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Life Cycle Assessment of Alfalfa Production and Prediction of Emissions using Multi-Layer Adaptive Neuro-Fuzzy Inference System in Bukan Township

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Introduction

Agricultural productions has been identified as a major contributor to atmospheric greenhouse gases (GHG) on a global scale with about 14% of global net CO_2 emissions coming from agriculture. Identification and assessment of environmental impact in the production system will be leading to achieve the goals of sustainable development, which would be achieved by life cycle assessment. To find the relationship between inputs and outputs of a production process, artificial intelligence (AI) has drawn more attention rather than mathematical models to find the relationships between input and output variables by training, and produce results without any prior assumptions. The aims of this study were to life cycle assessment (LCA) of Alfalfa production flow and prediction of GWP (global warming potential) per ha produced alfalfa (kg CO_2 eq.(ha alfalfa)$^{-1}$) with respect to inputs using ANFIS.

Materials and Methods

The sample size was calculated by using the Cochran method, to be equals 75, then the data were collected from 75 alfalfa farms in Bukan Township in Western Azerbaijan province using face to face questionnaire method. Functional unit and system boundary were determined one hectare of alfalfa and the farm gate, respectively. Inventory data in this study was three parts, included: consumed inputs in the alfalfa production, farm direct emissions from crop production and indirect emissions related to inputs processing stage. Direct Emissions from alfalfa cultivation include emissions to air, water and soil from the field. Data for the production of used inputs and calculation of direct emission were taken from the EcoInvent®3.0 database available in simapro8.2.3.0 software and World Food LCA Database (WFLD). Primary data along with calculated direct emissions were imported into and analyzed with the SimaPro8.2.3.0 software. The impact-evaluation method used was the CML-IA baseline V3.02 / World 2000. Damage assessment is a relatively new step in impact assessment. The purpose of damage assessment is to combine a number of impact category indicators into a damage category (also called area of protection). To assess the damage in this study, IMPACT 2002+ V2.12 / IMPACT 2002+ method was used. ANFIS is a multilayer feed-forward network which is applying to map an input space to an output space using a combination of neural network learning algorithms and fuzzy reasoning. In order to enable a system to deal with cognitive uncertainties in a manner more like humans, neural networks have been engaged with fuzzy logic, creating a new terminology called ‘‘neuro-fuzzy method. An ANFIS is used to map input characteristics to input membership functions (MFs), input MF to a set of if-then rules, rules to a set of output characteristics, output characteristics to output MFs, and the output MFs to a single valued output or a decision associated with the output. The main restriction of the ANFIS model is related to the number of input variables. If ANFIS inputs exceed five, the computational time and rule numbers will increase, so ANFIS will not be able to model output with respect to inputs. In this study, the number of inputs were ten, including machinery, diesel fuel, nitrogen, phosphate, electricity, water for irrigation, labor, pesticides, Manure and seed and GWP was as the model output signal. To solve this problem and employ all input variables, we proposed clustering input parameters to four groups. Correspondingly, the proposed model was developed using seven ANFIS sub-networks. To obtain the best results several modifications were made in the structure of ANFIS networks, and some parameters were calculated to compare the results of different models. Making a comparison between different topologies the employment of some indicators was a pivotal to get a good vision of various the structures, such as the correlation coefficient (R), Mean Square Error (MSE) and Root Mean Square Error

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(RMSE). In addition, for checking comparison between experimental and modeled data, the t-test was performed. The null hypothesis was equality of data average. To develop ANFIS models, MATLAB software (R2015a) was used.

Results and Discussion

Impact categories including Global warming potential (GWP), eutrophication potential (EP), human toxicity potential (HTP), terrestrial ecotoxicity potential (TEP), oxidant formation potential (OFP), acidification potential (AP), Abiotic depletion (AD) and Abiotic depletion (fossil fuels) were calculated as 13373 kg CO_2 eq, 19.78 kg PO_4^{-2} eq, 2054 kg 1,4-DCB eq, 38.7 kg 1,4-DCB eq, 3.84 kg Ethylene eq, 90.64 kg SO_2 eq, 0.015 kg Sb eq and 205169 MJ, respectively. The results of damage assessment of alfalfa production revealed that electricity in three categories, human health damage, climate change and ecosystem quality had maximum role, but in the resources damage category was the largest share of damage related direct emissions. The value of the climate change was calculated as 13373 kg CO2 eq. The best structure was including five ANFIS network in the first layer, two network in the second layer and a network in output layer. Values of R, MSE and RMSE for the final ANFIS in k-fold model were 0.983, 0.107 and 0.327 and in C-means model were 0.999, 0.007 and 0.082**,** respectively. The p-value in t-test was 0.9987 that indicates non-significant difference between the mean of modeling and experimental data. Coefficient of determination (R^2) between actual and predicted GWP based on the best k-fold and C-means models were 0.994 and 0.99, respectively. The coefficient of determination for these index demonstrated the suitability of the developed network for prediction of GWP of alfalfa production in the studied area.

Conclusions

Based on the results of this study, to reduce the emissions, electricity consumption should be reduced. Adapting of electro pumps power with the well depth and the amount of required water taken for field will be a possible solution to reduce the use of electricity in order to trigger of electro pumps and thus reducing of emissions related to it. In some situations, the type of mineral fertilizer is the main determinant of emissions at the whole farm level and changing the type of fertilizer could significantly reduce the environmental impact. Comparison of GWP modeling results using two methods of k-fold and C-means revealed that C-means method has higher accuracy in prediction of GWP. Also the high quantities for the determination coefficient related to both modeling methods demonstrates high correlation between actual and predicted data.

Keywords: Alfalfa, ANFIS, Bukan township, Electricity, GWP, LCA, Modeling