The Role of Biomass in Mitigation of Global Warming

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ABSTRACT

There is dramatic evidence that various Greenhouse Gases are responsible for global warming and climate change. Agriculture can play a role both for reducing GHG emission and to sequester carbon. Agricultures primary aim is food and feed supply, but energy crops implementation needs changes in land use. There are many questions, 'pro and contra' uncertainties in this topic. Converting secondary biomass, plant residues to valuable energy products might be a solution. Energy potential of Hungary is approximately half-half of products and by-products. In this paper, along the predicted yield we were interested in the available secondary biomass quantities and the proportion of the parts of the plant in biomass, as well. In our research we used the method of simulation modeling.
Climate scenarios - pictures of how the climate may look in the future – we used were downscaled to Debrecen, an important centre of agricultural production in Hungary. We have used five different scenarios which give predictions for the middle of the century as weather inputs in the crop model 4M. 4M has been developed by the Hungarian Agricultural Model Designer Group. It contains several sub-models to describe the physiological interactions of soil - plant systems. The simulations were also run using the historical data of the scenarios reference period.
We have analyzed the simulated secondary biomass quantities and the proportion of the parts in biomass of corn plant, which is one of the most cultivated crop. Analyzing and comparing the simulated values, the results are very promising. Bioenergy gives Europe an opportunity to reduce GHG emission and secure its energy supply. With this paper we would like to call the attention to the importance of creating well-designed descriptive-forecasting systems, as well as defining the optimal preparing and response strategies to the conditions in change.

Keywords: Climate change, climate scenario, crops, modeling, secondary biomass, Hungary.

1. INTRODUCTION

Global warming is one of the biggest problems of our days. The main reason for global temperature increase is the increase of carbon-dioxide concentration in the atmosphere (Barrow E.M. and Hulme M., 1996; IPCC, Climate Change Report, 1995 and 2007). The major cause of

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this increase is continued combustion of fossil fuels. Agriculture can help reducing global warming by increasing the absorption (land use (Hoogwijk M. et al., 2005), irrigation, plant improvement) and decreasing the emission (biomass as energy resource (Fodor, N., 2006; Kim. S. and Dale B.E, 2004), too. There is a wide scientific consensus that if these changes continue, significant damage to global ecosystems, food production and economy will ensue. We analyze the possibilities maize production can provide for bioenergy production (Boksai, D, 2006 and Ladányi, M., 2006). Energy potential of Hungary is approximately half-half of products and by-products (Horvath, L. and Erdélyi, É., 2006). It is an energy crop with significant by-production. Using by-products for biofuels production and as green dung can be a step in prevention of global warming. In this work we have used the method of modelling and present our simulation results for maize biomass. We have choosen this plant, because it is one of the most cultivated plants in Hungary (Hufnagel, L. et al., 2006).

2. BIOFUELS AND BIOMASS

"Biofuels" is a term that commonly denotes liquid or gaseous fuels made from biomass. The biomass can have different sources: starches from cereals, grains and sugar crops, waste products from agriculture and forestry, etc. Advanced biofuels from biomass can be produced using several different technical processes; a wider variety of potential feedstocks would be available such as crops residues. Agricultural residues include a wide range of plant material produced along with the main product of the crop. Biomass examples for energy production could be cereal straw, orchard pruning, corn stems. Producing biogas is also a sustainable technology. Biogas - produced from corn for instance - as a renewable fuel can be used to power electricity generators, provide heat and produce soil improving material. Europe is facing increased efforts for bioenergy production support, both based on existing resources and energy crops implementation. There are biomass-power projects in Hungary as well, in Pécs, Borsod, Tiszapalkonya, Ajka. Debrecen is a city where local buses are already operated by biofuels. Heat and electricity from bio-based origin, together with transportations fuels production will soon star strong competing demands for solid biomass origin supply. Therefore the assessment of biomass resources supply and future biomass potentials are of great importance.

3. MATERIALS AND METHODS

3.1 Scenarios

Climate scenarios can be defined as relevant and adequate pictures of how the climate may look in the future. During our research, we applied the most commonly accepted scenarios presented in international reports, such as

- scenario BASE which is the base of all other scenarios with the parameters of our days;
- two steady double carbon dioxide scenarios created by the Geophysical Fluid Dynamics Laboratory (USA), GFDL2535 and GFDL5564, concerning the years around 2030 and 2060 respectively;
- UKHI and UKLO (high and low-resolution equilibrium) and UKTR3140 (high-resolution transient climate change experiment) worked out by United Kingdom Meteorological Office (UKMO).

For scenario generation, the so-called GCM-s (General Circulation Model or Global Climate Model) are used, in this work GCMs downscaled to Debrecen, the basic object of our calculations, because it's an important centre of agricultural production in Hungary. The scaling of the scenarios for the region Hungary was made in the frame of CLIVARA project (Climate Change, Climatic Variability and Agriculture in Europe; Harrison, P.A., 2000). These meteorogical data consists of daily average, minimum and maximum temperature, precipitation amount, radiation values.

3.2. 4M Model

In our modeling research we used the 4M model, which has been developed by the Hungarian Agricultural Model Designer Group from the various institutes in the country (Fodor, N., 2006). It contains several models to describe the physiological interactions of soil - plant systems and offers a possibility of building up different system models in it for the specific purposes of the users need (Fodor, N. and Kovács, G., 2005). The CERES model was chosen to be a starting point and was adapted to Hungarian circumstances. The simulations were run for the daily average temperature, precipitation amount and radiation forecasted by climate scenarios.

4. MODELLING MAIZE BIOMASS FOR THE FUTURE

Living under changing climate conditions we need to prepare for the future. Energy potential of Hungary is approximately half-half of products and by-products. Maize is an energy crop with significant by-production. We analyzed the impacts of climate change on the growing periods of corn by using the 4M model for different climate scenarios. We analyzed the effects of changing temperature on the proportion of grain, leaf, corn-stalk and root in corn biomass by using the 4M model for different climate scenarios as weather inputs. Debrecen was the center of our research, as one of the most important centers of Hungarian agricultural production, as well. We analyzed the impacts of climate change on the growing periods of corn by using the 4M model for different climate scenarios (Erdélyi, É. et al, 2009). We examined the effects of changing meteorological conditions on the proportion of corn-stalk and leaf mass in biomass, as well. Using biomass as a substitute for fossil fuel is highly prioritized, but the primary aim of agricultural production is food and feed supply. Converting secondary biomass, plant residues to valuable energy products might be a solution. That's why we discuss the secondary biomass quantities. Using secondary biomass independently from grain mass is not useful; therefore evaluating the prospective grain quantity in biomass is of great importance, as well.

4.1. Modeling Corn Secondary Biomass

First we analyzed simulated the secondary biomass of maize and compare the simulation results of six climate scenarios. The result for the UKTR3140 scenario doesn't show significant difference comparing to the BASE scenario, but the result for GFDL2534 predicts smaller and UKHI the smallest values. The result of the GFDL5564 scenario shows significant increase in the predicted quantities of corn secondary biomass comparing to the scenario BASE. In averages UKHI shows the smallest values, GFDL2534 and UKTR3140 predict a little lower quantity, GFDL5564 and UKLO higher values compared to the results of the BASE scenario (Table 1).

Table 1. Predicted average quantities available for biofuel production (kg/ha)

Scenarios	BASE	GFDL2534	GFDL5564	UKHI	UKLO	UKTR3140
secondary biomass	4977	4454	9038	2142	6127	4665

Scenarios are given for 31 independent years (except for the UKTR3140 scenario), we could analyze them using statistical methods. We got the result that the UKTR3140 and GFDL2534 scenarios don't show significant difference comparing to the BASE scenario, the result for UKLO predicts a little higher maize secondary biomass quantity, the result of the GFDL5564 scenario shows significant increase in the predicted quantities comparing to all the other scenarios. UKHI shows much lower values. The applied scenarios give predictions for the middle of the century, except UKHI and UKLO. They show the most drastic change, very similar to the newest scenarios in Prudence database (IPCC, 2007) developed for studies about the end of this century (Diós et al., 2008), which models predict warming of even 6°C or more. These predictions carry uncertainty; the predictions of the others, except GFDL5564 with the best results are more or less the same (Figure1).

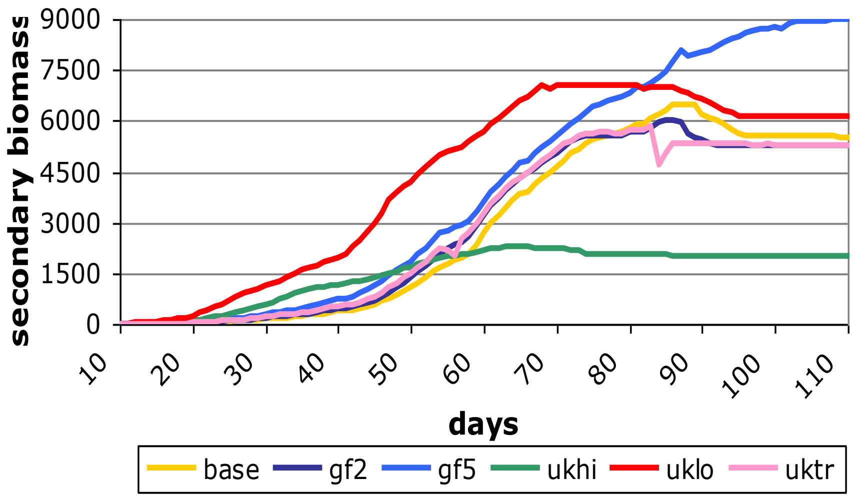

Figure 1. Predicted quantities of the maize secondary biomass, six different climate scenarios

4.2. Modelling corn phenology and biomass

Considering the big increase in risk of maize production in the last two decades (Erdélyi et al., 2007), we decided to analyze the future maize production using a crop model with climate scenarios. We have showed that the variability doesn't change much for the used climate scenarios, but the estimated mean yield does (Horváth, L. and Erdélyi, É., 2006). We wanted to learn, what we can expect from maize yield in the Debrecen region. For analyzing the biomass changes we used again the 4M model for different climate scenarios, as weather inputs. According to the results, we can say that moderate warming can increase the yield, but more increase of the temperature can cause big losses. Analyzing the climate scenarios for the same

region in the future we can see that the sum of the temperature averages increases over time in the past and the scenarios predict an even more drastic increase. This means that the starting date (sowing), ending date (ripening) and the length of the phenophases of growing plants will change, too. Examining the changes in the phenological phases of the plant we can see that climate change has the effect of shortening the length of the growing periods and, moreover, the starting dates of them are shifting to earlier dates (Erdélyi, É. et al, 2009).
We compared the sums of the precipitations for the growing season of crops, as well. We can see a slow decrease of the accumulated precipitation for these periods in the region of Debrecen and that the scenarios predict smaller values in the future. We can also see a great variability in the amount of precipitation, which means that the frequency of extreme weather events, such as droughts and floods are more probable.

4.3. Planning adaptation strategies

Modeling can be well applied in planning adaptation strategies, as well. This means that with the help of simulation case studies we can decrease the uncertainty the change could bring and concentrate on how to benefit from climate change. Applying irrigation raises economical questions and is not used nowadays. On the other hand decreased precipitation amounts are very probable in the future. We used the 4M model to trace when the corn plant is suffering from precipitation shortage in its development (Figure 2.).

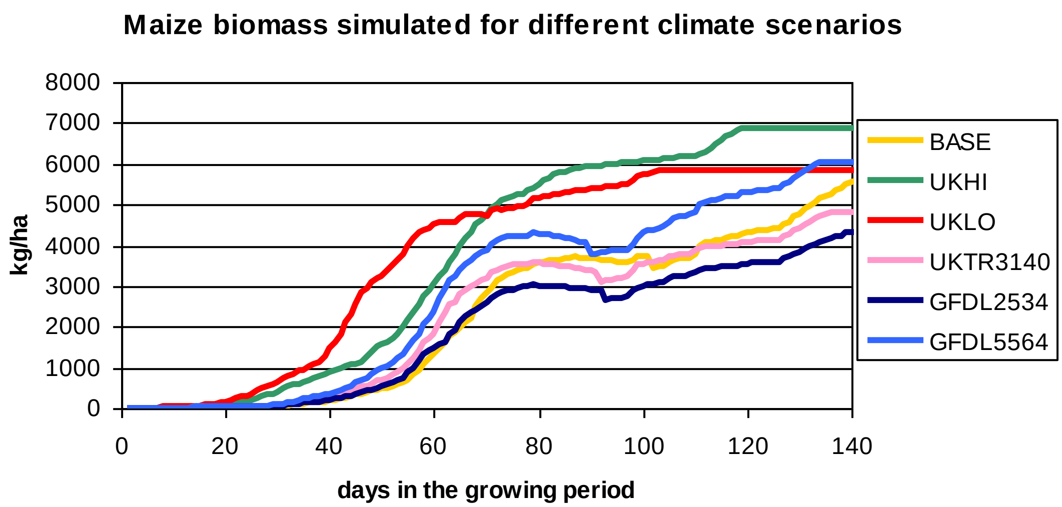

Figure 2. Simulation of corn plant biomass

Our next step was to test the efficacy of irrigation patterns and finding an adaptive strategy in order to increase the yield using two different irrigation systems. The location of our virtual experiment was the same, the Debrecen region. We used the climate scenarios mentioned above as weather inputs in the simulation. Our standard meteorological data was the BASE scenario, which represents the current weather conditions. It can be seen on Figure 2. that the optimal irrigation time could be around the 90th day of the growing period. We defined three irrigation strategies: irrigation 1 (2x50mm in July and another 50mm in August) and irrigation 2 (2x50mm in July) and production with no irrigation. For the simulated results with no irrigation it can be stated that biomass and grain levels decreased for all scenarios except in the case of GFDL5564 compared to BASE (Table 2.). When comparing runs without treatment and runs with irrigation, we found that biomass and grain levels increased significantly for all scenarios. Our results have shown that climate change in itself does not increase biomass or grain levels, while significant increase in yield can be reached by irrigation at optimal time. This probably means that economic aspects about not using watering crop fields in our country are worth reconsidering. According to our results we can state that irrigation in right time can even double the yield, but repeating irrigation one more time is not worth (Table 2).

Table Simulated maize grain-mass quantities for three irrigation strategies (no irrigation, irrigation 1: 2x50 mm in July, 1x50 mm in August, irrigation 2: 2x50 mm in July)

grain-mass kg/ha	BASE	GFDL 2534	GFDL 5564	UKHI	UKLO	UKTR 3140
no irrigation	4552	3104	5062	1990	4084	3277
irrigation1	10322	8289	8936	5536	5665	8439
irrigation 2	8978	6954	8262	5139	5592	7256

Adaptive capacity of a system can be both spontaneous and autonomous response. Alternatively, adaptive capacity may depend upon policy, planning and design decisions carried out in response to, or in anticipation of, changes in climatic conditions. Not only the plants can cope with the changing conditions (which might be a very long procedure), but we can help in introducing optimal interventions.

4.4. Modelling corn biomass proportion

In our previous results we have seen that there are possibilities of increasing the yield with appropriate interventions. Next we wanted to analyze how the proportion of grain mass in biomass is happen to change for the different hypothesized climate scenarios. The results for the proportion of the parts of the plant of the scenario GFDL2534 were very similar to the results for the GFDL5564, and the results for the UKTR3140 doesn't show significant difference comparing to the BASE scenario. We present the four most different cases on Figure 3. We can see that grain development could start earlier in the growing period of the plant for the scenarios with more drastic temperature increase assumptions UKHI and UKLO, UKLO has better grain-mass proportion. GFDL5564 and GFDL2534 has also very promising results for harvest index.

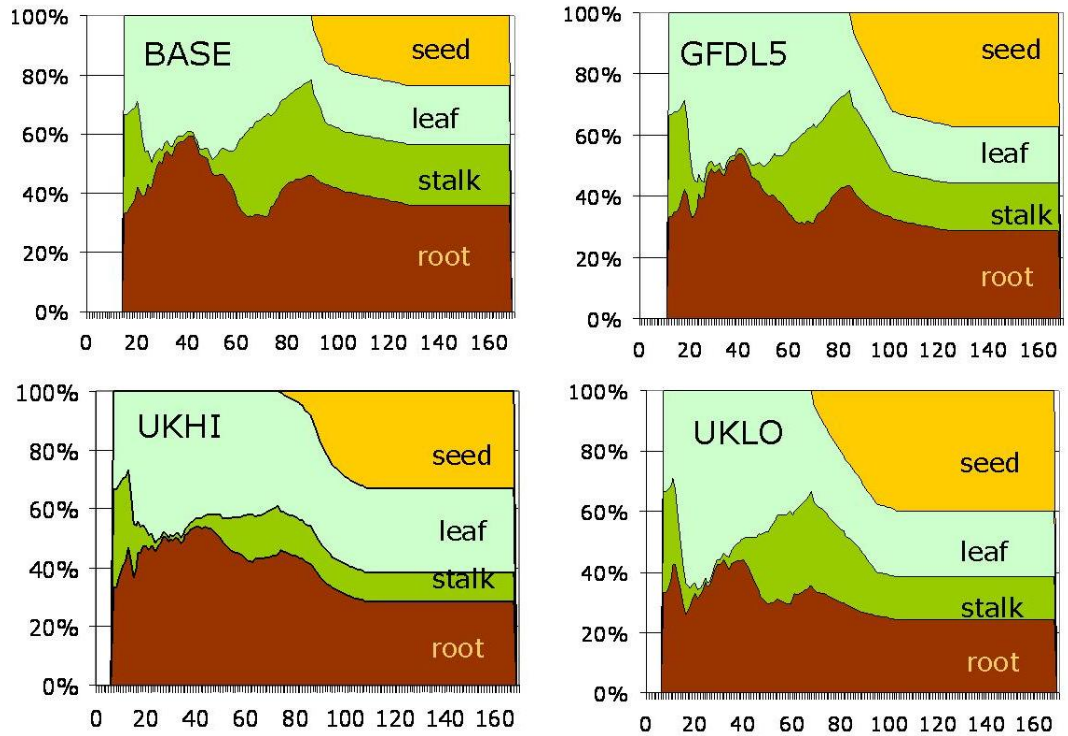

Figure 3. Proportions of the parts of the corn plant in simulated by climate scenarios BASE, GFDL5564, UKHI and UKLO

5. DISCUSSION AND CONCLUSION

The recently released IPCC WGI fourth assessment report (2007) is illustrating human influence in warming effect on the global climate. Nowadays, world energy supply is dominated by fossil fuels. Biomass resource sectors such as agriculture are playing a very significant contributing role. In order to accomplish the Kyoto greenhouse gas (GHG) reduction targets, the modern utilisation of biomass has to increase rapidly. Bioenergy gives Europe the best opportunity to reduce GHG emission and secure its energy supply. Biofuels nowadays are less competitive than fossil fuels. But the largest increase in renewable energy use, in the coming years, will take place in the EU countries driven by strong governmental support. Building the new energy structure based on different bioenergy sources should be the main target, where beside wind, solar and hydro, biomass becomes integrated part of the overall energy strategies with an important sustainable role for bioenergy and biorefineries to play. Energy crops production will have to compete for land areas with other crops, their production has been regarded as an interesting issue in most European countries. Research and field trials with different species of energy crops have been performed to estimate yields, growth rate, survival rate, harvesting technology, etc. On the other hand the role of agriculture in climate protection is in systematically sequestering carbon dioxide in soils and in plant biomass. Most promising crops for certain agro-climatic conditions have been selected already in some countries. We continue our research with investigating the potentials of agriculture residues in Hungary, so examining the potentials of other energy crops, as well. Simulations give us a great opportunity for this work.

With this paper we would like to call the attention to the importance of creating well-designed descriptive-forecasting systems, as well as defining the optimal preparing and response strategies to the conditions in change. Running crop models we can do many virtual experiments on very low cost and in very short time.

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