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SHORT NOTES

Emergy and value of the net primary production (NPP) above ground in natural areas

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1. Introduction

Net primary productivity (NPP) is an important index in the evaluation of the dynamics of carbon cycle in forest ecosystems at local, regional and global scales. The production of biomass for energy consumption was promoted in the 60s, and again in the first decade of this new century, to become an important component of energy offer in industrial countries. Besides that, nowadays, billions of people in developing countries use biomass as main energy source in rural areas (Bhattacharya 2002; Pimentel & Patzek 2005). The quantification of biomass production is important for building databases for many calculations (carbon sequestration, energy balances for regional planning, ecological performance evaluation) and discussion of energy policy using exergy, emergy and ecological footprint assessment.

Therefore there is a need to develop appropriate tools to calculate the NPP value of vegetation covers. Many techniques have been developed to estimate NPP, all of which need to face the issue of variability in datasets. The relative importance of the resources and environmental conditions that limit the net primary productivity (NPP) vary with scale and ecosystem. At the global scale, total NPP varies for each terrestrial biome. This variation strongly correlates with climate. In ecosystems where moisture is favorable, NPP increases exponentially with temperature; where temperature is favorable, NPP increases to a maximum in tropical rainforests with moderately high precipitation (up to 3 m annual precipitation) and declines at extremely high (above 3 m) precipitation, due to anaerobic conditions and/or depletion of soil minerals by leaching (Schuur 2003).

The objective of this short communication is to inform about the existence of BIOMASv1.0 software, based on compilation of existing statistical models, to quantify net primary productivity for natural areas in mass, energy, emergy and monetary value.

2. Method

The method used in this research relies on several first-level mathematical models, all of them published in scientific literature. The earliest attempt to evaluate NPP at a global scale was made by Lieth and Whittaker (1975), which is still quoted today. These estimates were based on regressions of temperature data of a thousand weather stations, computed to a simple measure of actual evapotranspiration (AET) in millimeters per year per square meter, and then correlated with NPP for several ecosystems (Running et al. 2004). The resulting equation was used to compute and to find the first global estimations of NPP in $g/m^2/yr$. Rosen-

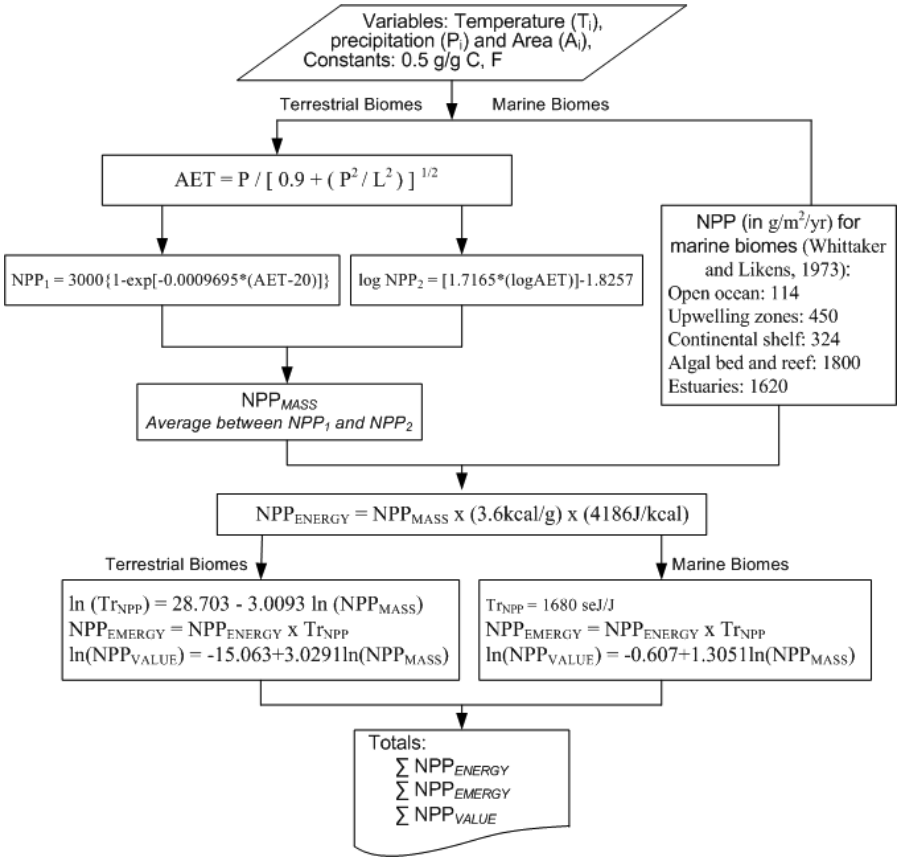

Figure 1. Algorithm used to calculate the net primary productivity of natural areas

zweig (1968) predicted annual aboveground net primary productivity of terrestrial plant communities as a function of AET [logNPP = (a(log AET)) + b]. Experimental data from Barnes et al. (1998) was used to calculate the constants: a = 1.7165 and b = –1.8257. Data from Whittaker and Likens (1973) was used for marine ecosystems, considering that 1 gram of dry-mass biomass is equivalent to 0.5 grams of carbon (Ponce-Hernandez et al. 2004).

In order to calculate the actual evapotranspiration of all ecosystems, the Turc (1961) model ([AET = P / (0.9 + (P^2/L^2))^{½}]; P = rain precipitation in mm/yr; L = 300 + 25T + 0.05T^3, T = annual average temperature in ºC) was used, which has temperature and rain precipitation as variables.

The software BIOMASSv1.0 is limited to ecosystems with evapotranspiration rates between 0 and 1600 mm/yr. It implements the algorithm shown in Figure 1. The output calculation is described below: NPP_{ENERGY}, NPP_{EMERGY} (Odum 1996), NPP_{VALUE} (Costanza et al. 1997).

3. Results and discussion

Statistical analysis was carried out in order to validate BIOMASSv1.0 (correlation coefficient, R^2, and ANOVA) between NPP values calculated with the software and those reported by the reference being used (Costanza et al. 2007). R^2 obtained for the proposed method was 0.59. This indicates that the values computed by BIOMASSv1.0 would explain in 59 percent the values found in the reference. Comparing this R^2 value with other NPP prediction methods, for example, Zhao and Zhou (2005) (R^2 between 0.55 and 0.92) and Costanza et al. (2007) (R^2 between 0.58 and 0.65), we can say that the prediction level of BIOMASSv1.0 is acceptable.

The ANOVA method was applied to determine whether significant differences exist between the two groups (program values and reference data) using a significance level of 5 percent. F-calculated = 22.97 is less than F-critic = 253.68; this indicates that the null hypothesis (no significant differences between reference data and BIOMASSv1.0 results) can be accepted. This conclusion is reinforced by p-value = 0.1651 (with $p > 0.05$), indicat-

ing that the averages of the two groups do not show significant differences.

4. Conclusions

The BIOMASSv1.0 software can be used for two purposes: (a) prediction of NPP for an ecosystem – there are only two inputs: temperature and precipitation; output is expressed per unit of area: mass (g/m^2/yr), energy (J/m^2/yr), emergy (seJ/m^2/yr) and monetary value (USD/m^2/yr); (b) calculation of NPP for a region or a country – in this case additional information about the subsystems' areas is required; output is expressed as flows of mass (g/yr), energy (J/yr), emergy (seJ/yr) and monetary value (USD/yr).

NPP values calculated in different units can be used in emergy evaluation and ecological footprint assessment. These values would be considered as an inflow to calculate the local natural resources (emergy analysis) or as a component to calculate the equivalence factors (ecological footprint). Finally, we want to clarify that BIOMASSv1.0 software has limitations because until this very moment it uses for validation only United States ecosystems data. This limitation can be overcome in future works. But, it can be used to esteem NPP for similar ecosystems, at national or regional scale.

References

Barnes B. V., Zak D. R., Denton S. R. & Spurr S. H., 1998, Forest Ecology, 4th ed., Wiley, New York: 774 pp.

Bhattacharya S., 2002, Biomass energy and densification: A Global Review with Emphasis on Developing Countries, Proceedings of The First World Conference on Pellets, Stockholm, September 2–4, Stockholm: 1–17.

Costanza R., Fisher B., Mulder K., Liu S. & Christopher T., 2007, Biodiversity and ecosystem services: a multiscale empirical study of the relationship between species richness and net primary production, Ecological Economics 61: 478–491.

Costanza R., D'Arge R., De Groot R., Farber S., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill R. V., Paruelo J., Raskin R. G., Sutton P. & Van den Belt M., 1997, The value of the world's ecosystem services and natural capital, Nature 387: 253–260.

Lieth H. & Whittaker R. H., 1975, Primary Productivity of the Biosphere, Springer-Verlag, New York.

Min Z. & Guang-Sheng Z., 2005, Estimation of biomass and net primary productivity of major planted forests in China based on forest inventory data, Forest Ecology and Management 207: 295–313.

Odum H. T., 1996, Environmental accounting, emergy and decision making, Wiley, New York: 370 pp.

Pimentel D. & Patzek T. W., 2005, Ethanol Production Using Corn, Switchgrass, and Wood; Biodiesel Production Using Soybean and Sunflower, Natural Resources Research 14: 65–76.

Ponce-Hernandez R., Koohafkan, P. & Antoine J., 2004, Assessing carbon stocks and modelling win–win scenarios of carbon sequestration through land-use changes, Food and Agriculture Organization of the United Nations.

Rosenzweig M. L., 1968, Net primary productivity of terrestrial communities: prediction from climatological data, The American Naturalist 102: 67–74.

Running S. W., Nemani R. R., Heinsch F. A., Zhao M., Reeves M. & Hashimoto H., 2004, A continuous satellite-derived measure of global terrestrial primary production, BioScience 54: 547–560.

Schuur E. A. G., 2003, Productivity and global climate revisited: the sensitivity of tropical forest growth to precipitation, Ecology 84: 1165–1170.

Turc L., 1961, Estimation of irrigation water requirements, potential evapotranspiration: a simple climatic formula envolved up to date, Ann. Agron. 12: 13–49.

Whittaker R. H. & Likens G. E., 1973, Carbon in the biota, [in:] G. M. Woodwell & E. V. Pecan (eds.), Carbon and the biosphere, Technical Information Center, Office of Information Services, U.S. Atomic Energy Commission, Springfield, Virginia, USA: 281–302.

Zhao M., Zhou G. S., 2005, Estimation biomass and NPP of major planted forests based on forest inventory data in China, For. Ecol. Manage. 144: 201–217.