (specify type)				
	Commercial	Evergreen			
		Deciduous			
Other					
Boreal Forests			81.99	2,343	28.577
Other Ecosystem Types					
Non-Forest Trees (specify type)			Number of Trees (1000)	Annual Carbon Uptake (Gg C)	Carbon Uptake Factor (t C/tree) C=B/A

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5A (Sheet 2) Changes in Forest and Other Woody Biomass Stocks - Annual Harvest

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	CARBON EMISSION ESTIMATES	AGGREGATE EMISSION FACTORS
Sector Specific Data (units)	A Amount of Biomass Removed (kt dm)	B Carbon Emission/Removal Estimates (Gg C)	C Carbon Emission Factors (t C/ t dm)
			C=B/A
Total Biomass Removed in Commercial Harvest			
Traditional Fuelwood Consumed			
Total Other Wood Use			
Total Biomass Consumption	2,402.3	1,262	0.525

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5A (Sheet 3) Changes in Forest and Other Woody Biomass Stocks - Net CO₂ Emissions/Removals

SOURCE AND SINK CATEGORIES	A EMISSIONS/UPTAKE C (Gg)	B EMISSIONS/REMOVALS CO ₂ (Gg)
		B = Ax(44/12)
Total Annual Growth Increment		
Total Annual Harvest		
NET EMISSIONS (+) OR REMOVALS (-) ¹	- 1,262	- 4,627

¹ Please put this estimate of "net" emissions of CO₂ in either the CO₂ emissions or CO₂ removals column of the Summary Report (Table 7A), as appropriate. Please note that for the purposes of reporting, the signs for uptake are changed from (+) in the Worksheets to (-) for these standard summary data tables. Similarly the signs for emissions are changed from (-) to (+).

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5B (Sheet 1) Forest and Grassland Conversion - CO₂ Release from Burning Aboveground Biomass

SOURCE AND SINK CATEGORIES			ACTIVITY DATA				EMISSIONS ESTIMATES		AGGREGATE EMISSIONS FACTOR	
Sector Specific Data (units) Land Types			A Area Converted Annually (kha)	B Annual Loss of Biomass (kt dm)	C Quantity of Biomass Burned (on and off-site) (kt dm)		D Quantity of C Released (kt C)		E Carbon Fraction of Biomass Burned	
									E=D/C	
					On Site	Off Site	On Site	Off Site	On Site	Off Site
Tropical Forests	Moist	Primary								
		Secondary								
	Seasonal	Primary								
		Secondary								
	Dry (or Woody Savannas)	Primary								
		Degraded								
Temperate Forests	Evergreen	Primary								
		Secondary								
	Deciduous	Primary								
		Secondary								
Boreal Forests		Primary	3.215	455	136.5	68.3	55.3	27.6	0.405	0.404
		Secondary								
Grasslands										
Other (specify)										
Total C Released										
Total of On Site and Off Site C Released							82.9			
Total CO ₂ Released (44/12 x C Released)							304.0	(1)		

1 Add total to Sheet 5

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5B (Sheet 2) Forest and Grassland Conversion - Release of Non-CO₂ GHG from On-Site Burning of Forests

SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSIONS ESTIMATES				AGGREGATE EMISSION RATIOS			
Sector Specific Data (units) Land Types	A Carbon Release ¹ (Gg)	B Nitrogen Release (Gg)	C Emissions Estimates (Gg)				D Aggregate Emissions Ratios			
							D=C/A		D=C/B	
			CH ₄	CO	N ₂ O	NO _x	CH ₄	CO	N ₂ O	NO _x
On-Site Burning of Forests	55.3	0.55	0.88	7.74	0.006	0.143	0.016	0.140	0.011	0.260

¹ Should agree with Column D, Table 5B (Sheet 1)

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5C (Sheet 1) Abandonment of Managed Lands - Annual Carbon Uptake from Lands Abandoned Over the Previous 20 Years

SOURCE AND SINK CATEGORIES		AVERAGE ANNUAL TOTAL AREA ABANDONED (PREVIOUS 20 YEARS)			ANNUAL CARBON UPTAKE ESTIMATES			AGGREGATE ANNUAL RATE OF UPTAKE	
Sector Specific Data (units) Land Type		A Total Area Abandoned (Previous 20 Years) (kha)	B Annual Rate of Aboveground Biomass Growth (t dm / ha)	C Carbon Fraction of Aboveground Biomass	D Aboveground Biomass Carbon Uptake (Gg C / yr)	E Soil Carbon Uptake (Gg C / yr)	F Total (Gg C)	G Rate of Aboveground Biomass Carbon Uptake (t C / ha / yr)	H Rate of Soil Carbon Uptake (t C / ha / yr)
							F=D+E	G= D/A	H=E/A
Tropical Forests	Moist								
	Seasonal								
	Dry (or Woody Savannas)								
Temperate Forests	Evergreen								
	Deciduous								
Boreal Forests		408	0.6351	0.45	117	816	933	0.287	2.0
Grasslands									
Other (specify)									
Total Carbon Uptake									

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5C (Sheet 2) Abandonment of Managed Lands - Annual Carbon Uptake from Lands Abandoned For More Than 20 Years

SOURCE AND SINK CATEGORIES		AVERAGE ANNUAL TOTAL AREA ABANDONED (20 - 100 YEARS AGO)			ANNUAL CARBON UPTAKE ESTIMATES			AGGREGATE ANNUAL RATE OF UPTAKE	
Sector Specific Data (units) Land Type		A Total Area Abandoned (Longer than 20 Years) (kha)	B Annual Rate of Aboveground Biomass Growth (t dm / ha)	C Carbon Fraction of Aboveground Biomass	D Aboveground Biomass Carbon Uptake (Gg C / yr)	E Soil Carbon Uptake (Gg C / yr)	F Total (Gg C / yr) F=D+E	G Rate of Aboveground Biomass Carbon Uptake (t C / ha / yr) G= D/A	H Rate of Soil Carbon Uptake (t C / ha / yr) H=E/A
Tropical Forests	Moist								
	Seasonal								
	Dry (or Woody Savannas)								
Temperate Forests	Evergreen								
	Deciduous								
Boreal Forests		572			572	572			1.0
Grasslands									
Other (specify)									
Total Carbon Uptake									

STANDARD DATA TABLE 5

Land Use Change & Forestry: 5C (Sheet 3) Abandonment of Managed Lands - Total CO₂ Removals

SINK CATEGORY	A Carbon Uptake (Gg C)	B CO ₂ Removals (Gg CO ₂) B=A x (44/12)
Lands Abandoned Over the Previous 20 Years	933	3,421
Lands Abandoned Between 20 + 100 years previously	572	2,097
Total	1,505	5,518

STANDARD DATA TABLE 6

Waste: 6A Solid Waste Disposal on Land, 6 C Waste Incineration, 6 D Other Waste

SOURCE/SINK CATEGORIES	ACTIVITY DATA Gg	EMISSION ESTIMATES						AGGREGATE EMISSION FACTORS						CH ₄ RECOVERED Gg
		Gg						kg/t						
Disposal Method	A	B ¹ CO ₂	C CH ₄	D	E	F	G	H ¹ CO ₂	I CH ₄	J	K	L	M	N
	Annual DOC Landfilled (Gg)							$\frac{1000B}{A}$	$\frac{1000C}{A}$					
A1 Landfills	222		109						491					
A2 Open Dumps														
	Quantity of Waste Treated (Gg)	CO ₂	CH ₄	N ₂ O	NO _x	CO	NMVOC	CO ₂ $\frac{1000B}{A}$	CH ₄ $\frac{1000C}{A}$	N ₂ O $\frac{1000D}{A}$	NO _x $\frac{1000E}{A}$	CO $\frac{1000F}{A}$	NMVOC $\frac{1000G}{A}$	
C Waste Incineration														
D Other Waste														

¹ Note that CO₂ from Waste Disposal or Incineration should only be included if it stems from non-biologic or inorganic waste sources.

STANDARD DATA TABLE 6

Waste: 6B Wastewater Treatment

SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSION ESTIMATES			AGGREGATE EMISSIONS FACTORS			CH ₄ RECOVERED
Wastewater Type	A	B	C	D	E	F	G	H	I
	Annual BOD (Gg BOD ₅)	Quantity of BOD Anaerobically Treated (Gg BOD ₅)	Total Methane Released (Gg)	Carbon Dioxide (Gg)	Nitrous Oxide (Gg)	(Gg CH ₄ /Gg BOD ₅) F = C/B	(Gg CO ₂ /Gg BOD ₅) G = D/B	Gg N ₂ O/Gg BOD ₅) H = E/B	Quantity CH ₄ (Gg)
B 1 Industrial Wastewater									
B 2 Domestic and Commercial Wastewater	148.2	14.8	3.3			0.223			
B 3 Other									

TABLE 7A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (SHEET 1)										
(Gg)										
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂ Emissions	CO ₂ Removals	CH ₄	N ₂ O	NO _x	CO	NMVOC	HFCs	PFCs	SF ₆
Total National Emissions and Removals	190,466		1,862	2	1,198	3,108	260			
I All Energy (Fuel Combustion + Fugitive)	190,128		916	2	1,198	2,966	260			
A Fuel Combustion	190,128		12	2	1,198	2,966	260			
1 Energy & Transformation Industries	94,211			1	253	39				
2 Industry (ISIC)	32,275			0.4	43	623				
3 Transport	32,471		6	0.6	474	2,016	260			
4 Small Combustion	31,171		0.2		83	167				
5 Other										
6 Traditional Biomass Burned for Energy	(3182)		6	0.1	345	121				
B Fugitive Emissions from Fuels			904							
1 Solid Fuels			752							
2 Oil and Natural Gas			152							
2 Industrial Processes	4349					134				
3 Solvent and Other Product Use										

TABLE 7A SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (SHEET 2)										
(Gg)										
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂ Emissions	CO ₂ Removals	CH ₄	N ₂ O	NO _x	CO	NMVOC	HFCs	PFCs	SF ₆
4 Agriculture			833							
A Enteric Fermentation			693							
B Manure Management			82							
C Rice Cultivation			58							
D Agricultural Soils	(1)	(1)								
E Prescribed Burning of Savannas										
F Field Burning of Agricultural Residues										
G Other										
5 Land Use Change & Forestry	(1)	(4011) (1)	1	0.01	0.1	8				
A Changes in Forest and Other Woody Biomass Stocks	(1)	(4627) (1)								
B Forest and Grassland Conversion	(616)		1	0.01	0.1	6				
C Abandonment of Managed Lands	(1)	(1)								
D Other										
6 Waste			112							
A Solid Waste Disposal on Land			109							
B Wastewater Treatment			3							
C Waste Incineration										
D Other Waste										
7 Other										
International Bunkers										

¹ Please do not attempt to provide an estimate of both CO₂ emissions and CO₂ removals. Instead, you should estimate "net" emissions of CO₂ and place a single number in either the CO₂ emissions or CO₂ removals column, as appropriate.

TABLE 7B SHORT SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES

SHORT SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES										
(Gg)										
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂ Emissions	CO ₂ Removals	CH ₄	N ₂ O	NO _x	CO	NMVOC	HFCs	PFCs	SF ₆
Total National Emissions and Removals	190,466		1227	2	1,198	3,108	260			
1 All Energy (Fuel Combustion + Fugitive)	190,128		281	2	1,198	2,966	260			
A Fuel Combustion	190,128		12	2	1,198	2,966	260			
B Fugitive Fuel Emission			904							
2 Industrial Processes	4349					134				
3 Solvent and Other Product Use										
4 Agriculture			833							
5 Land Use Change & Forestry	(1)	4,011 (1)	1	0.01	0.1	8				
6 Waste			112							
7 Other										
International Bunkers										

¹ Please do not attempt to provide an estimate of both CO₂ emissions and CO₂ removals. Instead, you should estimate "net" emissions of CO₂ and place a single number in either the CO₂ emissions or CO₂ removals column, as appropriate.

TABLE 8A OVERVIEW TABLE FOR NATIONAL GREENHOUSE GAS INVENTORIES

OVERVIEW TABLE (SHEET 1)																					
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂		CH ₄		N ₂ O		NO _x		CO		NMVOC		HFCs		PFCs		SF ₆		Documentation	Disaggregation	Footnotes
	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality			
Total National Emissions and Removals	PART	M	PART	M	PART	H	PART	M	PART	M	PART	L	NE		NE		NE		M	1	
I All Energy (Fuel Combustion + Fugitive)	PART	M	PART	M	PART	H	PART	M	PART	M	PART	L							M	1	
A Fuel Combustion	PART	M	PART	M	PART	H	PART	M	PART	M	PART	L							M	1	
1 Energy & Transformation Industries	ALL	H	NE		ALL	H	ALL	M	ALL	M	NE								M	3	
2 Industry (ISIC)	PART	M	NE		PART	H	ALL	H	ALL	H	NE								M	3	
3 Transport	PART	M	PART	M	PART	H	PART	M	PART	M	PART	M							M	1	
4 Small Combustion	PART	M	PART	M	PART	H	PART	M	PART	M	NE								M	1	
5 Other	NE		NE		NE		NE		NE		NE										
6 Traditional Biomass Burned for Energy	PART	M	PART	M	PART	H	PART	M	PART	M	NE								M	1	
B Fugitive Emissions from Fuels	NE		PART	M	NE		NE		NE		NE								M	3	
1 Solid Fuels	NE		ALL	H															M	3	
2 Oil and Natural Gas	NE		PART	L															M	3	
2 Industrial Processes	PART	L	NE		NE		NE		PART	L	NE								M	2	
3 Solvent and Other Product Use	NE		NE		NE		NE		NE		NE										

TABLE 8A OVERVIEW TABLE FOR NATIONAL GREENHOUSE GAS INVENTORIES

OVERVIEW TABLE (SHEET 2)																						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂		CH ₄		N ₂ O		NO _x		CO		NMVOC		HFCs		PFCs		SF ₆		Documen- tation	Disaggreg- ation	Footnotes	
	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality	Estimate	Quality				
4 Agriculture	IE	L	ALL	H	IE	L	IE	L	NE		NE								M	1		
A Enteric Fermentation			ALL	H															M	1		
B Animal Wastes			ALL	H															M	1		
C Rice Cultivation			ALL	H															M	1		
D Agricultural Soils			NE																			
E Prescribed Burning of Savannas			NO																			
F Field Burning of Agricultural Residues			NO																			
G Other			NE																			
5 Land Use Change & Forestry	ALL	H	IE	H	IE	H	IE	H	IE	H	NE								M	3		
A Changes in Forest and Other Woody Biomass Stocks	ALL	H																	M	3		
B Forest and Grassland Conversion	ALL	H																	M	3		
C Abandonment of Managed Lands	IE																					
D Other	NE																					
6 Waste	NE		ALL		NE		NE		NE		NE								M	1		
A Solid Waste Disposal on Land			ALL																M	1		
B Wastewater Treatment			ALL																M	1		
C Waste Incineration			NE																			
D Other Waste			NE																			
7 Other	NE		NE		NE		NE				NE											
International Bunkers	NE		NE		NE		NE				NE											