Modeling forest CO_2 emissions for Ukraine affected by bioenergy and carbon sequestration policies

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Abstract: A set of scenarios and a version of the Global Forest Model (G4M) developed for Ukraine are considered. The scenarios simulate possible policies of the Ukrainian government to stimulate 1) use of forest biomass to substitute fossil fuels, 2) sequester carbon in forest living biomass by introducing a carbon tax and 3) combination of both policies. Key issues of the G4M algorithm for modeling land-use changes and forest management actions are presented.

Key words: modeling, policy scenarios, land-use change, CO_2 emissions, decision making, carbon price

I. Introduction

Increasing of bioenergy production and carbon sequestration are important targets of climate mitigation policies. The point is to find the optimal way of reaching the targets and reduce bigger amount of CO_2 emissions.

Assessments of effectiveness of bioenergy and carbon sequestration policies as well as reliable long-term projection of carbon sequestration in forests require an accurate simulation of forest dynamics.

Forest is a source of biomass for energy production and from the other side it is a large carbon pool. Intensification of forest harvest leads to forest biomass degradation that is CO_2 emissions. Simulation of the policies by developing respective scenarios and modeling forest dynamics allows to discover optimal policies.

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The Global Forest Model (G4M) is a well developed tool for simulation forest management and land use change and exploration of policies.

II. General algorithm of decision making during simulation

Geospatial approach realized in the Global Forest Model is convenient for simulation of land use changes and forest management. G4M calculates decisions on 0.5×0.5˚ geographic grid [1]. The model version developed for Ukraine is based on the grid 300 by 300m, uses regional and subregional statistical data and has improved forest management algorithm. Each grid cell may contain different types of vegetation (land cover) and be used for different purposes (land use), for example: agricultural land, buildings and forest. Use of forest age structure information is necessary for simulation of future forest management actions. Primary land use of the grid cell may look like shown in Fig.1:

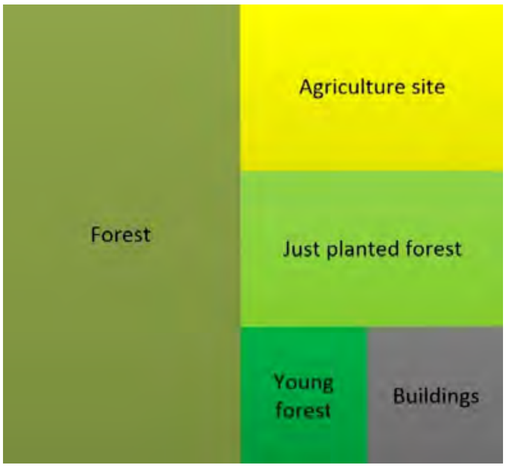

Fig. 1. Primary land cover

First step is to decide will the land use type change or not. Comparing net present values (NPV) of forestry and agriculture is relevant in this case [2]. After the NPV comparing one of three possible actions is applied:

- If primary land cover is agricultural land and $NPV_{forestry} > NPV_{agriculture}$, then land use is changed to forest (afforestation);
- If primary land use is forest and $NPV_{forestr} < NPV_{agriculture}$, then land use is changed to agriculture land (deforestation);
- If primary land use is forest and $NPV_{forestry} > NPV_{agriculture}$ or it is agricultural land and $NPV_{forestry} < NPV_{agriculture}$ then no changes occur (Fig. 2).

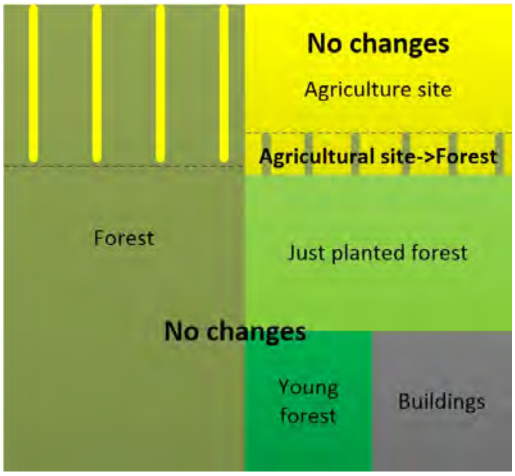

Fig. 2. Land use changes required

Next step is to provide respective forest management actions after land use changing, in particular wood harvesting for satisfying wood demand.

Two types of harvesting are possible – thinning and final cut. Final cuts are applicable when forest reaches its "optimal" rotation age [3]. Thinning is used for most of forest age classes except newly planted forest. Thinning is possible in protected forests and harvested wood can be used for satisfying country's demand (Fig. 3).

Fig. 3. Forest management actions

Applying land use changes before forest management actions allows accounting harvested trees from deforestation for satisfying wood demand.

At the beginning of next year land use in grid cell looks like shown in Fig. 4:

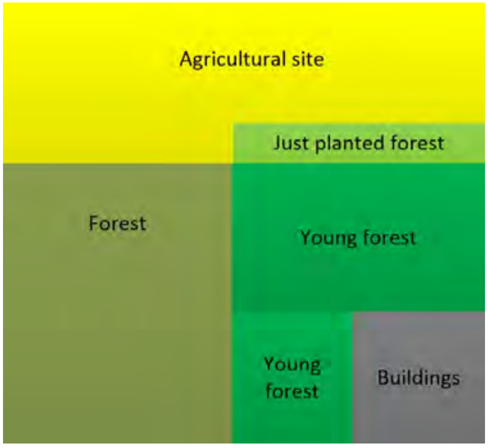

Fig. 4. Land use at the beginning of next year

The same set of steps is applied every year. Buildings and infrastructure, water areas and natural reserves are not considered as feasible land for conversion.

III. Developing scenarios for simulation carbon sequestration policies

An abovementioned algorithm requires a lot of input data to produce the result. Some data are indicators of economic or political development, e.g.:

- land price;
- wood price;
- wood production;
- carbon price;
- gross domestic product (GDP);
- population density etc.

Alteration of one of those parameters during time scale provides a background for simulation of a policy through development of a scenario.

We develop a set of scenarios for simulation of a policy stimulating: 1. use of fuelwood (e.g., introduction of special elevated price for energy produced using of fuelwood); 2. carbon sequestration in forest standing biomass by introduction of a "carbon tax" (forest/land owner pays a tax proportional to decrease of forest biomass or gets money if forest biomass increases due to forest management or land use change); 3. combination of these two policies. One more scenario assuming no policies (so called "business as usual") is used as reference. We assume that the first policy will result in wood demand increase. The idea is to investigate impact of the policies on forest CO_2 emissions, forest area and wood harvest.

There is an example of a set of scenarios based on changes of carbon price (Fig. 5).

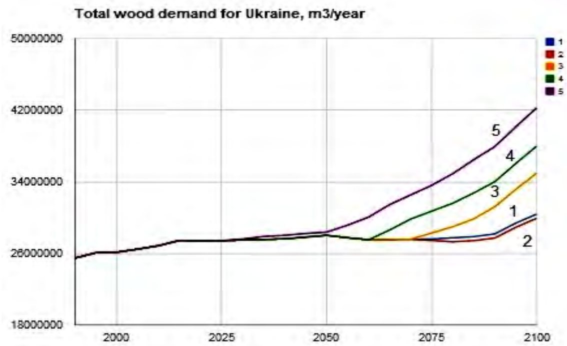

Fig. 5. Total wood harvest within different scenarios, m^3

Carbon price changes in different ways within 100 years considering various mitigation policies:

1. Reference scenario: carbon price is equal 0 $/tCO$_2$ for the whole period;
2. Carbon price increases to 12 $/tCO$_2$;
3. Carbon price increases to 130 $/tCO$_2$;
4. Carbon price increases to 350 $/tCO$_2$;
5. Carbon price increases to 800 $/tCO$_2$.

Conclusions

To assess policies and choose most effective policies one can use scenario development with consequent modeling. A G4M version developed for Ukraine provides a possibility to discover how different drivers change forest parameters. In particular, we presented an effect of carbon prices on total harvested wood as an example.

More complicated combinations of policies will be used for developing a set of bioenergy and carbon sequestration scenarios. We will analyze impact of the policies on CO_2 emissions from forests in Ukraine.

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