**Fig.S1** Soil chemical properties changes with the addition rates of exogenous organic materials (mean ± standard deviation). Different letters indicate significant differences (least significant difference). The red line represents linear regression. The gray shadow represents a 95% confidence interval.

**Fig.S2** The mass ratios of soil organic carbon and other elements change with the addition rates of exogenous organic materials (mean ± standard deviation). Different letters indicate significant differences (least significant difference). The red line represents linear regression. The gray shadow represents a 95% confidence interval.

**Fig.S3** The mass ratios of soil inorganic carbon and other elements change with the addition rates of exogenous organic materials (mean ± standard deviation). Different letters indicate significant differences (least significant difference). The red line represents linear regression. The gray shadow represents a 95% confidence interval.

**Fig.S4** The mass ratios of soil alkali hydrolyzed nitrogen, available phosphorus and other elements change with the addition rates of exogenous organic materials (mean ± standard deviation). Different letters indicate significant differences (least significant difference). The red line represents linear regression. The gray shadow represents a 95% confidence interval.

**Fig.S5** The results of interpretable XGBoost model for soil organic carbon density. The final regression fitting results for the interpretable XGBoost model for soil organic carbon density (a). The importance of driving forces (features) based on the loss of root mean squared error (RMSE, b), the importance was showed by value±95% confidence interval. The mean of absolute SHAP values (i.e. mean |SHAP values|) quantifying the importance of driving forces for soil organic carbon density (c). The beeswarm plot of the SHAP value explaining global importance of driving forces for soil organic carbon density (d), each dot corresponds to an individual sample in the study. The dot’s position on the x-axis shows the impact that driving forces have on the interpretable XGBoost model’s prediction for that sample. When multiple dots land at the same x position, they pile up to show density. The low Mean Absolute Error (MAE), Mean Square Error (MSE) and Root Mean Square Error (RMSE) and the good fit (R2) of observed value and predicted value suggested the predictive power of interpretable XGBoost models for soil organic carbon density.

**Fig.S6** The results of interpretable XGBoost model for soil inorganic carbon concentration. The final regression fitting results for the interpretable XGBoost model (a). The importance of driving forces (features) based on the loss of root mean squared error (RMSE, b), the importance was showed by value±95% confidence interval. The mean of absolute SHAP values (i.e. mean |SHAP values|) quantifying the importance of driving forces for soil inorganic carbon concentration (c). The beeswarm plot of the SHAP value explaining global importance of driving forces for soil inorganic carbon concentration (d), each dot corresponds to an individual sample in the study. The dot’s position on the x-axis shows the impact that driving forces have on the interpretable XGBoost model’s prediction for that sample. When multiple dots land at the same x position, they pile up to show density. The low Mean Absolute Error (MAE), Mean Square Error (MSE) and Root Mean Square Error (RMSE) and the good fit (R2) of observed value and predicted value suggested the predictive power of interpretable XGBoost models for soil inorganic carbon concentration.

**Fig.S7** The results of interpretable XGBoost model for soil inorganic carbon density. The final regression fitting results for the interpretable XGBoost model for soil inorganic carbon density (a). The importance of driving forces (features) based on the loss of root mean squared error (RMSE, b), the importance was showed by value±95% confidence interval. The mean of absolute SHAP values (i.e. mean |SHAP values|) quantifying the importance of driving forces for soil inorganic carbon density (c). The beeswarm plot of the SHAP value explaining global importance of driving forces for soil inorganic carbon density (d), each dot corresponds to an individual sample in the study. The dot’s position on the x-axis shows the impact that driving forces have on the interpretable XGBoost model’s prediction for that sample. When multiple dots land at the same x position, they pile up to show density. The low Mean Absolute Error (MAE), Mean Square Error (MSE) and Root Mean Square Error (RMSE) and the good fit (R2) of observed value and predicted value suggested the predictive power of interpretable XGBoost models for soil inorganic carbon density.

**Fig.S8** The results of interpretable XGBoost model for soil total carbon concentration. The final regression fitting results for the interpretable XGBoost model (a). The importance of driving forces (features) based on the loss of root mean squared error (RMSE, b), the importance was showed by value±95% confidence interval. The mean of absolute SHAP values (i.e. mean |SHAP values|) quantifying the importance of driving forces for soil total carbon concentration (c). The beeswarm plot of the SHAP value explaining global importance of driving forces for soil total carbon concentration (d), each dot corresponds to an individual sample in the study. The dot’s position on the x-axis shows the impact that driving forces have on the interpretable XGBoost model’s prediction for that sample. When multiple dots land at the same x position, they pile up to show density. The low Mean Absolute Error (MAE), Mean Square Error (MSE) and Root Mean Square Error (RMSE) and the good fit (R2) of observed value and predicted value suggested the predictive power of interpretable XGBoost models for soil total carbon concentration.

**Fig.S9** The results of interpretable XGBoost model for soil total carbon density. The final regression fitting results for the interpretable XGBoost model for soil total carbon density (a). The importance of driving forces (features) based on the loss of root mean squared error (RMSE, b), the importance was showed by value±95% confidence interval. The mean of absolute SHAP values (i.e. mean |SHAP values|) quantifying the importance of driving forces for soil total carbon density (c). The beeswarm plot of the SHAP value explaining global importance of driving forces for soil total carbon density (d), each dot corresponds to an individual sample in the study. The dot’s position on the x-axis shows the impact that driving forces have on the interpretable XGBoost model’s prediction for that sample. When multiple dots land at the same x position, they pile up to show density. The low Mean Absolute Error (MAE), Mean Square Error (MSE) and Root Mean Square Error (RMSE) and the good fit (R2) of observed value and predicted value suggested the predictive power of interpretable XGBoost models for soil total carbon density.

**Fig.S10** The results of interpretable XGBoost model for the ratio of soil organic carbon and inorganic carbon. The final regression fitting results for the interpretable XGBoost model for the ratio of soil organic carbon and inorganic carbon (a). The importance of driving forces (features) based on the loss of root mean squared error (RMSE, b), the importance was showed by value±95% confidence interval. The mean of absolute SHAP values (i.e. mean |SHAP values|) quantifying the importance of driving forces for the ratio of soil organic carbon and inorganic carbon (c). The beeswarm plot of the SHAP value explaining global importance of driving forces for the ratio of soil organic carbon and inorganic carbon (d), each dot corresponds to an individual sample in the study. The dot’s position on the x-axis shows the impact that driving forces have on the interpretable XGBoost model’s prediction for that sample. When multiple dots land at the same x position, they pile up to show density. The low Mean Absolute Error (MAE), Mean Square Error (MSE) and Root Mean Square Error (RMSE) and the good fit (R2) of observed value and predicted value suggested the predictive power of interpretable XGBoost models for ratio of soil organic carbon and inorganic carbon.

**Fig.S11** The influence pattern of the addition rate of moss powder on soil organic carbon concentration. The SHAP values quantified the influence of addition rate on the soil organic carbon concentration. EC, soil electrical conductivity; WSCaD, soil water-soluble calcium density.

**Fig.S12** (a) The influence pattern of the addition rate on soil organic carbon density. The SHAP values quantified the influence of addition rate on the soil organic carbon density. (b-g) The influence pattern of the soil alkali hydrolyzed nitrogen density on soil organic carbon density. The SHAP values quantified the influence of soil alkali hydrolyzed nitrogen density on the soil organic carbon density. AND, soil alkali hydrolyzed nitrogen density; NCP, soil non-capillary porosity; TP, soil total porosity; BD, soil bulk density; WSCaD, soil water-soluble calcium density.

**Fig.S13** (a) The influence pattern of the addition rate on soil inorganic carbon concentration. The SHAP values quantified the influence of addition rate on the soil inorganic carbon concentration. (b-d) The influence pattern of the soil electrical conductivity on soil inorganic carbon concentration. The SHAP values quantified the influence of soil electrical conductivity on the soil inorganic carbon concentration. EC, soil electrical conductivity; WSMgC, soil water-soluble magnesium concentration; IC\_AP, the mass ratio of soil inorganic carbon and available phosphorus; WSNaD, soil water-soluble sodium density.

**Fig.S14** The influence pattern of the addition rate on soil inorganic carbon density. The SHAP values quantified the influence of addition rate on the soil inorganic carbon density. EC, soil electrical conductivity; BD, soil bulk density; WC, soil water content.

**Fig.S15** The influence pattern of the addition rate on soil total carbon concentration. The SHAP values quantified the influence of addition rate on the soil total carbon concentration. EC, soil electrical conductivity.

**Fig.S16** (a) The influence pattern of the addition rate on soil total carbon density. The SHAP values quantified the influence of addition rate on the soil total carbon density. (b-c) The influence pattern of the ratio of soil organic carbon and alkali hydrolyzed nitrogen on soil total carbon density. The SHAP values quantified the influence of ratio of soil organic carbon and alkali hydrolyzed nitrogen on the soil total carbon density. OC\_AN, the mass ratio of soil organic carbon and alkali hydrolyzed nitrogen; TP, soil total porosity.

**Fig.S17** The influence pattern of the addition rate on the ratio of soil organic carbon and inorganic carbon. The SHAP values quantified the influence of addition rate on the ratio of soil organic carbon and inorganic carbon. TS, soil total salt content; EC, soil electrical conductivity; WSCaD, soil water-soluble calcium density; WSCaC, soil water-soluble calcium concentration.

**Table.S1** Results of Pearson correlation analysis for soil physical and chemical properties and soil stoichiometric ratios

**Data1** Relationships of soil inorganic carbon content with soil physical and chemical properties and soil stoichiometric ratios

**Data2** Relationships of soil inorganic carbon density with soil physical and chemical properties and soil stoichiometric ratios

**Data3** Relationships of soil organic carbon content with soil physical and chemical properties and soil stoichiometric ratios

**Data4** Relationships of soil organic carbon density with soil physical and chemical properties and soil stoichiometric ratios

**Data5** Relationships of soil total carbon content with soil physical and chemical properties and soil stoichiometric ratios

**Data6** Relationships of soil total carbon density with soil physical and chemical properties and soil stoichiometric ratios

**Data7** Relationships of the ratio of soil organic carbon and inorganic carbon with soil physical and chemical properties and soil stoichiometric ratios