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BULGARIA CLIMATE CHANGE COUNTRY STUDY

PROJECT:	*Support for National Climate Change Action Plan for Bulgaria*
ELEMENT 2:	*Preparation of National Climate Change Action Plan*
Stage A:	*Preparation of Action Plans at Sectoral Level*

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National Institute of Meteorology and Hydrology, Bulgarian Academy of Sciences
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ACTION PLANS AT SECTORAL LEVEL

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I. ANALYSIS OF FORESTRY POLICY. IDENTIFICATION OF GREENHOUSE GAS EMISSIONS MITIGATION AND ADAPTATION MEASURES IN REGARD TO CLIMATE CHANGE. ANALYSIS OF THE TECHNICAL AND ECONOMIC FEASIBILITY OF THE MEASURES

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ANNOTATION

Element 2 stage A covers the preparation of action plans at sectoral level. After a Scooping Workshop with all stakeholders that discussed basic response measures to climate change, this stage focused at the researches in al sectors of interest providing information on the measures assessed as appropriate for Bulgaria in order to address climate change.

The main sectors addressed are agriculture, forestry, waste management and renewable energy sources. The report is organised in 5 chapters as follows:

1. Analysis of forestry policy. Identification of greenhouse gas emissions mitigation and adaptation measures in regard to climate change. Analysis of the technical and economic feasibility of the measures. This chapter is developed by experts form the Forestry Research Institute (Prof. Ivan Raev, Prof. Alexander Alexandrov, Dr. Ognyan Grozev) and National Administration of Forests (Rumyan Petrov and Dimitar Bardarov).
2. Application of GAP models (Changes in biological productivity) developed by Ognyan Grozev, Radoslav Miltchev and Plamen Ivanov from the Forest Research Institute - BAS.
3. Action plan for agricultural sector of Bulgaria under climate change. The chapter is elaborated by a team of experts in agriculture representing different organisations active in agricultural research ad policy making. This includes representatives of the Ministry of Agriculture, Forestry and Land Reform (Elena Ivanova, Naska Houmbadjieva), National Institute of Hydrology and Meteorology (Prof., Dr. Nicola Slavov) and from the Agricultural Academy (Nikolai Rousev and Dimitar Slavov).
4. Climatic scenarios, vulnerability and adaptation of basic agricultural crops in Bulgaria are studies by Veselin Alexandrov from the National Institute of Hydrology and Meteorology - BAS.
5. National action plan on penetration of renewable energy sources in Bulgaria is developed by Peter Ivanov and Lyubov Trifonova - National Institute of Meteorology and Hydrology.
6. Action plan for reduction of CH_4 emissions from MSW dumps and landfills is recommended by Rumiana Ilieva, Ministry of Environment and Waters.

Data provided in the chapters will be further assess and discussed in order the best mix of mitigation to be selected for the National Action Plan.

I. ANALYSIS OF FORESTRY POLICY. IDENTIFICATION OF GREENHOUSE GAS EMISSIONS MITIGATION AND ADAPTATION MEASURES IN REGARD TO CLIMATE CHANGE. ANALYSIS OF THE TECHNICAL AND ECONOMIC FEASIBILITY OF THE MEASURES

1. Analysis of the forestry policy in regard to climate change

As a result of the first research, directed to the vulnerability of forests in Bulgaria to future climate change, elements of a strategy for increasing the adaptation of the forest ecosystems during the next decades are suggested (Raev et al., 1996).

For the forests in the low part of the country (up to 800 m a.s.l.), where most significant climate changes can be expected, as a strategic task in the management of the forest resources in our country, the aim for ‘a fight for adaptation of the forests to the aridisation of the climate and for prevention of the forest resources from worsened climatic conditions’ is put in question.

For the forests in the higher parts of the country, i.e. over 800 m a.s.l. where the expected changes probably will not be drastic, the more ambitious aims of ‘preserving the biodiversity’; resistance of the ecosystems; multifunctional utilisation; system of protected natural territories’ are discussed.

Due to the study results the first *National strategy for conservation of the forests and development of the forestry in the Republic of Bulgaria* (1996), along with the basic priorities addresses also subjects as:

- ‘Helping the forests adaptation to the unfavourable climatic conditions’
- ‘Preserving the biodiversity and genetic resources of the flora and fauna at an ecologically suitable reproductivity of the forest resources’;

The aim of this work is to stress on the most important and applicable measures for adaptation of the forests to unfavourable climatic conditions in the next century. Thus a National action plan to be developed aiming at mitigation of adverse effect on the forests.

2. Selection of the species for afforestations for gradual adaptation of our forests to future climatic changes

The change in the selection of the species for afforestation is the most realistic method for adaptation of the forest ecosystems to future climate changes.

If the experience at the Bulgarian forestry from the last few decades is analysed, it will be find out that there is a clear tendency to a change (Figure 1.)

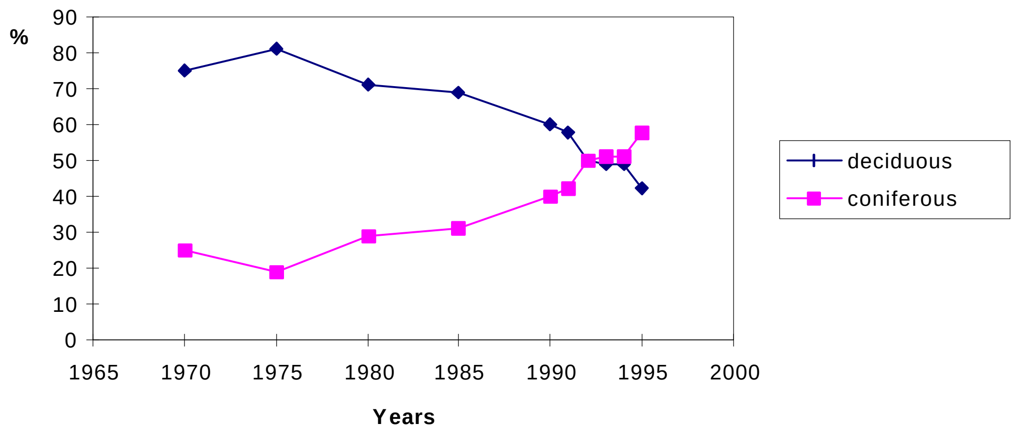


Figure 1. Afforestation with coniferous and deciduous species in Bulgaria during the period 1970-1995

During the period 1955-1990, the afforestation mainly with coniferous species predominates. This is especially striking in the period 1970-1980 as the coniferous to the deciduous species ratio varies from 84:15 to 70:30. During the next decade (1980 - 1990) this correlation is changed from 70:30 to 60:40 because of the proved better resistance to atmospheric pollution and the better water balance of the deciduous tree species.

Since 1991-1992, the deciduous tree species already dominate in the afforestation policy in our country: from 48:53 to 42:58 in 1992 and 1995, respectively. This is a positive trend which corresponds both to the ecological situation in Bulgaria and the climate changes tendency. The conifers' growing requires lower temperatures but significant precipitation distributed evenly through the year. That's why they are better adapted to the climate of our high mountains (over 900 m a.s.l.). The deciduous tree species are better adapted to the climate of low altitudes. They can survive as well at less equable precipitations because through the fall of the leaves they provide enough moisture stock in the forest soils during the cold months and through their vessels they can accumulate their annual biomass during the short spring-summer season when there is still enough soil moisture (Raev,1989).

All this shows that the tendency of more wide use of the deciduous species in the afforestations in our ecological conditions is correct. At future warming and drought, expected as a consequence from the greenhouse effect in the atmosphere, the participation of the deciduous tree species must grow.

It should be known that in 1955 the conifers in Bulgaria were only 11% of the forest area and after 40 years of increased afforestation activity with conifers this percent increases to 38.

A small number of conifers have been used: *Pinus sylvestris* L., *Pinus nigra* Arn., *Picea abies* (L.) Karst., *Abies alba* L., etc. The afforestations with this species occupy not only areas over 900 m a.s.l. where is situated their natural habitat, but also the lower parts of the country. Due to these reasons, a large scale withering of the coniferous monoplantations has begun, especially during dry periods (e.g. 1983-1994).

This process will be further aggravated in case of warming and future drought. That's why the conifers will have to reduce their areas in our country. The participation of deciduous genera and species like *Quercus sp. Fagus sp., Populus sp.*, *Robinia pseudoacacia* L., *Tilia* sp., *Fraxinus sp.,* etc. will have more and more importance especially at an altitude under 800 m a.s.l., i.e. it can be expected that the deciduous will participate with not less than 60, 70 or 80% from the afforestations in the country during the next century. Perhaps some typical species from the Mediterranean region could be applied.

At eventual increase of the average annual temperature from 2 to 3° C, a change in the forest vegetation regioning of the country will occur and the former zones will move by about 400-500 m in height. If these changes take place in short period (50-70 years), current tree species, and especially the coniferous once, will live though a stressful situation and they will hardly survive.

There will be favourable conditions for growing of a considerable number of deciduous species and from the conifers perhaps only for species like *Pinus nigra Arn., Cedrus sp*., etc.

3. Changes in the biodiversity and methods for its conservation under expected climatic changes

If the changes are in a direction of warming and drought, a considerable xerophytisation of the vegetation can be expected. The hygrophytes and some mesophytes will be strongly reduced. The vegetation will be concerned on a species and intraspecies level.

A strong reduction can be expected among the representatives of 32 local vegetation genera and 57 species.

This concerns also the introduced forest tree and shrub species. About 17 genera and 22 species are assumed as being too sensitive to the expected climatic changes.

The coming changes in the biodiversity will appear in reduction and fall off of the boreal forest species and increased participation of the species more resistant to drought and warming. Main role for conservation of the vegetation cover most probably will play these natural species which have the necessary morphological and physiological features to survive under the new forest vegetation conditions. Such a resistance can be expected mainly from 18 families with forest tree and shrub species, 46 genera and 70 species.

At an eventual xerophytisation of the growth conditions, from the introduced species, representatives of 21 families, 33 genera and 48 species could be suitable.

These data show that the natural and introduced forest tree and shrub species in Bulgaria have great capacity for good adaptation to the eventual climate change in the next century.

Besides these possibilities which could be defined as a potential at a ‘species level’, there are great ‘intraspecial level’ possibilities. It means a biodiversity on a subspecies, variety and form level, that strongly widens the possibilities for adaptation under climate change. The bigger this adaptation potential, the more probable the surviving of the species is. That’s why the composition and the structure of the forests in our country will depend on the scale of the intraspecies diversity of the basic forest formations and on the speed of the formation processes.

Among the studied drought-resistant and thermophylic autochtonous forest formatters, the taxons from 9 studied species with 21 varieties show better adaptivity capabilities under conditions of the expected xerophytisation.

In terms of the so called ‘in sity’ method for conservation of the biodiversity, the major importance belongs to the 12 national parks in Bulgaria with an area of 77 526 ha mainly situated under 1000 m a.s.l. and especially 5258 seed-producing stands with an area of 48970 ha including 16 coniferous and 40 deciduous species.

The plans show that during the next 10 years, about 65 000 ha can be afforested with suitable coniferous species and 75 000 ha with deciduous. As planting material, about 350 mln coniferous and 566 mln deciduous saplings will be necessary. About US $ 10 mln will be needed to provide saplings of 94 deciduous and about 30 coniferous species and cultivars.

From the ‘ex sity’ method for biodiversity conservation, the so called seed banks are mostly relied upon. With their help it is possible to provide the afforestations with coniferous seeds for a durable period but for the deciduous species the methods are not well developed and additional capital investments will be needed.

4. Increasing of the forest biomass through fellings

The fellings are a powerful method for improving the condition and increasing the productivity of the forests. Through them, the species composition can be regulated and the adaptation of the forest ecosystems to the changed climatic conditions can be considerably increased.

Through thinning out of the young stands, the living space of the rest of the specimen is increased, the light and water regime is improved. In that manner the adaptation possibilities of the tree stands are increased and as a result the biomass increases too. This is a method of a large-scale improvement as well as shortening the period for obtaining maximal quantity of quality timber.

In this way, through application of fellings, the productivity of the forests in Bulgaria will increase as well as the accumulation of CO_2 through the annual increment.

The forestry management plans project about 120 000 ha to be cultivated annually with average timber output of 2 801 800 m^3.

More precisely, through the fellings the following positive results can be obtained:

- *Saved funds by increassed income from timber use. In case of timper prices of US $16*[1] *per cubic meter of timber, the savings will amount to:*

  2 801 800. m^3 õ $ 16.2/ m^3 = $ 45.4 mln.

- *Saved funds by reduction of the period for timber 'maturing'*
- *Saved funds from the decreased sanitary cuttings as countermeasures against calamities and natural disasters.*
- *Increased effectiveness of the environmental impact of the thinned forests.*
- *Conservation and sustainability of the forest ecosystems and their biodiversity.*

The plans assume budget requirements enivisaged for young forests on an area of 121 100 ha. The total sum of the required state subsidies will be:

121 100 ha / year õ $ 98 / ha = $ 11.87 mln/ year

5. Lowland Forest Creation

More than two thirds of Bulgarian territory (72.35%) is covered by plains, from 0 to 200 m a.s.l. and hills, from 200 to 600 m a.s.l. In the same time the percentage of forests in the lowlands is very low, between 3.9 and 9.5%. These forests are under critical minimum, which is in range of 12% for the plains and 24% for the hills.

There are too many perspectives for the forest territories to be extended in these parts of the country. In this way it could be sufficiently helped the adaptation process to the future climate changes:

5.1. Afforestation of lands, inappropriate for agricultural activities

At present, there are estimated approximately 250 000 ha waste lands - eroded, degraded, marshy, salted and other inappropriate for agricultural production territories. The costs for afforestation activities in these lands would be about US $ 45 mln. Lands along bigger and smaller rivers, appropriate for reclamation with poplar plantations could be added to this category.

It would be very useful commissions to be established from foresters and agronomists to assess what part of the uncultivated lands could be planned for afforestation by appropriate species. The decision have to be co-ordinated with the new land/forest owners.

5.2 Afforestation in forest shelter belts (FSB)

More than 10 000 ha FSB have been established in the last 35-60 years in Bulgaria, mainly in the north-east region of Bulgaria, the Danube plain and the Trakia plain (Peev, 1990). These FSB serve as effective protection on approximately 500 000 ha arable lands, which is about 10% of the total tillage land in our country. First of all, this protection is expressed in the wind velocity decrease, snow cover homogenous distribution, agricultural lands evaporation reduction, cultivated plants yield increase and others. The FSB are a mighty instrument for the microclimate improvement, biomass productivity and biodiversity improvement, as well as for an increase of forest adaptation to the changed climate conditions.

At present, there is a necessity for the new FSB establishment of nearly 50 000 ha as an effective protection of about 2 mln ha arable lands.

The new FSB creation would cost approximately $ 8 mln for the 10-15 year period, and the investments could pay back in 4-5 years after afforestation. An additional sum of US $ 6 mln are needed for the reconstruction of

[1] All prices are according to the operating tariff of the National Forestry Administration

existing protective ecosystems (FSB), because their are too thick and windproof. The expenses could be paid back immediately out of the profit from the derived wood products and timber.

The FSB creation could have quite positive meaning, because of the great possibility of setting of a network of forest corridors which will increase biodiversity in the plain territories, enhance adaptation of the vegetation species. It will lead to environment conditions improvement, CO_2 absorption increase, etc. The creation of the shelter belts should be co-ordinated with the interests of the private owners, municipalities and government consistent with the land reform and private forest restitution.

5.3. Linear afforestations

These afforestations are performed in the homogenous schemes along the agricultural property borders, along the roads and rivers. There is no need of special land for these afforestations. Meanwhile the landscape could be improved.

The costs of such kind of afforestation range from $35 to $40 per 1 km (distance between saplings = 1 m). In this case forest fruit tree species could be widely used. The creation of linear plantings requires the private farmers to be encouraged with tax-free seedlings and consultancy services.

5.4. Urban afforestations

This afforestation might include shady trees in the residential areas both in the court yards and between the block houses as well as the line, fruit and ornamental trees. This vegetation helps the microclimate to be more favourable, dust and CO_2 to be absorbed, etc. The trees have a great aestetical effect and some times the vegetation could also have a financial effect.

For this purpose, public awareness for the benefits of these afforestations, ecology culture development and economical interest are necessary.

As an executive institutions of all these measures for forest creation in the lowlands the following organisations could be shown: The Ministry of Agriculture, Forests and Agricultural Reform, The Ministry of Environment and Water, the municipalities, the non-governmental organisations etc. But first of all, the private owners, is necessary to be convinced in the benefit role of these initiatives.

6. Extension of afforested areas with introduced drought-resistant species (Cedrus ssp.) - Cedrus atlantica and Cedrus libani

The Cedar ssp. trees are representatives of the few conifer species which would be recommended as appropriate in the future afforestations in the conditions of climate changes. Besides they are drought-resistant, have a great potential of bioproductivity which responses quite well to the new ecological conditions.

There are favourable conditions for cedar trees growth in the lowland belt - from 0 to 700 m a.s.l., and appropriate terrain for these species are localised in the southern half of the country. The annual areas for afforestation might reach from 180 to 400 ha.

The financing for 1 ha is calculated to US $ 2000. This means that the annual costs (1997 prices) for implementation of this measure would be:

400 ha x $ 2 000 /ha = $ 800 000/ year.

As a clause of this measure is the application of the Forests Restitution Act, the New Special Forests Act, as well as the return of the agricultural lands. It is also necessary the sowing areas for the production of saplings for the both species to be extended.

7. Pilot projects related to future climate change

The implementation of the recommended measures and strategies in the forestry for changes in the afforestation practices, mainly related to the selection of tree and shrub species resistant to the future climate change, should be tested through special pilot projects on limited areas, a number of native and introduced species might be tested, from which the selection to be made for a wide application. By means of these projects new technologies could be also tested defining whether appropriate for aggravated climate conditions.

7.1. Biological and technical stabilisation of 'Racovitza' river watershed in the Rila mountain with respect to future climate change

The purpose of the project is an afforestation project on determining the ability of tree and shrub species to adapt to the aggravated climate conditions to be studied for a region in Bulgaria that is vulnerable to future climate change.

The 'Racovitza' watershed is located on the territory of RDG - Blagoevgrad, 15 km to the south of Blagoevgrad, on the southern slopes of Rila mountain. The river Racovitza is a left tributary of the Struma river.

The climate is semi-arid transitional Mediterranean with clearly expressed deficit of summer precipitations. Soils are eroded, poor forest. The terrain is devastated, with scare vegetation.

The area is 600 ha, 50% forest lands and 50% agricultural lands.

The action program comprises of defining of watershed physico-geographycal characteristics; investigation, development and accomplishment of the project for a complex watershed treatment with stress on the utilisation to the aggravated climate conditions; constructing works.

The expected effect of the project includes: protections of soils against erosion; regulation of the water balance in the watershed area; improvement of the river water quality in the watershed area; planting forest vegetation (producing from 45 000 to 70 000 m^3 wood boimass for 50 years); improvement of the biodiversity; accumulation of CO_2 (37 000 t for 50 years); release of oxygen; improvement of the microclimate; use of the pilot project results for solving ecological problems in other country's regions and others.

Executors: The Forest Research Institute - BAS, the Forestry University, the Agrolesproect, National Administration of Forests - RDG, State forestry.

Investors: The Ministry of Agriculture, Forests and Agricultural Reform, the Ministry of Environment and Waters and others.

Necessary funds:

- Afforestation: $ 355 per ha x 300 ha	= $ 106 000
- Hydrotechnical facilities (barrages and others)	= $ 125 000
- Agricultural fund: 300 ha x $ 150	= $ 45 000
	Total: $ 276 000 for 4 years.

7.2. Forest biological recultivation of spoil banks in open-cast mining in the region of the Maritza-East coal mines in regard to future climate change

The project aims a pilot project to be accomplished for utilisation a number of forest tree and shrub species, resistant to the unfavourable climate and soil conditions in the largest complex of open-cast coal mines in Bulgaria.

The site is in Maritza-East coal mines on area of 59 ha of the lands of the communities Gulubovo, Radnevo, Haskovo district.

The climate is semi-arid transitional continental, influenced by the Mediterranean Sea and deficit precipitations. The soil substrate is of Gliocene geological materials.

The working program includes the following: physico-geographycal characteristic; investigation, development and implementation of the project for forest biological recultivation with stress on the utilisation of variety of species, resistant to the aggravated climate and soil conditions.

Expected effect of the project realisation: recultivated terrain wealth restoration; acceleration of the soil formation process; anti-erosion effect; recreational utilisation of the terrain; establishment of forest plantations, resistant to the climate change and poor soil conditions; microclimate improvement; creation of producing forest vegetation (6 900 to 10 000 m^3 wood biomass for 50 years); CO_2 accumulation (6 000 t for 50 years); oxygen release; the pilot project results utilisation for the other country's regions.

Executors: The Forest Research Institute - BAS, the Forestry University, the Agrolesproect, the National Administration of Forests - RDG, State forestry.

Investors: the Ministry of Environment and Waters, the Ministry of Agriculture, Forests and Agricultural Reform, the Ministry of Energy, Maritza-East Mines.

Financing: Recultivation of a ha amounts to US $565. Then the total sum is:

US $ 565 x 50 ha = US $ 28 000

II. GAP MODEL ÀPPLICATION(CHANGES IN BIOLOGICAL PRODUCTIVITY)

1. Introduction

The prediction of the forest ecosystem responses to long-term climate changes requires hierarchical constructed dynamic models, which to be capable to cover and describe in a mechanistic manner the combination of the basic ecosystem processes and their interrelationships in space and time. The forest gap models are individually based programs which simulate the vegetation response functions to the environmental conditions. The model could evaluate the possible changes in the species composition, forest structure and productivity of specific forest sites. The model requires detailed information on specific forest species and environmental factors. The model could evaluate the dynamics of particular forest site in response to the climate change.

The purpose of this investigation is to identify the development (establishment, growth and mortality of individual trees) of the most widely spread in Bulgaria tree species in different climate situations (‘normal’ weather and ‘global warming’ weather) using a transient scenario, which assumes a ‘business-as-usual’ continuous increase in greenhouse gases generation. The results derived from the gap model usage would show us the possible effects of one changed climate on forests in the next decades and could help us to undertake measures directed to the forest adaptation and its role as a mitigation factor to the expected climate change.

2. Materials and methods

For gap model application, JABOWA-II (Botkin, 1993), a computer model of forest growth, has been used. The model simulates the growth of individual trees on small forest plots, taking into account air temperature, precipitation, soil moisture and nitrogen, and competition among trees for light.

The program has been charged with data about: 1) tree species; 2) communities; and 3) climate information (weather records).

There are 40 tree species, considered as the most widely spread in Bulgaria, (Penev et al., 1969) used in this program, 10 from which are conifer species: *Pinus mugo Turra, Abies alba Mill., Picea abies (L.) Karst., Pinus peuce Gris., Pinus silvestris L., Pseudotsuga menziesii (Mirb.)Franco, Pinus nigra Arn., Pinus leucodermis Ant., Cedrus atlantica (Endl.) Manetti, Juniperus excelsa M.B.* and 30 deciduous: *Fagus sylvatica L., Quercus petraea Liebl., Carpinus betulus L., Populus tremula L., Betula pendula Roth, Alnus glutinosa (L.) Gaertn., Fraxinus excelsior L., Acer pseudoplatanus L., Ulmus glabra Huds., Sorbus torminalis (L.) Crantz, Sorbus aucuparia L., Fraxinus ornus L., Castanea sativa Mill., Aesculus hippocastanum L., Ostrya carpinifolia Scop., Populus balsamifera L., Fagus orientalis Lipsky, Fraxinus oxycarpa Willd., Acer campestre L., Acer hyrcanum Fisch. et Mey., Tilia tomentosa Moench, Juglans regia L., Platanus occidentalis L., Quercus rubra L., Robinia pseudoacacia L., Quercus robur L., Quercus cerris L., Quercus frainetto Ten., Quercus pubescens Willd., Carpinus orientalis Mill.*

In this list, the most largely introduced tree species like Douglas fir, Cedar, Robinia and Red oak are included. For all of these species a process of naturalisation could be observed.

The selected species have been included in 4 communities of investigation. The information about communities is given in Table 1.

Climate data from the following meteorological station are used for the studied communities (sites): Varna (43°,20’N, 3 m a.s.l.) for “Suvourovo”; Ecological station “Balkanetz” (42°,28’ N, 1300 m a.s.l.) for “Jalna”; Ecological station “Govedartzy” (42°,25’N, 1500 m a.s.l.) for “Govedartzy”; and Ecological station “V. Serafimov” (42°,10’N, 1500 m a.s.l.) for “Leeve”. The weather records (average month temperature and total month precipitation) for the 4 sites cover 30-year period (1961 - 1990).

Table 1.

Community	Latitude	Elevation a.s.l.	Relief/Slope	Exposition	Climatic zone
Suvourovo	43^{o},25’N	150 m	hilly / 7°	SE	Transient- continental
Jalna	42°,28’N	1300 m	mount. Slope / 23°	NE	mountain
Govedartzy	42°,25’N	1550 m	mount. Slope / 17°	N	mountain

Leeve	42°,10'N	1510 m	mount. Slope /14°	S	mountain

The model was used to investigate four variants for all of the sites as follows: clear-cut plot and afforested plot either for the 'normal' climate and for the 'global warming' climate respectively. The tree vegetation development processes have been followed in 10 years interval (50 iterations per run, 95CI= 95% confidence interval) and as a result General Statistics Output File (GSOF) has been composed. The GSOF includes data for soil conditions, climate conditions and information for tree species chosen for work by the program as the most suitable for the above mentioned soil/climate conditions.

3. Results and discussion

The JABOWA-II Program is selective towards the tree species. Only about 15 species out of 40 tree species have been studied within the different variants.

For the processes of establishment, growth and mortality of the individual tree in the next 90 years, the following could be generalised briefly:

1. It could be seen that the number of the tree species increases (with 2 to 3) in sites representative for mountain regions (Jalna, Govedartzy and Leeve) under 'global warming' weather conditions.
2. In the lowlands (Suvourovo object) the number of species forming the forest stand is decreasing under the 'global warming' conditions, but at the same time the tree species suitable for lowland conditions are more than these suitable for the mountain regions.
3. The results concerning the bioproductivity show a particular, in some cases (variants) considerable, increase of the total biomass (all of the tree species are included) due to the 'global warming' climate (Figure 1).

Taking into account the above mentioned results, in case of climate warming in the near 90 years, the following consequences could be expected:

A. In the lowlands - Tree species diversity reduction. In spite of that, this biodiversity would be greater compared with the biodiversity in the mountain regions. The selected tree species guarantee increased bioproductivity. It could be considered that if proper selection is made, optimal bioproduction could be realised under changed climate conditions.

B. In mountains - It could be expected increase of tree biodiversity. It could be realised by means of the natural shifting of tree vegetation from lower to higher sites in the mountains. This process would be combined with biomass production increase.

C. Both in lowlands and mountains - Increased biomass productivity would be accompanied by increased CO_2 absorption.

Either using Holdridge Life Zones Classification Model and JABOWA-II Gap Model, two climate zones (Grozev et al., 1996) of climate change influence have been established: from 0 to 600-800 m a.s.l. and over 800 (1000) m a.s.l.

Working with Holdridge model, apocaliptical situation for the future of the forests in the lowlands and lowhill regions on the whole was outlined, while developing gap model situations it could be seen that the status of the forests (in all altitudes) wouldn't be critical at all. Because the Holdridge model provides a regional mapping system for interpreting spatial changes throughout the country or regions, while the forest gap model evaluates the temporal dynamics of a given forested site in response to climate change, it could be considered that the gap model results are more objective.

III. ACTION PLAN IN AGRICULTURE UNDER CLIMATE CHANGE IN BULGARIA

1. Vulnerability of agriculture under climate change

According to the World Meteorological Organisation the monitoring of the greenhouse gasses concentration shows velocity detention of the concentration increasing. However, the increase of their total content is retained. According to investigations carried out in Bulgaria the trend of the greenhouse gasses concentration is similar to the above mentioned. The methane produced by the stock-breeding and rice production could be considered as a major pollutant. Nitrogen and carbon oxides produced by plant-growing, especially during the burning of agricultural refuse, are also important pollutants.

The investigations, by means of climate change scenarios simulated by the global atmospheric circulation, showed that during the next century significant changes in thermal and moisture regimes are expected across the country under GHG concentration rise. Several researches, carried out at the National Institute of Meteorology and Hydrology in Sofia, addressing the long-term variations of air temperature and precipitation show that some trends to warming and drought have been already established in Bulgaria.

The influence of climate change on the processes of maize and wheat growth, development and yield formation was evaluated using the simulation CERES models of maize and winter wheat, which have been integrated into the American Decision Support System for Agrotechnology Transfer DSSAT. It was obtained that the average crop yield is expected to decrease which will reflect negatively on the bread and fodder balances in the country. Therefore a problem regarding the population feeding could arise in the future.

The results obtained during the investigation of the climate change impacts on the Bulgarian agriculture force the action plan to focus upon two major goals: 1. GHG mitigation; 2. Adaptation of agriculture under climate change expected on the Bulgarian territory.

2. GHG mitigation

In order to achieve this goal it is necessary to concentrate over some priority tasks:

1. Reduction of methane emissions by biological fermentation in stock-breading:

1.1. Increasing the stock-breading production by means of improving the genetic characteristics and reproductive abilities of all kinds of animals.

1.2. Improving the animal feeding and increasing the quality of animal production by reinforced supplements, specific substances, etc.

1.3. Increasing animal productivity by mechanisation of the processes in all sectors of livestock breeding.

1.4. Improving the meadow and pasture utilisation mode in stock-breeding.

2.Methane emissions reduction through effective utilisation of solid and liquid manure

2.1. Improving the devices and equipment for collection and storing solid and liquid manure.

2.2. Constructing and establishment of equipment for underground storage of manure, methane extraction and its utilisation.

2.3. Composting manure by use of agricultural, industrial and municipal wastes at special sites.

2.4. Improvement of organic fertilisation with manure (rates, dates of application, machines for transport and spreading) of different agricultural crops.

2.5. Development of qualitative characters of manure-based fertilisers and defining their prices.

3. Improving mineral fertilisation

3.1. Use of nitrogen fertilisers, especially urea, to be in a form, time schedules and qualities consistent with the soil profiles.

3.2. The use of nitrogen mineral fertilisers to be combined with manure in order to decrease N-gasses.

3.3. Incorporated fertilisers containing nitrogen to be immediately tilled and sowed.

4. Decreasing the carbon emissions containing gasses and retaining the soil carbon

4.1. Burning termination of stubble-fields and plant remainders.

4.2. Introduction of methods for keeping and improving soil fertility under decreasing carbon dioxide emissions.

4.3. Application of a system against soil water erosion, especially against irrigation erosion.

4.5. Application of methane emission under rice cultivation.

5. Decreasing methane emissions under rice cultivation.

5.1. Rice field construction including an improved system of water drainage.

5.2. Improving the rice production technology.

5.3. Cultivation of new high-productivity rice varieties with improved botanical qualities.

3. Adaptation measures in agriculture under climate change

Warming will lead to increase of crop growing season and will move upper limits for agricultural production to 1000 m a.s.l. at suitable areas. This result will impose:

1. New zoning of the agroclimatic resources and agricultural crops

1.1. Expanding areas of the most important agricultural crops over new regions characterised by improved thermal and moisture conditions.

1.2. Utilisation of a variety of cultivars and hybrids, especially long-maturing, high-productive cultivars and hybrids with better industrial qualities.

1.3. Cultivation of new agricultural crops grown with Mediterranean origin.

2. New cultivars and hybrids to be adapted to climate change

2.1. The new cultivars of winter agricultural crops to pass through the winter season organogenesis under higher temperatures without deviations from the normal crop growth and development.

2.2. The new cultivars and hybrids to be with higher dry-resistance, especially at the end of the vegetative period and at the beginning of the reproductive period.

2.3. Higher maximal air temperatures not to provoke thermal stress effects, especially during crop flowering and formation of the reproductive organs.

2.4. The new cultivars and hybrids to grow and photosynthesis under an increased concentration of carbon dioxide.

3. Measures for increase of the irrigation effectiveness

3.1. Introduction of irrigation technologies with decreased water charges and without losses during water transportation and distribution.

3.2. Restoring and reconstruction of the already constructed hydromeliorative fund.

3.3. Reconstruction and building of new test-pits for utilisation of groundwater.

3.4. Utilisation of river water and precipitation for moisture storing irrigation during the winter season.

3.5. Utilisation of waste water and drainage system water.

4. Adaptation phytosanitary measures

4.1. Development of special submodels incorporated into models of agroecosystems which simulate plant-protection situations, related to climate change.

4.2. Assessment of already used pesticides and the way of their utilisation and potential effectiveness of the chemical method against crop diseases and pests.

4.3. Improving technologies for plant protection and priority development of non-chemical methods against crop diseases and pests.

4.4. Improving the monitoring for the phytosanitary situation in the country.

4. Research projects

Action plan in agriculture under changed climatic conditions is the first stage of the program related to the expected climate change. The second stage will begin by plan application in the agricultural practice. Along with this, researches should continue in two major directions:

1. Investigation of climate change

1.1. Utilisation of different global circulation model outputs for assessment of the regional climate changes in Bulgaria.

1.2. Utilisation of simulation models of agroecosystems for assessment of the influence of climate change on major crop productivity.

1.3. Periodical zoning of the agroclimatic resources in Bulgaria under climate change.

1.4. Periodical zoning of the major agricultural crops under already established changes of the agroclimatic resources in the country.

2. Investigation of vulnerability and adaptation of agricultural crops under climate change

2.1. Discovering and gathering in a genetic bank agricultural crops and wild plants samples steady to thermal anomalies, water shortage, diseases and pests.

2.2. Selection and introduction of high-productive cultivars and hybrids which will be tolerant to climate change and will have high quality production.

2.3. Development of technologies for production of agricultural crops adapted to climate change.

2.4. Improvement of the methodology for land evaluation in relation to climate change.

2.5. Development of technologies for effective utilisation of manure and crop waste.

2.6. Development of technologies for improvement of measures against soil erosion.

2.7. Development of measures for animals’ adaptation under climate change.

2.8. Development of feasibility studies for the applied measures.

IV. CURRENT CLIMATE, CLIMATE CHANGE SCENARIOS, VULNERABILITY AND ADAPTATION OF MAJOR AGRICULTURAL CROPS IN BULGARIA

1. Current climate

It is necessary to pay attention to the regional current climate when climate change studies are carried out. Regional climate variability and trends are often different from the global climate. That is why, climate variability during the last decade relative to the current climate, recommended by the World Meteorological Organization (1961-1990), was analysed. A slight warming is observed till 1994 which was the warmest year in the country since the late 19th century - the annual air temperature was approximately 1.5°Ñ above the current climate (Fig. 1).

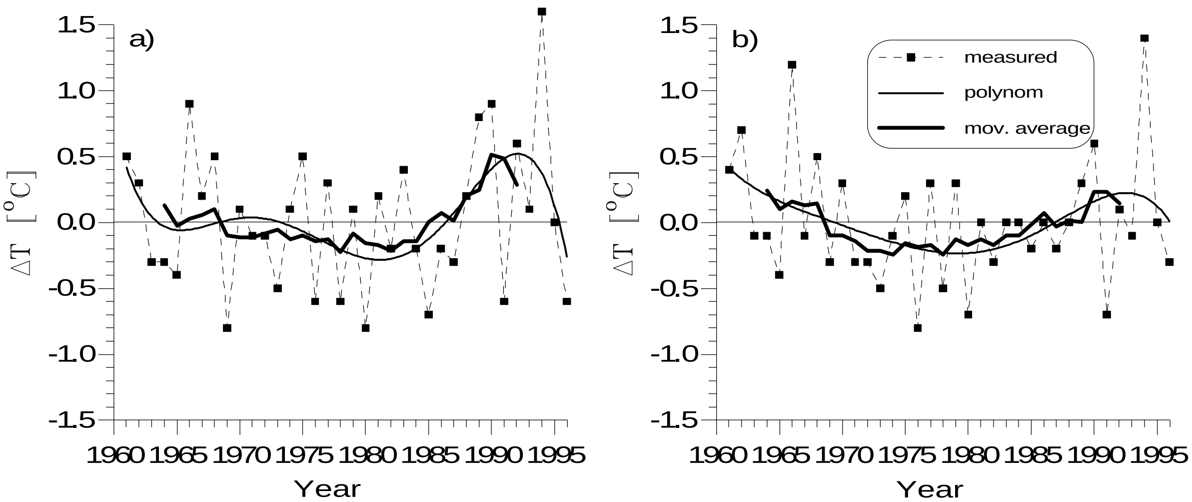


Fig. 1 Anomalies of annual air temperature in North (a) and South (b) Bulgaria relative to the current climate (1961-1990).

However in 1995 and 1996 the measured annual air temperatures were similar and below current values, respectively. Nevertheless, during the last years only positive anomalies of air temperature during the warm half-year were observed. The observed deficit of annual precipitation during the 1980s continued during the first years of the current decade (1992-1994) - Fig. 2. Less annual precipitation occurred last year (1996) in North Bulgaria, however during the warm-half year (actual crop growing season) rainfall decreased throughout the country. There are some indications that an relative annual precipitation increase will be observed during the next years followed by new deficit during the next decade.

2. Climate change scenarios

Several climate change scenarios were created by changing observed data from

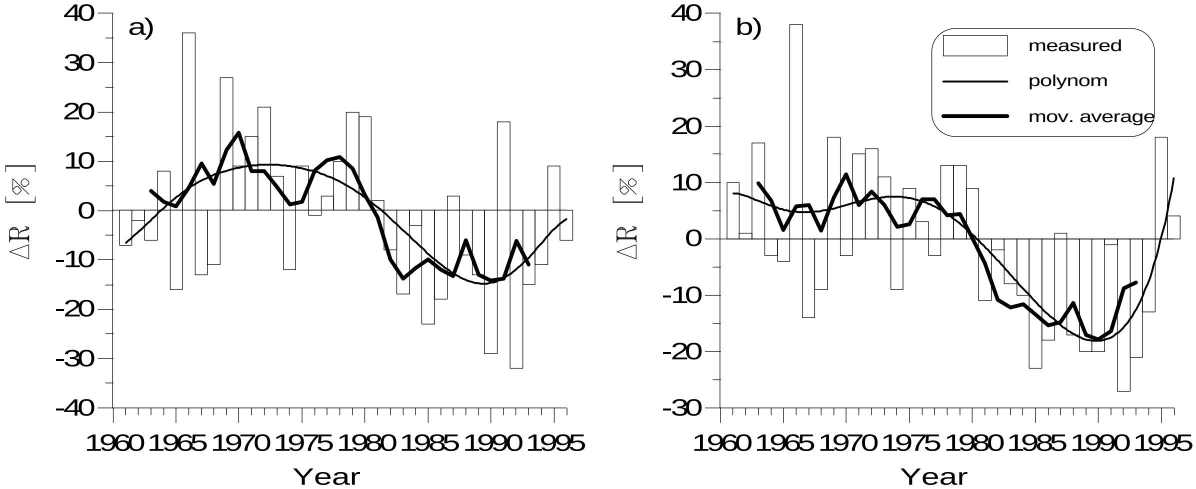
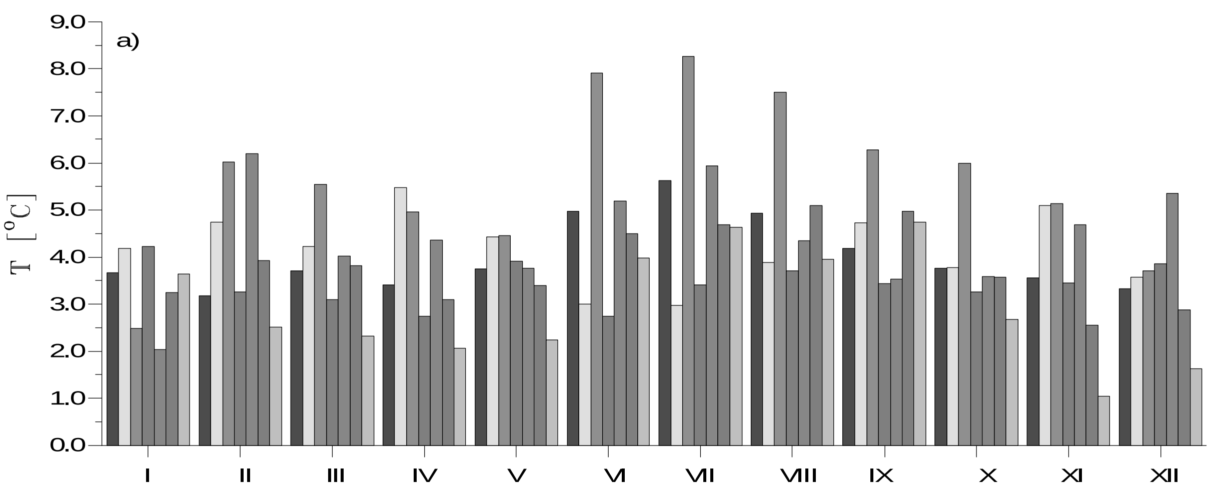


Fig. 2 Anomalies of annual precipitation in North (a) and South (b) Bulgaria relative to the current climate (1961-1990).

the current climate (1961-1990) this time according to doubled CO_2 simulations of seven general circulation models (GCMs). The GCMs which were used are those from the Goddard Institute for Space Studies (GISS), Geophysical Fluid Dynamics Laboratory (GFDL), Canadian Climatic Centre (CCC), Oregon State University (OSU), United Kingdom Meteorological Office (UK89) and Hadley Centre (HCGG and HCGS which integrates the negative forcing effect from sulphate aerosols) (Alexandrov, 1997b,d).

The single levels of CO_2 ($1xCO_2$) outputs from the GCMs were compared with the average observed regional climate. The $1xCO_2$ OSU, HCGG and HCGS outputs are in a relatively good agreement with baseline air temperature from June to March. They could be considered as the most appropriate global circulation models for monthly air temperature in Bulgaria (except April and May) among the GCMs used in the study. The $1xCO_2$ CCC and GFDL models simulate relatively well current precipitation throughout the period from November to April. The most of GCMs used in the study underestimate precipitation during the summer months (June-August). The GISS, HCGG and HCGS outputs are most similar to the baseline precipitation during the same period of the year. Generally, the GCMs do not perfectly simulate the present climate in Bulgaria. The model changes from the present to the future climate are more reliable than the present or the future simulation alone. According to the GCMs used in the study annual temperatures in Bulgaria are predicted to rise between 2.9° (HCGS) and 5.8°C (UK89) under an effective doubling of CO_2 ($2xCO_2$) - Fig.3.



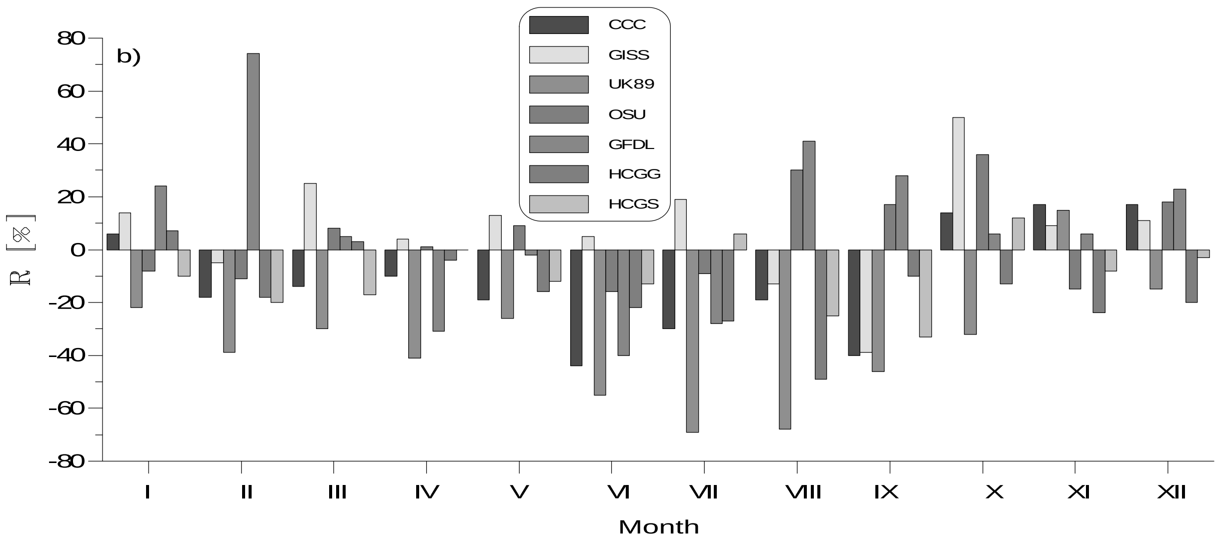


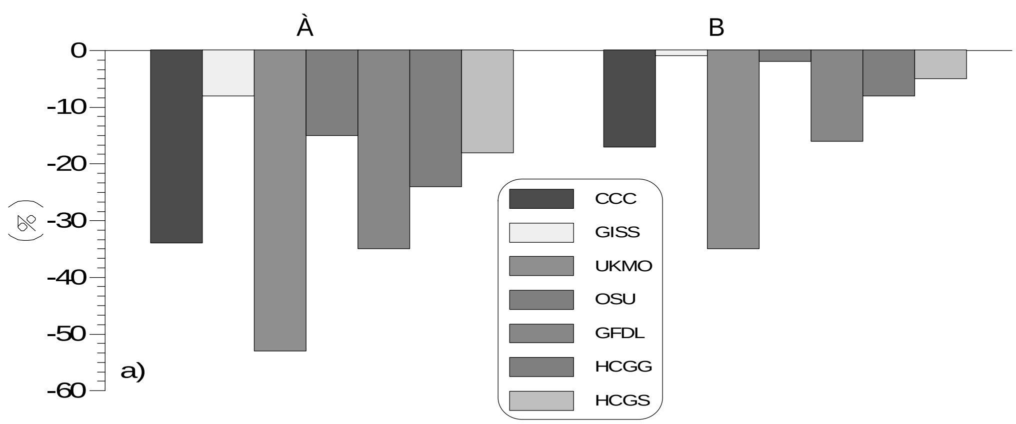
Fig. 3. Climate change scenarios for Bulgaria - differences/ratios between $2xCO_2$ and $1xCO_2$ GCM outputs for monthly air temperature (a) and precipitation (b).

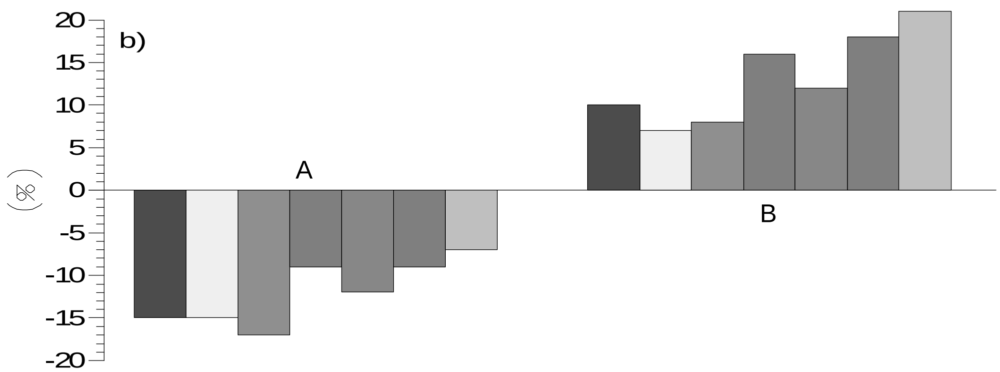
In general, precipitation is expected to increase during the winter and to decrease during the warm half-year (CCC, GISS, GFDL, OSU). The $2xCO_2$ UK89 and HCGS models even project minor increasing only in November and July, respectively (Fig. 3). It is essentially to emphasise on the fact that these climate change scenarios were not constructed to help predict the future. They were designed to help identify the sensitivity of sectors to climate change (such as agriculture and forests).

3. Vulnerability of major agricultural crops

The climate change scenarios derived for Bulgaria were used to evaluate potential changes in potential and actual crop growing season and grain yield of maize and winter wheat. Under equilibrium $2xCO_2$, the potential crop growing season was projected to increase by 1-2 months. Hence, a northward shift of productive potential was evident. The sum of the plant effective temperatures will also increase.

The altered temperature and precipitation databases corresponding to each of the climate change scenarios were used to run the GENERIC CERES 3.00 simulation models of maize and winter wheat. All scenarios projected shorter vegetative (sowing-silking/anthesis) and reproductive (silking/anthesis-full maturity) stages of maize and winter wheat. These changes were driven by the temperature increases of the scenarios. There was an obvious trend of decreasing grain yield of maize and wheat (Alexandrov, 1997a,c) -Fig.4.





Legend: À, Â - without/with direct influence of ÑÎ$_2$ on development, growth and yield formation of maize and winter wheat

Fig. 4 Departures of grain yield of maize (a) and winter wheat (b) under 2xCO_2 scenarios, relative to the current climate at 2 experimental crop stations - Kojnare (a) and Zinmica (b).

Simulated grain maize yield decreases in Bulgaria were caused primarily by warming and precipitation deficit during the growing season of this crop. Some changes were observed when the direct effect of increased CO_2 had been assumed in the study. In this case the decrease of maize grain yield was no so adverse and winter yield increased relative to the current climate. The reason of these changed results was the influence of increased levels of CO_2 as a fertilizer (Fig. 4).

4. Adaptation measures under climate change

Using a computer Decision Support System for Agrotechnology Transfer (DSSAT) some possible adaptation measures for maize were tested. Under 2xCO_2 climate change scenarios the sowing dates should occur 15-30 days earlier than those under current climate conditions. Generally, the changes in fertilisation (N, P and K) did not compensate grain decreasing. The DSSAT Seasonal Analysis program was run to determine the most appropriate timing and water amount of irrigation applications. The tested treatments of the irrigation numerical experiment assumed maize growth and development under rained conditions, different date(s) and water amount of irrigation. Both biophysical and economic analyses were done. The strategic analysis, was done in respect to the simulated value of harvest maize yield and net return (Alexandrov, 1997e) - Fig. 5.

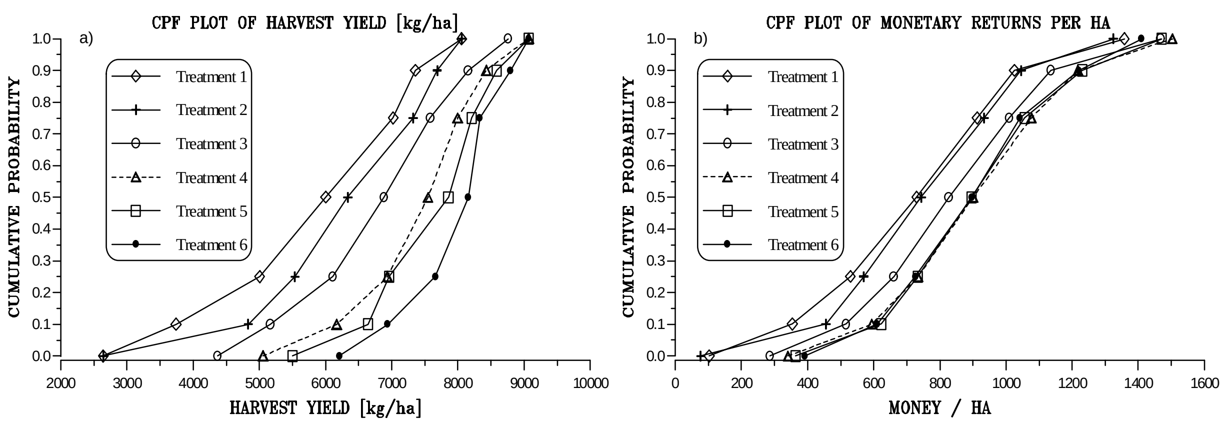


Fig. 5. Cumulative probability function plots of the simulated harvest maize yield (a) and monetary returns (b) in Kojnare under 2xCO_2 CCC climate change scenario.

An attempt to estimate the genetic coefficients for new maize hybrids which might be more adaptable to the changed climate conditions in the future was also done. An increase in the actual value of the respective coefficients compensated for the projected grain yield losses caused by the 2xCO_2 climate change scenarios in the country. Moreover, maize grain increase was observed in some cases.

V. NATIONAL ACTION PLAN ON RENEWABLE ENERGY SOURCES PENETRATION IN BULGARIA

1. Introduction

Recently the interest in renewable energy sources (RES) has grown mainly in connection with the changes in the field of energy policy around the world and in particular in Bulgaria as a result of the air pollution and the climate change.

The establishement of a National Energy Efficiency Agency (NEEA) is an important element of state policy in support to development of energy efficiency (EE) and RES in Bulgaria. The adoption of a law on energy would have primary importance to favour RES development. The wide utilisation of RES, as none of other energy sectors, would contribute to energetic independence of the country, development of technological base, creation of new working places, conservation of the environment. It would involve local and foreign investments. According to the scenario of country integration to EC, RES may cover about 7-8% from total energy demand, and along with big Hydro Power Plants (HPP) this value may reach up to 20%. It is necessary the state administration and National Electric Company (NEC) to treat RES with priority to the rest energy sources and especially imported energy sources. It is necessary a preferential financing scheme to be adopted for RES.

2. National energy policy

Production of electricity from RES. It is necessary NEC to pay preferential guarantee prices for electricity generated from RES on the base of long-term contracts.

Environment. The Ministry of environment and waters and NEEA must contribute actively for development and utilisation of RES as alternative of conventional fuels aiming environmental improvement of the country.

Regulations and standards. Committee of Energy (CE) and NEEA together with representatives from industries-producers of RE equipments, Bulgarian Academy of Sciences, Ministry of Environment and other organizations must draw up necessary instructions, regulations and standards for projects and investments for RES development in Bulgaria.

Finances and fund for RES. The financing is an important barrier for market penetration of RES. The lack of financing makes excessively difficult the encouragement of RES development. It is necessary to establish a fund for encouragement of RES development, similar to that proposed for development of energy efficiency. Such fund for RES would finance appropriate projects and would ensure stimuli necessary for their development.

The initial capital may to be collected with support by EBRE, European commission, World bank, Agency for international development of USA and others. Different possibilities (grants, subsidies) may be used, which present different funds as GEF, IFC, UNDP, PHARE and others. The main contribution has to be from two sources:

- state subsidies for assistance to realization of expected benefits in the field of conservation of the environment and climate change, currency exchange, employment, etc.
- laying a tax on consumers of energy from fossil fuel sources, which pollute the environment.

Initially, this laying may be financed directly from NEC or from companies importing or trading petroleum products.

Local banks. Through local banks the concession financing may be conceded to appropriate projects developing RES. Initially they could only provide the mechanisms for canalisation of financing and credits from such funds as Fund for RES or Fund for energy efficiency. Later they might provide also the basic financing.

Priority financing. The presence of an open energy market allows establishment of priority financing for RES, companies being enabled to make use of it.

Local investments. Local investments are crucial for RES development.

Foreign investments. Central and local administration must encourage foreign investments, that could provide necessary capital and facilitate technology transfer.

License and concede of rights. One good possibility for RES development is utilisation of technologies by buying of licenses. Joint ventures and direct local and foreign investments would stimulate the development of the sector.

Public opinion and education. A wide public awareness campaign in favour of RES development is necessary. Official administration, state employees and most of the population know very little about the advantages and gains of RES utilisation in Bulgaria. From the other hand, there are groups of people who are familiar with RES potential. These are above all academic circles that carry out researches in the field of RES, some firms, that have direct relation to production of equipment for renewable energy technologies (RET), as well as common citizens using firewood, agriculture wastes burning, drying fruits on the sun heat, etc. This knowledge however has to be classified and become conscious of. The best way to do this is given by respective programs for education in schools, colleges, universities and other institutions of higher education, by organising conferences, meetings, publishing of booklets and special literature, use of mass media. An opportunity for acquaintance of population with RES advantages is the foundation of centres for propaganda of RES ideas, where through demonstration installations the society will be convinced in RES benefits.

Education. Programs for primary, secondary and higher education must be adapted for acquaintance of students with possibilities and expected advantages from RES.

Professional training. Introducing of especial programs for training in institutions of higher technical education and more specifically in Technical universities of Sofia, Varna, Gabrovo, Burgas, in Forest University (Sofia), in Agriculture University (Plovdiv) and others.

Local administration. Local administration will have increasing authority and responsibilities in Bulgaria. Their will influence on finding necessary investments, provide concess permission, license concede, preparation of environment impact assessment, public awareness, etc.

Local investors. A Manuel for designers, producers and investors in the field of RES, has to be issued with the assistance of NEEA. It will facilitate corresponding activities and in particular political, legal, administrative and other aspects of the investment process.

Energy efficiency. The energy efficiency and RES promotion have be the two parts of a general state strategy for limiting the country's dependence upon imported energy carriers, for environment improvement, as well as for creation of new working places, stable development of the country as a whole. The passing of the Law on Energy Efficiency, including RES development as one element of the total energy strategy, is necessary in the nearest future. Some of the investments in the National Energy Efficiency Fund (NEEF) may be allocated for RES development.

Fiscal support from the state. It is indispensable the Government to cancel all taxes and import charges (including customs duties) on equipment for RES (parts and components for RE equipments which are not produced in Bulgaria). This is important especially for initial stages of RES development. It is necessary to encourage and to train highly qualified specialists working in the field of RES, able to realise relevant projects. This will allow competitive production of equipment for different technologies using RES to be organised in the country. It is necessary projects and investments in the field of RES to be free of taxes and charges at the initial period. The Government may subsidise some projects. Initially the NEEF may support them until the revenues become stable and increased. The significant RES resources in Bulgaria are prerequisite for this. There is no need for their import. Only parts of RET equipment has to be imported.

Open energy markets. The experience of other countries (in Europe, America, Asia) shows that open energy markets provide lots of opportunities for big investments in the field of RES. The energy sector is the greatest industrial sector in the world, that is projected for many years forward. Along with economy development the needs of electricity and heat increase. Thereby the state and private investments increase as well. Except for the big HPP, RET for electricity and heat production are usually small and do not require big investments. Open markets contribute to development of independent small producers, for whom RES will be attractive option in Bulgaria. The energy sector in Bulgaria is old and warned out. For its rehabilitation enormous investments would be necessary. Some part of these investments may be redistributes and directed to RES development. This is the case especially for micro-HPP development, utilisation of biomass and solar radiation for electricity and heat generation, wind for electricity production and geothermal energy for heating.

Legal frames and recommendations. The Act on prices, Concessions Law and Investments Law are very important for RES development. Generally the legislation which refers to stimulation of RES utilisation in Bulgaria may be used for solving the following problems: legalising of long-term supplies of electricity on preferential prices (within or out of fixed parameters range); NEC to propose economically feasible and transparent conditions for inclusion of producers and/or suppliers as a third party in the distribution systems and to ensure conditions for buying of electricity produced from the third parties; to establish legally some form of addition value at local self-government level and at national level, which have to ensure RES priority utilisation; state and municipal possessions and other rights, which comes under the Concessions Law, should be negotiated for the purposes of a particular project without obligatory auction procedure; it is necessary the Act on agricultural lands utilisation to be revised as to encourage biomass utilisation, including energy crops, for energy purposes; some restrictions for interference to be imposed upon owners of neighbour lands in case of water energy (micro HPP) and wind generator utilisation; foreign investors must have the same property rights as Bulgarian citizens, in order to satisfy World Bank and other international institutions requirements.

National Federation of RES. It is necessary to create National Federation of RES which aims to unify efforts of all parties concerned with RES development. This federation should protect commercial interests of the sector, should undertake research and development activities, should provide development strategy, should ensure access of its members to financial and technical support.

The federation must be organised on commercial base. It has to support Bulgarian firms, branches and partners for RES development; to contribute for technology and export improvement to the highest feasible levels; to contribute for limit country dependency on imported fuels; to accelerate economic and social development of the country; to ensure employment and good income for Bulgarians; to generate receipts for business, local authorities and the state; to transform Bulgaria into regional leader in RES development; to ensure low cost high quality renewable energy for consumers; to stimulate research and development activities in the field of RES, as well as their practical utilisation, to keep leadership of Bulgaria in international development of RES.

The federation is governed by a board of directors, which represents main membership groups as follows: researchers working in the field of RES; investors and workers in the field of RES; producers of energy and equipment for RES; designers of equipment using RES; exporters of energy and equipment for RES.

The federation may be organised in groups according to resources or technologies, for example solar energy, wind energy, hydroenergy, biomass, geothermal energy. The Federation must have strong commercial, practical and financial status. Members must be selected among stakeholders: power engineers, researchers, architects, designers, civil engineers, jurists and others. It may have sections for: commercial projects' development; researches and activities of development; finances and credit; legal consulting; public relation; relation with state authorities.

These sections must use their own regulations and be presented by the board of directors. The membership in federation could be in two forms: “full” (producers, investors and others) and "associated" for all of the rest. The rights have to be defined at the organisational stage.

The Federation must have rights to receive and transfer financial resources. Each member has to pay his membership dues. This would define his right to vote. The Federation must have rights to receive credits from external institutions as follows: the state, associations from Europe and elsewhere, as well as from sponsors.

The Federation have to borrow and to give funds for projects of its members, to make popular its activity, to increase the number of its members. It has to be able to sigh contracts for technical assistance with its members as well with companies, foundations and institutions, to protect interests of its members.

The Federation must lobby for RES development in the country and abroad, to advertise renewable energy to the Government and society.

Commercial associations. Commercial associations are a mode for support of RES development. They may facilitate relations with existing chambers of commerce and economic groups as Association of Bulgarian producers and others.

Programs for RES development. Each kind of renewable energy (solar, wind, water, biomass, geothermal) may be developed within well structured 10-years programs. For example, Program on solar radiation, Program on wind energy, etc. On this basis, some relations with similar European programs may be established, financial and other support for RES development may be received; grants and investments; preparation of regulations and standards; elaboration of syllabus.

Specific measures go along the development of different kinds of renewable energies.

3. Demonstration projects

Some ideas for development of concrete demonstration projects in the field of solar, wind, hydro, geothermal and biomass energy utilisation will be discussed in this item. These ideas are developed on the base of present state of RES in Bulgaria, as well as on the basis of CSP's and PHARE's projects considerations. Although these projects are preliminary, they take into account the available potential in each domain, the private and governmental incentives for participation, show something new, reveal possibilities for financial support, have a market future.

Solar energy. There is available some experience in Bulgaria in design, assembling and exploitation of solar hot water collectors. Built solar collectors are over 50000 m^2. They are produced mainly from steel, the basic part from which being amortized due to expired lifetime. These collectors are mount on different hotels and administrative buildings mainly at Black Sea Coast and south-east of Bulgaria. Other solar collectors are built with financial support of different programs: PHARE,TEMPUS and others, or imported by different private companies. Such collectors are produced by different technologies with unknown efficiency, so it is necessary to analyse and summarise results on efficiency and performance of installed collectors (both small household and big ones).

PROJECT:

Comparative assessment of old hot water solar collectors produced in Bulgaria

AIM: The basic aim of this project is to elaborate national strategy to select appropriate solar collectors comparable to European standards.

The project includes two types of collectors: small type modules for households; and solar installations for municipal buildings, hotels, hospitals.

The basic issues to be solved are: investigation, measurement, gathering of information for installation of small and municipal-type collectors; technical and economic analysis of different systems performance; stand and laboratory tests of different systems (Bulgarian and imported); recommendations for appropriate system selection; recommendations for retrofit of old systems; dissemination of the results of investigation, public awareness, seminars, publications and etc.

Wind energy **.** Besides some small wind aggregates, there is no experience in Bulgaria in using modern equipment producing electricity from wind. For this reason it is necessary to develop some projects for demonstration of wind energy potential. The most economically feasible option is construction of wind farms in plane part of the country, for the regions with average wind velocity per year > 6 m/s. This climate prerequisite is met in the regions of capes Kaliakra and Emine on the Black Sea Coast. Besides the presence of sufficient wind energy density flow on h=10 m a.g.l. which exceed 700 W/m^2 these areas are situated just next to the distribution network. For the annual mean wind velocity of 6 m/s and an interest rate of 5% the price of produced electricity from a single wind generator is about 0.09 USD/kWh, and for velocity of 8 m/s - it is 0.05 USD/kWh. The consumer price of electricity generated by traditional power plants in Bulgaria is 0.04 USD/kWh for base load and exceeds 0.15 USD/kWh under peak load. Thus, the price of electric power produced in wind farms is comparable with electricity generated by a classical producer of electricity if the terrain is windy enough.

In long-term perspective, for facilitation of electricity generation by wind farms it could be useful to develop a demonstration project in the region of cape Kaliakra, supported by the government.

PROJECT:

Wind master for electricity generation - installed capacity up to 100 kW; connected to the distribution network

AIM: To demonstrate possibilities for utilisation of wind energy for electricity production on a large scale; gaining experience in construction and exploitation of such equipment.

If the expenses for installation of a single wind generator are similar to those in Great Britain (1700 USD/kW), then the price for installation, which includes the price of the wind power station, construction and mounting works and connection to the grid, in case of 50 kW unit capacity would be about 100000 USD. Taking into account the lower prices in Bulgaria for construction and mounting works (labour force, building of a tower, connection to the grid), this total sum could be reduced or a wind master with higher capacity could be installed.

With developing of private farming in Bulgaria, especially in the region of Dobrudja and Black Sea Coast, where wonderful conditions for agricultural producing exist, it is indispensable agricultural land to be irrigated, as well as to develop stock-farming. One way of solving these problems, is the wind energy utilisation by the so called wind pumps. They are two kinds: the first one represents wind masters generating electricity to be used later for supply of water pumps; the second one represents wind pumps for which mechanical wind power is directly applied in combination with pumps for drawing of water from wells for irrigation purposes. The second type of pumps work under low wind velocities (below 2.5 m/s). There is a Bulgarian company, which produces 3-meters model of wind pump at a price of 465 USD.

PROJECT:

Wind pumps for water pumping for irrigation purposes and supplying animals with fresh water

AIM: The basic aim of the project is to demonstrate possibilities for utilisation of wind energy for agricultural purposes.

This project must include assembling, monitoring and use of a Bulgarian type wind pump, as well as such produced abroad (England) in order to define the basic characteristics of the equipment, which can be recommended to the Bulgarian producers, and to demonstrate to farmers remote from the grid, the possibilities of the system.

Combined utilisation of solar and wind energy. There are over 150 chalets built in Stara planina, Rila, Pirin, Rhodopa and Rila mountains. Many of these chalets are supplied with electricity, but others are not. There are some equipments such as transformers (peak Botev), meteorological observatories (peak Murgash) and others objects, which are not connected to the power grid, and the personnel works under bad life conditions.

PROJECT:

Combined PV-Wind installation for electricity supply to remote sites

AIM: The basic aim of the project is to demonstrate possibilities for combined utilisation of solar and wind energy and electricity supply to remote object (lighting, supplying of radio, TV-set, refrigerator and others appliances).

The best places to develop such ecological project are regions suitable for development of international mountain tourism. The most appropriate place for this purpose is the region of the Shipka or Petrohan passes, situated along the international tourist pathway Kom - Emine.

Biomass energy. The biomass, especially burning of wood and agricultural wastes is the traditional energy source in Bulgaria. Unfortunately some old combustion systems are used - stoves, boilers. Due to the increased heating and electricity prices, the share of biomass consumption for cooking and heating increased and reached 0.5% of the energy consumption in the country.

PROJECT:

Installation for efficient burning of wood residues for domestic purposes

AIM: Gaining of experience, know-how, for producing of energy effective equipment for burning of biomass residues.

Such an installation will be used for production of hot water and heating of a building using a boiler installation with capacity up to 20 kW, which will satisfy one family power demand.

Due to the construction of high capacity plants from chemical, energy and engineering industry like KZM "Plovdiv", Soda plants "Devnia", "Chimko" - Vratza and others, considerable areas of agricultural lands are polluted with heavy metals. Measures for rehabilitation are carrying out, but they are funds and time consuming. That is why, it is impossible to use them for agricultural needs for many years. It is necessary to develop a demonstration project on such land to plant energy crops to be used in the power generation. With regard to the particular soil and climatic conditions, it is indispensable to select appropriate crops and processing and utilisation scheme.

PROJECT:

Cultivation of energy crops in regions with land polluted by heavy metals

AIM: The aim of the project is gaining experience in cultivation of energy crops and their further utilisation for energy production.

Hydroenergy. There are 25 MW built in Bulgaria for micro HPP with a single unit capacity below 2 MW. For the currently known potential of 755 GWh, it is necessary to build several hundreds micro HPP in order to utilize it. Basically micro HPP potential is situated in the valleys of rivers running in Stara planina (Lovech and Montana regions), as well as those in Vitosha, Pirin and Rhodopa mountain. There is also perspective hydropotential not studied yet situated in the water-supply and irrigation systems (trade out and pumping shafts). It is necessary to develop a project focused at this hydroenergy potential.

PROJECT:

Assessment of hydroenergy potential in the country for building of micro HPP (< 2 MW installed capacity)

AIM: The basic aim of the project is studying of hydroenergy potential in rivers, river flows, and in water-supply and irrigation systems.

*Geothermal energy***.** There are some geothermal installations built with total capacity of 95 MW, used for heating of hotels, administrative buildings and others. These installations are constructed in different periods, following different schemes and by different organizations. It is necessary to summarise the experience from exploitation of these installations, to make recommendations for choice and retrofit the old systems.

The basic tasks are: investigations, measurements, gathering of information needed; technical and economic analysis of existing systems operation; recommendations for construction of new systems; recommendations for retrofit of the old systems; result dissemination.

VI. ACTION PLAN FOR REDUCTION OF CH_4 EMISSIONS FROM DUMPS AND LANDFILLS FOR MUNICIPAL SOLID WASTES (MSW)

1. Background

Methane is one of the main greenhouse gases (GHG) contributing to the global warming. There are several sources of CH_4 emissions, including the dumps and MSW landfills.

Currently there are no adopted State standards concerning the CH_4 emissions from dumps and MSW landfills. There is no concept developed for their reduction and potential capture and utilization for household and energy needs. Worldwide there exist methods to extract biogas out of organized and unorganized landfills for MSW. The CH_4 mitigation measures could rely on incineration, extraction of energy gas from waste disposal sites in order to utilize it and/or programs aiming recycling of MSW.

Some attempts to study the opportunities for collecting the biogas from the MSW landfills are already carried out in Bulgaria. Generally they didn't provoke investments to promote the process of utilization of the biogas. The reasons are mainly economic and they are closely related to the waste disposal practices that do not always facilitate anaerobic decomposition of wastes which determines the quantity of the biogas formation in the process of decomposition.

Recently, the search for additional energy sources is reactivated. Some municipalities support the research activities in the field of utilization of biogas from municipal waste landfills.

The study to address climate change made a review of those attempts in waste sector, as well as it provided an assessment of existing dumps and landfills as a potential source for significant amounts of CH_4 emissions.

The development of an Action plan for reduction of CH_4 emissions from dumps and landfills requires different actions to be identified and analyzed that could be implemented to promote introduction of new technologies to reduce emissions.

1.1. Waste management measures

The development of Action Plan for CH_4 Emission Reduction is closely related to the National Plan for MSW Management and it has to be studies as integrated part of it. The development of waste management measures to reduce the CH_4 emissions in Bulgaria is significantly facilitated by the Policy on MSW Management.

In 1995-1995 Bulgarian and American experts cooperatively developed a National Policy for MSW Management Project. The project involved a wide range of experts in the field, representatives of interested institutions and NGOs. Pursuant to the Bulgarian legislation, to be adopted this project has to be submitted and adopted by the Government. This is projected to be done at the beginning of 1998.

The adoption of the National Policy for MSW Management as an official document will allow a National Plan for MSW Management to be prepared. The measures included in the National Plan for MSW Management will have direct or indirect effect on the CH_4 emissions.

When addressing the global climate change issue, the problems, targets and priorities that affect the CH_4 emissions and some additional specific mitigation measures set by the project for National Policy for MSW Management will be discussed.

Main **problems**:

- Increased amount of generated wastes
- Lack of waste separation and recycling
- Improper solid waste disposal methods
- Great number of illegal waste disposal sites
- Lack of control of the landfills and waste disposal sites

- Insufficient knowledge and motivation of the population and low percentage of public participation
- Insufficient qualification of the employees in the field of environmental protection
- Lack of proper legislation
- Lack of economic instruments - sanctions and incentives
- Bad co-ordination among institutions

Specific **problems**:

- Lack of monitoring of the CH_4 emissions from dumps and landfills
- Lack of valid estimates for the biogas amounts generated in the dumps and landfills
- Lack of motivation for development of system of measures for collection and utilization of biogas generated in dumps and landfills
- Lack of financial and environmental studies to prove the feasibility of CH_4 capturing and utilization, etc.

The principles which lay the grounds of the National Policy for MSW Management Project are valid also in the development of the plan for reduction of the CH_4 emissions from dumps and landfills. These **principles** are as follows:

1. Clean and healthy environment
2. Rational use of available raw materials and resources
3. Integrated waste management
4. 'Polluter pays' principle (full responsibility)
5. Public participation

1.2. Number of MSW dumps

MSW treatment in the country is carried out through waste disposal in unorganised dumps and small village disposal sites with total number of more than 2000 covering a total area of about 14000 dka. Actually almost each village or town has one or few landfills which are sources of serious environmental pollution and groundwater contamination in particular. The preliminary data provided by the National Statistics Institute (NSI) show that in 1996 there were about 4 million tons municipal wastes disposed by 1 172 villages and towns with organised waste collection and transportation. About 78% of the population of the country with average MSW for those inhabitant 618 kg/capita lives at these places.

The dumps and landfills for these towns and villages are 682 and 99% of the collected wastes are disposed in them.

According to the municipalities, almost 27% of the landfills are organised and they comprise 54% of the used MSW landfills and disposal sites. About 77% of the gathered households wastes are pilled there.

The specialised monitoring system of the Ministry of Environment and Waters covers MSW 57 landfills with total area of 3590 dka. In 1996 about 3 million tons wastes were disposed by approximately 170 towns and cities with population over 60% of the country's population.

Problems related to the exploatation of the existing landfills:

- lack of fences to limit the access of people and animals;
- daily soil cover of the disposed waste, that will ensure anaerobic decomposing is rarely applied technology;
- there are no circular protection channels to prevent surface water contamination;
- there are no forest belts;

- drainage system construction and screens to hinder the MSW light fraction to disperse are rarely used practices;
- lack of monitoring and control of the pollutants (infiltrates, biogas) to the environmental components;
- lack of reliable estimates for the biogas amounts generated from MSW dumps and landfills;
- Lack of motivation for development of system of measures for collection and utilization of the biogas from dumps and landfills
- Lack of financial and environmental studies to prove the feasibility of CH_4 capturing and utilization;
- lack of drainage system to capture and discharge generated biogas, which create conditions for self-ignition and/or self-exploding, etc.

1.3. MSW amounts and content

In Bulgaria municipal, industrial and agricultural wastes are disposed together. The useful components are not utilised. The average quantity of wastes annually generated by an inhabitant in the country is 618 kg/capita (in 1996). This quantity is significantly higher when compared to the values in the developed countries. The reason is the lack of a system to separate industrial, agricultural and other types of wastes out of the MSW, lack of technical devices to assess and. control the input wastes, lack of system for separate disposal of useful wastes, increased consumption of goods and single use packaging materials, insufficient public support to waste reduction due to ineffective legislation and lack of economic incentives.

MSW content is one of the major indicators when choosing the way of waste treatment, as well as when estimating the projected amounts of CH_4 emission generation in landfills.

MSW consist of organic and inorganic compounds. The ratio of the components in the overall waste composition is variable and it depends on a number of factors such as:

- public services quality in villages and towns;
- type of the town/village system;
- climate profile;
- lifestyle and culture of the population;
- demographic conditions, etc.

The calorific value of MSW varies by seasons and regions. It is related to the changing morphology of wastes. Due to the lack of representative data on MSW composition, the projections on generated biogas from landfills will be based on the deductive approach.

1.4. Economic instrument, legislation and regulation framework

There is not yet a legislation and regulation framework concerning reduction of the CH_4 emissions from MSW. MSW management is not completely regulated. The adoption of the *Law on mitigation of the adverse effect of wastes on the environment* is an attempt to regulate all activities and responsibilities related to the waste management process. A series of regulations will be adopted in order to specify the responsibilities and duties of each participant in the process, to define a tax system that allows a self-financing of activities that stimulate waste reduction and utilization.

2. Action plan and measures to manage CH_4 emission reduction

2.1. CH_4 mitigation measures

The measures to limit the impact of CH_4 emissions from anaerobic decomposition of municipal wastes include:

- Reduction of the total MSW
- Choice of alternatives for waste treatment:
  - MSW sanitary landfills
  - Recycling
  - Composting
  - Incineration
- Collecting and incineration (flare) of biogas produced in MSW dumps and landfills.
- Utilization of the methane from MSW dumps and landfills for:
  - Electricity generation;
  - Direct gas supply - medium gas quality;
  - Processing in vehicle fuel.

2.2. Assessment of CH_4 mitigation measures and recommended actions

- Reduction of the total MSW

This measure is complex and its application will certainly lead to diverse impacts on the environment. Because of this, it forms the basis of the National Policy for MSW Management and will be priority in the National Action Plan to Address MSW, as well as in the guidelines of the Governments to the municipalities for development of municipal action plans to address MSW.

- **Choice of alternatives for waste treatment**

⇒ **MSW sanitary landfills**

MSW sanitary landfilling is among the CH_4 mitigation measures that are financially feasible for our municipalities.

The national and municipal policy for MSW management focuses on this method for waste treatment. Construction of sanitary landfills with planned biogas capturing and emissions discharge to the atmosphere is underway.

The easiest to achieve among the measures related to climate change is the setting of an additional requirement to the companies using the landfills to incinerate their biogas.

The enforcement of supplementing requirements aiming emission reduction could be done in the process of preparation and adoption of different regulations, including Regulation on the circumstances and requirements for construction and exploitation of facilities and installations for MSW treatment.

Alongside with the compulsory monitoring and control of the environmental components, the requirements for design, construction and exploitation of modern sanitary landfills should include also measures for collection, transportation and treatment/utilisation of the generated biogas, incl. methane.

If the efforts of municipalities for construction and exploitation of regional MSW landfills are coordinated, they could ensure implementation of up-to-date technical and technological solutions, reduction of the percent share of treatment cost, as well as utilization of generated methane by introduction of better technical and economic solutions. Construction of such regional landfills is supported by the Government by means of funding from the National Environmental Fund.

The implementation of the measure will lead not only to CH4 emission reduction, but also to improvement of air and water quality, reduced risk to spread diseases.

⇒ **Recycling**

Reuse and recycling of useful components from wastes is beneficiary to the environment in terms of reduction of used raw materials and waste minimization, and hence they lead to CH_4 emission reduction.

Recycling is among the priorities of MSW management. It is environmentally and economically effective measure and it has positive impact not only to the environment and climate, but to the entire society, too.

⇒ **Composting**

Composting is studied as an option for MSW treatment in some of the bigger villages and towns in Bulgaria. The application of the method has also complex impacts - in terms of waste treatment, as well as for CH_4 emission reduction. If the output compost has good characteristics, its application in agriculture to recultivate soils will lead to additional benefits.

⇒ **Incineration**

Under the circumstances of the Bulgarian economic situation, the efforts for CH_4 mitigation are recommended to take the radical form of waste minimization (i.e. incineration) only as an extreme measure in case other alternative waste treatment approaches are inapplicable. The construction and exploitation of MSW incineration facilities requires serious investments and substantial operational costs which doesn't match the financial opportunities of the municipalities.

⇒ **Complex measures**

The selected CH_4 mitigation measures could be a combination of the enumerated measures suitable for particular circumstances.

- **Collecting and incineration (flare) of biogas produced in MSW dumps and landfills**

The measure that combines the collection and gas removal system, wells and tubes, is the most easy to apply in terms of construction and investments. However, when applied to old landfills, it requires preliminary investigation to specify the composition of generated biogas. If there are hazard wastes together with the municipal wastes, there is a pollution risk from biogas combustion.

- **Utilization of the methane from MSW dumps and landfills**

Biogas collection, removal and utilization could be considered as a combination of potential measures for CH_4 reduction and development of clean energy source. The benefits out of the application of this measure are increased security of the landfills, increased air and water quality, decrease of the disease spread risk, prevention of odor contamination and last but not least, economic benefits.

Methane utilization by integrating in the energy system for electricity generation, biogas processing to engine fuel or the direct gas supply with medium quality gas seems attractive at first sight, but the lack of experience in the fields, as well as the high capital costs required, makes each of the recommended measures not feasible.

If the result of the attempts of electricity production from the biogass in old and new constructed environmentally-friendly MSW landfills prove to be good, further popularity gaining of the measure could be expected.

As a next step of the experiment biogas utilization via processing in motor fuel for the specialised waste transportation machinary and for direct medium quality gas supply could be included. If the experiments are succesful, the practices could become popular and more operating landfils will be involved, incl. application of combined methods for CH_4 utilization.

The studied measures are compatible with the MSW management policy. The experiments could be run as a combination of sanitation, recultivation and treatment of old contamination and utilization of generated CH_4.

The economic feasibility could be theoretically defined and proved after the experiments. In all cases the experiments will have positive impact both on the society and on the environment, no matter what are the values obtained.

Theoretical CH_4 generation conditions for the MSW dumps and landfills in Bulgaria, indicate CH_4 emissions amounts that will allow processing to motor fuel in the landfills constructed and operating under a mode of regular sealing and soil cover over the wastes. The isolation at the bottom of some of the landfills increases the gas capturing potential.

Expected reduction of biogas from MSW landfills due to planned collection and incineration
(utilization for energy and household needs is not included)

	MSW landfill	CH_4 reduced emissions		$_2$ equivalent reduced emissions		$_2$ emissions reduced emissions	
		average for project's life-time	total for project's life-time	average for project's life-time	total for project's life-time	average for project's life-time	total for project's life-time
		kt/yr	**kt**	**kt/yr**	**kt**	**kt/yr**	**kt**
1	2	3	4	5	6	7	8
1.	Sofia - Dolni Bogrov	1 173,74	17 606,04	24 648,46	369 726,88	37,97	569,61
2.	Sofia - Suhindol	721,60	10 823,93	15 153,50	227 302,49	23,35	350,19
3.	Varna	415,06	6 225,95	8 716,34	130 745,03	13,43	201,43
4.	Veliko Turnovo	314,87	4 723,07	6 612,30	99 184,44	10,19	152,81
5.	Rousse	266,58	3 998,66	5 598,12	83 971,85	8,62	129,37
6.	Stara Zagora	263,23	3 948,46	5 527,85	82 917,76	8,52	127,74
7.	Gabrovo - new landfill	232,67	3 490,06	4 886,08	73 291,27	7,53	112,91
8.	Bourgas	217,19	3 257,83	4 560,96	68 414,34	7,03	105,40
9.	Sliven	171,83	2 577,45	3 608,42	54 126,35	5,56	83,39
10.	Dobrich	166,21	2 493,20	3 490,48	52 357,27	5,38	80,66
11.	Pleven	160,93	2 413,88	3 379,44	50 691,58	5,21	78,10
12.	Iambol	160,88	2 413,16	3 378,42	50 676,34	5,20	78,07
13.	Plovdiv	144,53	2 167,99	3 035,19	45 527,83	4,68	70,14
14.	Pernik	129,84	1 947,56	2 726,58	40 898,69	4,20	63,01
15.	Shoumen	117,13	1 756,97	2 459,75	36 896,31	3,79	56,84
16.	Targovishte-old landfill	109,59	1 643,89	2 301,44	34 521,63	3,55	53,18
17.	Razgrad	107,34	1 610,14	2 254,20	33 812,95	3,47	52,09
18.	Pazardjik	95,93	1 438,96	2 014,55	30 218,19	3,10	46,55
19.	Montana	94,33	1 415,02	1 981,03	29 715,44	3,05	45,78
20.	Vratza	92,16	1 382,35	1 935,29	29 029,40	2,98	44,72
21.	Kardjali	90,53	1 358,00	1 901,20	28 517,98	2,93	43,94
22.	Dimitrovgrad	90,11	1 351,68	1 891,35	28 385,30	2,92	43,73
23.	Silistra	90,06	1 350,93	1 891,30	28 369,53	2,91	43,71
24.	Targovishte- new landfill	88,98	1 334,71	1 868,59	28 028,92	2,88	43,18
25.	Doupnitza	83,12	1 246,76	1 745,46	26 181,89	2,69	40,34
26.	Haskovo	76,96	1 154,38	1 616,13	24 241,90	2,49	37,35
27.	Petrich	74,81	1 122,15	1 571,02	23 565,25	2,42	36,31
28.	Gorna Oriahovitza	73,46	1 101,83	1 542,56	23 138,41	2,38	35,65
29.	Vidin	66,77	1 001,56	1 402,19	21 032,82	2,16	32,40
30.	Sandanski	66,06	1 004,42	1 406,19	21 092,90	2,17	32,50
31.	Velingrad	47,43	711,38	955,93	14 938,93	1,53	23,02
32.	Lovech	45,48	682,24	955,13	14 326,94	1,47	22,07
33.	Blagoevgrad	41,91	628,70	880,18	13 202,65	1,36	20,34
34.	Gabrovo - old landfill	38,07	551,07	799,49	11 992,41	1,23	18,48
35.	Lom	36,73	551,01	771,41	11 571,12	1,19	17,83
36.	Sevlievo	36,39	545,84	764,17	11 462,55	1,18	17,66
37.	Smolian	32,86	492,97	690,15	10 352,27	1,06	15,95
38.	Svishtov	27,66	414,96	580,94	8 714,11	0,90	13,43
39.	Popovo	25,12	376,86	527,61	7 914,16	0,81	12,19
40.	Asenovgrad	24,45	366,78	513,49	7 702,35	0,79	11,87
41.	Teteven	21,14	317,08	443,92	6 658,76	0,68	10,26
42.	Gotze Delchev	16,67	250,12	350,17	5 252,58	0,54	8,09
43.	Samokov	14,50	217,49	404,48	4 567,20	0,47	7,04
44.	Troian	8,31	124,69	174,56	2 618,43	0,27	4,03
	Total:	**6 376.22**	**95 596.18**	**133 921.02**	**2 007 861.4**	**213.24**	**3 101.36**

Conclusions:

At this stage of the SNAP project there are mitigation measures recommended for each sector in the field of forestry, agriculture, waste management and renewable energy. The main measures that could be addressed by the National action plan are listed. The climate scenarios used in the stage are updated.

The vulnerability of the main agricultural crops in Bulgaria is assessed. There is a section that applies GAP models for prediction of the responses of forest ecosystems to the long-term climate changes. The adaptation measures in forestry and agricultural sectors are developed and assesses in terms of climate change.

All discussed measures are preliminary database that will be used to rank and select measures to be included in the aggregated National action plan to address climate change in Bulgaria.