Analysis of bioenergy by using linear regression

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Abstract

Prediction of bioenergy production is challenging in the machine learning field. In this article, bioenergy production data from different countries (Russian Fed, Turkey, Armenia, Azerbaijan and total Eurasia) were analyzed to predict future bioenergy production in these countries using the linear regression. Data on output production of bioenergy in megawatt were obtained from the International Renewable Energy Agency, and (MW). We implemented the linear regression method redundant to predict the future production of bioenergy data and attained good accuracy. The aforementioned method is applicable to developing countries and can be used to predict bioenergy production and formulate new policies that are adapted to an increasing population in a particular country. Our results (average accuracy is 49.61%) revealed that bioenergy production levels in developing countries are not sufficient to cater for bioenergy needs of fast growing populations. Thus we recommend that governments should formulate adequate policies aimed at improving bioenergy production.

Keywords Bioenergy · Energy production · Linear regression model · Yearly production · International renewable energy agency

1 Introduction

Bioenergy is renewable energy made available from materials derived from biological sources. Bioenergy is organic material, which stores energy from sunlight, in the form of chemical energy that can be used as a fuel in the form of liquid biofuels or biogas. Biomass may include wood waste, wood, straw, sugarcane, manure and many other products, which are by-products of a variety of agricultural processes [1–6]. Concerns about energy security, climate policy and search for new alternative sources of agricultural income have greatly increased interest in bioenergy and fossil fuels. A number of studies have projected considerable growth in bio-energy use, and thus important changes have been made in both energy systems and land use [1, 4–8]. However, the use of bioenergy and its implications have been for some time a subject of a fierce debate

[5, 9–16]. One of the critical issues linked to bioenergy production is the emission of greenhouse gases and finding a balance between bioenergy production and minimizing environmental pollution has always been elusive. Several studies have published the estimates of potential and actual use of bioenergy under different scenarios [5, 17–23]. Previous studies have reported on the different modes of producing bioenergy (biomass) [3, 5, 24–26]; however, none of them are able to predict with accuracy the future implications of bioenergy production. Biomass is commonly used to increase yields of agricultural crops via fertilization and irrigation, and may similarly increase biomass yields for perennial bioenergy crops [5, 26–29]. In this paper we have suggested a predictive method for future bioenergy production using the technique of machine learning, an evaluation method that automates the creation of evaluation models. Machine learning uses

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artificial intelligence based on the idea that systems can learn from data, identify patterns and make decisions with minimal human intervention. Previously, machine learning techniques have been used to predict a number of other fields (linear regression technique) [30, 31] stock price (deep belief network) [32] price movement (LSTM neural network algorithm) [33], real Estate price [34], amazon spot price (ANFIS model) [35], closing price prediction. (two dimensional principal component analyses) [36], electricity price prediction (neural network model) [37], housing price (neural network) [38]. However, previous studies did not focus on the bio energy; we have predicted the future bio energy production. As many countries around the world are trying to increase bioenergy production. It is anticipated that the main outcome of this research will critically influence the rationale behind bioenergy production and determine the future of bioenergy production. This paper focused mainly on bioenergy prediction in Eurasian countries, using linear regression model to predict the future bioenergy production in the Russian Federation, Turkey, Armenia, Azerbaijan and the whole Eurasia. The time series data were collected from 2006 to 2016. Because the data size was small, the linear regression model and the prediction accuracy was 49.61%.

2 Bioenergy production

The trend nowadays is to promote bioenergy as a fuel on a large scale. A number of key factors are considered when promoting bioenergy production, including: (1) greenhouse emission reduction, (2) direct impact on biodiversity or potential biodiversity loss and food production, (3)

ecological problems, such as water shortage and (4) costs associated with bioenergy production. Estimation studies usually put emphasis on the entire potential of associated costs and bioenergy by a set of nominal application criteria [13, 17, 18, 20–22] and bioenergy is a renewable energy source made from biomass [40–43]. In strategic terms, the discussion on the penalties of extensive bioenergy usage has managed by rule manufacturers in sustainability principles, such as those careful in present EU legislature. The biomass main sources are shown in Fig. 1.

3 Problem definition

3.1 Problem statement

This study proposes to predict future production using a model of bioenergy production using agricultural analysis and linear regression. The Eq. 1 show that the prediction of the problem of bioenergy production is formally defined as follows: N number of training samples $\{(X_1, Z_1), (X_2, Z_2), \dots, (X_n, Z_n)\}$ where X_1 is the annual vector of bioenergy a_1 , and A is the set of n countries in which $A = \{a_1, a_2, a_3, \dots, a_n\}$. In Eq. 2 shows the total number of functions is $\{X | \text{total} = R^m\}$ and m , and the status of bioenergy production (increased or decreased) is Z_i , where the number of features is $Z_{\text{total}} \{yes, no\}$. The following predictive function is proposed to predict annual production of bioenergy:

$$Z = f\left(\frac{A}{X}\right) \quad (1)$$

$$f\left(\frac{A}{X}\right) = \begin{cases} \geq 0 & \text{if } Z = \text{yes increasing} \\ < 0 & \text{if } Z = \text{no decreasing} \end{cases} \quad (2)$$

Fig. 1 Bioenergy sources

The Eq. 3 show the primary objective of the learning task is to study a predictive function $f^{\wedge} = (.)$ or to increase or decrease the predicted bioenergy production.

$$Z^{\wedge} = f^{\wedge}\left(\frac{A}{X}\right) \quad (3)$$

4 Materials and methods

Bioenergy prediction is a challenging task in the field of machine learning. The main challenge is to guide government and bioenergy production organizations, especially in countries where less energy is produced as compared to energy use or needs. A number of learning methods have been applied to predict the stock market, including Genetic Algorithm, Artificial Neural Network and Support Vector Machine. The Artificial Neural Network is the main method that is widely used in this field. Therefore, to understand how ANN can be used to predict bioenergy production in agriculture, techniques that enhance ANN's performance are reviewed. Price prediction can be demonstrated by two methods: the technical method by which statistical data analysis is performed and the fundamental method by which all available details and growth agents that affect bioenergy production are considered. These methods are carried out on present and historical data with the aim of forecasting bioenergy. Technical analysis with the linear regression algorithm was used in this paper to predict bioenergy production. Data on the production of bioenergy from Eurasia were obtained from available public records and used for prediction. Linear Regression is a well-established technique in a wide range of applications and has been widely studied for its bioenergy prediction capabilities. However, the inputs considered are mostly derived from the data within the annual bioenergy data itself. Such separation

could ignore the factors affecting production. Consideration of publicly available bioenergy prediction data can improve the accuracy and future bioenergy production. Figure 2 shows the predictive model of bioenergy.

4.1 Prediction of bioenergy production using machine learning

For statistical classification techniques, the machine learning algorithm with linear regression was used and the results were determined by one or more independent variables. The natural outcome of the model of linear regression is categorical. The model of linear regression was represented as follows (see Eq. 4):

$$Y_i = \beta_0 1 + \beta_p x_{i1} + \dots + \beta_p x_{ip} = X^T i \beta + \varepsilon_i, \quad i = 1 \dots n \quad (4)$$

T denotes transposing, so that $X^T i \beta$ is the inner product between x_i and β vectors (see Eq. 5). The form of the vector is

$$Y = X \beta + \varepsilon \quad (5)$$

Therefore, the confidence interval of $E(y|x^*)$ is the average expected value of y for a given x^* (see Eq. 6).

$$y^{\wedge} \pm t_{n-2}^* S_y \sqrt{\frac{1}{n} + \frac{(x^* - x')^2}{(n-1)s_x^2}} \quad (6)$$

where S_y is the standard deviation from the residues, the residual error in the R regression output is calculated as and as S_y (see Eq. 7).

$$s_y = \sqrt{\frac{\sum (y_i - y^{\wedge})^2}{n-2}} \quad (7)$$

Fig. 2 Bioenergy production prediction model

The proposed model consists of vectors with dimensional feature space m . The real number range is $-\infty$ to $+\infty$ in the space x points feature, which projects it on m and converts it to a real number z (see Eq. 8).

$$Z = C + m \cdot x = C + m_1x_1 + m_2x_2 + \dots + m_dx_d \quad (8)$$

Future prediction is a difficult task, whether in stock market or bioenergy forecasting. Projection of production trends for bioenergy involves predicting hidden relationships and characterizing data intensity, noise and high degree of uncertainty. In bioenergy prediction, forecasts are made for future production (next year) of 'high' or 'low'. Therefore, linear regression method outfits fine for prediction of bioenergy and trend prediction. Highly connected features are trained for the linear regression model. The training data model is built and used to test data. The

training data model is constructed and used to test data. Complete features were highly connected and accuracy of 49.61 percent. Precision was calculated by confusion matrix.

Accuracy

$$= \frac{(\text{True Positive}) + (\text{True Negative})}{(\text{True Positive}) + (\text{False Positive}) + (\text{False Negative}) + (\text{True Negative})}$$

where genuinely positive (TP) is an upward trend and is classified as upward. True Negative (TN), a downward trend, is described as downward. False Positive (FP) is a downward trend, but it is categorized as upward. False negative (FN) is a rising trend categorized as downward. Figure 3 shows the detailed steps of this method.

Fig. 3 Bioenergy future production method

Algorithm 1:

Bioenergy production prediction

Input: X is the input

Output: Future bioenergy production prediction is P

Algorithm:

Step 1: take matrix M of data for the last one year, data size (15)

Step 2: take matrix P of data for the previous / last ten years, data size 10

Step 3: make a sliding window and the window size is 16 for each matrix P as W1, W2...

W10

Step 4: calculate the Euclidean distance of s. D10

Step 5: Select matrix Wi as Wi= corresponding matrix (min Di) [1, 10]

Step 6: for I=1 ton 1)

- 1) calculate the moving average (MA) of two matrix D and save as Q 2)
- 2) calculate the CMA (central moving average) of matrix Q and save as R.
- 3) calculate the mean Q matrix
- 4) calculate the mean of matrix R
- 5) calculate the average of both mean and apply LR (linear regression) and predict the P.
- Add P to previous data for getting prediction

4.2 Data set

Time sequence data were collected from the International Renewable Energy Agency (IRENA). Annual time data sequences from 2006 to 2016 were used to inspect the association between bioenergy GDP and bioenergy outputs. The variables used in this study are: production of bioenergy, output of the Russian Fed in (MW), output of Turkey is (MW) and output of Armenia is (MW), output of Azerbaijan (MW) and output of total Eurasia in (MW). Table 1 provides a detailed description of the datasets.

Table 1 Detailed description of datasets

Bioenergy production of Eurasia countries		
Countries (bioenergy)	Study range	Production (MW) Mega watts
Russian Fed	2006–2016	12,545
Turkey	2006–2016	1789
Armenia	2006–2016	154.000
Azerbaijan	2006–2016	6.000
Eurasia	2006–2016	15,862

Data were taken from the (International Renewable Energy Agency)

5 Results and discussion

5.1 Russian federation

The Russian Bioenergy Organization is an industrialized holding corporation in the arena of fuel energy, biotechnology and engineering. Assets of the corporation make a complete production cycle available for industrial engineering, processing and peat extraction, distribution and production of finished products generating electricity and heat. Bioenergy production in Russian Fed in 2006 was 1667 (MW) and in 2008, the production of bioenergy decreased and reached 1253 (MW). Production in 2010 was 1197 (MW). Production increased in 2014 and reached 1370 (MW), and in 2016, production was also 1370 (MW). The production of bioenergy from 2006 to 2016 is shown in Fig. 4, and the forecast of bioenergy production is shown in Figs. 4 and 5. We predicted the production of bioenergy from 1980 (past) to 2030.

5.2 Turkey

Turkey has a high potential for biogas production [1]. More than 85 million tons of animal wastes are produced annually, which is estimated to over 1.8 million tons of oil (toe) equivalent. When plant waste is included, the potential rises to over 5.3 million tons of oil equivalent

Fig. 4 **a** Bioenergy of Russian Fed, the graph shows bioenergy production and predicted bioenergy. **b** Bioenergy of Turkey, the graph shows bioenergy production and predicted bioenergy. **c** Bioenergy of Armenia, the graph shows bioenergy production and predicted bioenergy. **d** Bioenergy of Azerbaijan, the graph shows bioenergy production and predicted bioenergy. **e** Bioenergy of Eurasia, the graph shows bioenergy production and predicted bioenergy

Fig. 4 (continued)

(toe). However, only 85 biogas facilities with 36 plants are currently in operation [1]. Eighty (80) MW of landfill power is in operation while 78 MW is under construction [7]. Bio-energy production in Turkey in 2006 was 86 (MW) and in 2008, the production of bioenergy increased and reached 102 (MW). Production in 2010 was 118 (MW). Production increased in 2014 and reached 214 (MW), and in 2016, production increased and reached 395 (MW). Bioenergy production increased from 2006 to 2016 (Fig. 4), and the forecast of bioenergy production is shown in Fig. 4. We have predicted the production of bioenergy from 1980 to 2030.

5.3 Armenia

Bioenergy production in Armenia in 2006 was 0 (MW) and in 2008, the bioenergy production increased and reached 1 (MW). Production in 2010 was also 1 (MW). Once again, production decreased in 2014 and reached 0 (MW), and in 2016, there was no production, 0 (MW). The Upward and downward bioenergy production and no production trends from 2006 to 2016 are shown in Fig. 4. Forecast of bioenergy production is shown in Fig. 4. We have predicted the production of bioenergy from 1980 to 2030.

Fig. 5 (continued)

Fig. 5 **a** Error bars and mean connected of Bioenergy production (Russian Fed), **b** Error bars and mean connected of bioenergy production (Turkey), **c** error bars and mean connected of bioenergy production (Armenia), **d** error bars and mean connected of bioenergy production (Azerbaijan), **e** error bars and mean connected of bioenergy production (Eurasia)

5.4 Azerbaijan

Bioenergy is the biggest source of renewable energy nowadays and can generate electricity, heat and can also be used as transport fuel. This roadmap envisions, whole world total bioenergy supply increasing from 50 EJ today to 160 EJ in 2050, with 100 EJ of 160 EJ for generation of power and heat. In Azerbaijan, there was no bioenergy production from 2006 to 2010. In 2011, production increased and reached 1 (MW). In 2012 production was again 1 (MW). Production increased in 2014 and reached

38 (MW), and in 2016, production was again 38 (MW). An upward increase in bioenergy production (up) from 2006 to 2016 is shown in Fig. 4, and the forecast of bioenergy production is shown in Fig. 4. We have predicted the production of bioenergy from 1980 to 2030.

5.5 Eurasia

Bioenergy production in Eurasia in 2006 was 1353 (MW) and in 2008, the production of bioenergy increased and reached 1356 (MW). Production in 2010 was 1316 (MW). Production increased in 2014 and reached 1662 (MW), and in 2016, production increased and reached 1803 (MW). An upward increase in bioenergy production (up) and a downward increase from 2006 to 2016 are shown in Fig. 4. The forecast of bioenergy production is shown in Fig. 4. We have predicted the production of bioenergy from 1980 to 2030. Figure 5 shows two columns, one for original bioenergy production data and the second column shows predicted data. Each column has a mean value and the mean is plotted as the SD. The bar between the mean and SD shows the error bar and mean connections are shown in Fig. 5.

(a) Bio Energy 2016 **(b) Bio Energy 2030**

Fig. 6 **a** Bio energy production of four countries till 2016 and **b** shows the predicted bioenergy of four countries till 2030

2016, bioenergy production in Turkey was 395 (MW) and the future prediction for 2030 will be 626.7197 (MW). In Armenia bioenergy production was 0 in 2016, and the future prediction for 2030 will be 0.74545 (MW). In Azerbaijan production was 38 (MW) in 2016, and the prediction for Azerbaijan will be 201.4236 (MW) in 2030. In Eurasia production was 1803 (MW) in 2016, and the prediction for bananas will be 2491.216 (MW). Figure 6 shows the bioenergy production in 2016 and future bioenergy production prediction in 2030.

Currently, there is a need to increase bioenergy production in Russian Fed, Turkey, Armenia, Azerbaijan and Eurasia. It is the government's responsibility to support all bioenergy organizations by providing them with all services that needed to increase bioenergy production. This prediction method is applicable to all developing countries. If developing countries can increase their bioenergy production to meet the demands of their increasing energy requirements, they will be in a better position to provide energy to their respective populations. Table 2 shows the result of bioenergy production.

6 Discussion and recommendation

Biomass energy is increasingly becoming a part of global renewable energy. World-wide, electricity generated from biomass is also on the rise. According to the UNEP report, in 2012 the total power capacity world-wide exceeded 1470 GW and increased up to 8.5% from 2011. A large quantity of energy is consumed in the agriculture sector and waste from a number of crops, including coconut sugarcane and rice has become an energy-rich source of electricity [39]. This study has used data from RFED, Turkey, Armenia, Azerbaijan, and Eurasia as a whole nation on bioenergy production to predict future bioenergy growth. We used linear regression models for high accuracy to generate these predictions. Russian Fed bioenergy production in 2016 was 1370 (MW). According to our future predictions, in 2030, bioenergy production will be 1540.801 (MW). In

7 Conclusion

Bioenergy production is important for any nation. Production depends upon services available to the bioenergy organizations, which totally depends on government bioenergy policies. If the government supports bioenergy production organizations, production will increase. In this study, we developed techniques for predicting bioenergy production using existing bioenergy production data, and we presented the results of the analysis. In the prediction model, we used linear regression model that periodically predicts the trends of bioenergy production. Algorithms that were used had a good accuracy, average accuracy is 49.61% and dataset is so small and linear regression performs better as compared to other methods.

Table 2 Data and results (Bio Energy)

Bioenergy production and accuracy				
Data sets	Predicted data	Current production (MW)	Predicted production (MW)	Accuracy
Bio Energy data of Russian Fed 2006–2016	2006–2030	1370	1540.801	51.02
Bio Energy data of Turkey 2006–2016	2006–2030	395	626.7197	49.03
Bio Energy data of Armenia 2006–2016	2006–2030	0.00	0.74545	48.8
Bio Energy data of Azerbaijan 2006–2016	2006–2030	38	201.4236	49.03
Bio Energy data of Eurasia 2006–2016	2006–2030	1803	2491.216	50.18
Average	Nil	721.2	972.1811	49.61

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Compliance with ethical standards

Conflict of interest On behalf of all the authors, the corresponding author states that there is no conflict of interest.

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