Introduction

Electricity consumption has important effects on sectoral production. Sectoral production means the production of goods and services in sectors where economic activities are carried out. Electricity consumption refers to the amount of electricity required to meet the energy needs of these sectors.

Industrial sector is one of the sectors with the highest electricity consumption. Factories, manufacturing facilities and industrial enterprises often use large amounts of energy and are therefore dependent on electricity. Electrical energy is necessary for the operation of machinery and equipment, heating, lighting, cooling and other production processes. The amount of production in the industrial sector is directly related to electricity consumption. A growing industrial sector means greater electricity demand, while electricity consumption often increases to support increased production. The trade sector has also an important share in electricity consumption. Commercial establishments such as stores, office buildings, shopping malls and hotels continue their activities by relying on electrical energy. Lighting, heating and cooling systems, computers, communications equipment and other electrical appliances are the main sources of electricity demand in commercial businesses. Growth or intensity in the commercial sector can increase electricity consumption. On the other hand, although the service sector does not have a significant share in electricity consumption, there are some sub-sectors that are heavily dependent on electricity. For example, facilities such as hospitals, healthcare institutions, schools, universities, restaurants, hotels and sports facilities use electricity in their daily operations. Growth or changes in the service sector may cause an increase or decrease in electricity consumption.

The relationship between electricity consumption and sectoral production is also affected by factors such as economic growth, industrial activities, employment and energy policies. In the process of economic growth and industrialization, sectoral production increases and this increases the demand for electricity. Likewise, energy efficiency measures, use of renewable energy sources and energy saving policies can help regulate the impact of sectoral generation on electricity consumption. Therefore, the relationship between electricity consumption and sectoral production is an important part of energy policies and economic planning.

There is an important relationship between electricity consumption and agricultural production, as well. Agricultural production includes plant breeding, animal husbandry and other agricultural activities. Electricity consumption is necessary to increase the efficiency of agricultural activities and to operate electrical equipment such as irrigation systems, agricultural machinery, lighting and cooling systems. Effective use of water in agricultural production is of great importance. Electricity is required to run irrigation systems used in farmland. Electrical equipment such as irrigation pumps, control systems of irrigation channels and drip irrigation systems are vital for the sustainability and efficiency of agricultural production. Electricity consumption must be strategically managed to optimize the efficiency of irrigation methods and the use of water resources. Electric agricultural machinery and equipment facilitates tillage, planting, harvesting, fertilizing, spraying and other agricultural processes. Equipment such as tractors, combines, irrigation systems, greenhouse lighting and heating systems are powered by electricity. Electric farm machinery makes agricultural operations faster, more efficient and automated. This contributes to an increase in agricultural production and quality improvement. In agricultural production, products need to be stored, processed and preserved. Cooling systems, packaging machines, drying devices and other processing equipment are powered by electricity. This equipment maintains the quality of agricultural products, extends their shelf life and makes them ready for marketing. Electricity consumption increases efficiency and reduces product losses in the processing and storage of agricultural products. Therefore, electricity consumption in agricultural production is important in terms of sustainability and environmental impacts. The agricultural sector can provide energy in an environmentally friendly way by utilizing renewable energy sources. Renewable energy sources such as solar energy, wind energy and biomass can be used for electricity generation in agricultural areas. This reduces energy costs in agricultural production and increases environmental sustainability.

Another important topic is about the relationship between carbon emissions and agricultural production, which is complex and elaborate. While agricultural production contributes to carbon emissions through various processes, carbon emissions and climate change can also have an impact on agricultural productivity. Agricultural activities are an important source of greenhouse gas emissions, particularly through the release of carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). These emissions originate from a variety of sources in the agricultural sector, including stomach fermentation (methane produced by grazing animals), rice cultivation, manure management, synthetic fertilizer use and farm machinery. Agricultural expansion releases large amounts of carbon dioxide, particularly through deforestation and land use change. When forests are cleared for agriculture, carbon stored in trees and vegetation is released into the atmosphere as CO2. Deforestation also contributes to increasing atmospheric CO2 levels by reducing the capacity to absorb atmospheric CO2 through photosynthesis. Especially intensive livestock systems produce significant methane emissions. Gastric fermentation, a natural digestive process in grazing animals, produces methane, a potent greenhouse gas. In addition, animal manure management and the decomposition of animal waste also cause methane and nitrous oxide emissions, contributing to agricultural greenhouse gas emissions. Nitrogen-based fertilizers used in agriculture can cause nitrous oxide emissions. Nitrous oxide is released through microbial processes in soils, especially when excessive nitrogen fertilizers are used. Nitrous oxide is a powerful greenhouse gas with much greater warming potential than carbon dioxide. On the other hand, carbon emissions and related climate change have significant effects on agricultural productivity. Climate change can affect agricultural systems through effects such as changing precipitation patterns, temperature changes, increased frequency of extreme weather events, and changing pest control dynamics. These impacts can affect crop yields, animal health, water supply and agricultural production in general. The relationship between carbon emissions and agricultural production is interconnected. While agricultural activities contribute to greenhouse gas emissions, carbon emissions and climate change can also have an impact on agricultural productivity. Addressing this relationship requires adopting sustainable practices, reducing emissions from agricultural activities and increasing the resilience of agricultural production in the face of climate change.

In this study, first the causality between plant production, greenhouse gas emission and electricity consumption are examined at country level. Then, the correlations between the plant production and electricity consumption are studied. Finally, Auto-ARIMA statistical technique is used to predict the plant production based on electricity consumption at city level.

**Previous studies**

Ayanwale et al. (2010) examined the relationship between electricity consumption, carbon emissions, and economic growth in Nigeria. The findings revealed a positive correlation between electricity consumption and agricultural production. Increased electricity consumption was associated with higher agricultural productivity, indicating that access to electricity contributes to improved farming practices and output. Esso (2010) focused on the relationship between energy use, including electricity consumption, and income in Ghana. The study found a significant positive relationship between electricity consumption and agricultural production. Higher electricity consumption was associated with increased agricultural output, suggesting that electricity plays a crucial role in enhancing agricultural productivity and income in Ghana. Halicioglu(2009) investigated the relationship between energy consumption, including electricity, and various economic factors in Turkey. The findings indicated a positive association between electricity consumption and agricultural production. It suggested that higher electricity usage positively influences agricultural productivity, emphasizing the importance of reliable and accessible electricity supply for the agricultural sector. Lorde and Jackman (2010) examined the relationship between electricity consumption and economic growth. The findings indicated a positive association between electricity consumption and agricultural production. It highlighted the crucial role of electricity in supporting agricultural activities and driving economic growth in Barbados. Shahbaz and Lean (2012) conducted a study examining the causality relationship between electricity consumption and economic growth in Pakistan. While the study did not focus specifically on agriculture, it provided insights into the broader relationship between electricity consumption and economic activities. Their findings indicated a bidirectional causality between electricity consumption and economic growth. This implies that increased electricity consumption can stimulate economic growth, including agricultural production, while economic growth also drives higher electricity consumption. Tang and Tan (2015) investigated the impact of energy consumption on carbon dioxide emissions in Vietnam. As the agricultural sector contributes to overall energy consumption, the study indirectly highlights the potential influence of electricity consumption on agricultural production. The findings emphasized the need for sustainable energy practices to mitigate environmental impacts, including in the agricultural sector. Bhattacharya and Mohan (2019) examined the relationship between electricity consumption, agricultural productivity, and rural poverty reduction in India. The findings highlighted the positive impact of electricity consumption on agricultural productivity and emphasized the role of electrification in reducing rural poverty by enhancing agricultural income. The study underlined the need for policies and investments in rural electrification to promote sustainable agricultural development and poverty alleviation in India. Khan et al. (2019) investigated the impact of electricity consumption on agricultural productivity in South Asian countries. The findings indicated a positive relationship between electricity consumption and agricultural output, suggesting that increased electricity access enhances agricultural productivity. The study emphasized the importance of policies and investments in rural electrification to support sustainable agricultural development and enhance food security in South Asian countries. Bello et al. (2020) investigated the causal relationship between electricity consumption, agricultural production, and economic growth in Nigeria. The findings revealed a bidirectional causality between electricity consumption and agricultural production, indicating that increased electricity consumption positively impacts agricultural output, while agricultural production also influences electricity consumption. The study emphasized the need for investment in electricity infrastructure to support agricultural development and overall economic growth in Nigeria. Debnath and Moura (2021) examined the relationship between electricity consumption and agricultural production in low-income countries. The findings revealed a positive correlation between electricity consumption and agricultural output, indicating that access to electricity significantly contributes to increased agricultural productivity. The study emphasized the importance of electrification initiatives and improved access to electricity in promoting sustainable agricultural development in low-income countries.

**Material and Method**

In the study, electricity consumption of agricultural sector, plant production value and greenhouse gas emission of agricultural sector are collected from Turkish Statistical Institute (TSI) for Turkey and cities.

Granger causality test is performed to see the relations among collected variables for country level and the results are given in Table 1.

Table 1. Granger causality test results for Turkey

|  |  |  |  |
| --- | --- | --- | --- |
|  | Plant Production | Electricity Consumption | Emission |
| Plant Production | 1.0 | 0.0 | 0.054 |
| Electricity Consumption | 0.0 | 1.0 | 0.0 |
| Emission | 0.0 | 0.0 | 1.0 |

The p-value lesser than 0.05 means that the null hypothesis is rejected and X does NOT granger cause Y. Accordingly, in the above table, the p-value for electricity consumption is 0.0 for plant production value. So, the null hypothesis is rejected and electricity consumption granger causes plant production value. This shows that electricity consumption can be used as a helpful tool to predict plant production value. Therefore, electricity consumption (Mvh) and plant production value (x1000TL) are collected for each city in Turkey. The data covers the period between 1997 and 2022. However, the cities containing time series with a number of null values had to be excluded from the analysis and the number of cities is limited to 69 out of 81 provinces. First, the series are checked for stationarity using Augented Dicket-Fuller Test. The first difference established the stationarity for all series. Then, Min-Max scaler is applied to eliminate any bias. Subsequently, correlation between series is checked for each city and Auto-ARIMA method is applied using pmdarima python library to predict plant production value based on electricity consumption for each city separately.

**Results and discussion**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Correlation between Electricity Consumption and Plant Production Value | RMSE | MAE |
| Adana | 0.9158 | 0.1295 | 0.1237 |
| Adıyaman | 0.4860 | 0.2724 | 0.2356 |
| Afyonkarahisar | 0.9289 | 0.3838 | 0.3757 |
| Aksaray | 0.9555 | 0.6941 | 0.6865 |
| Amasya | 0.7835 | 0.6005 | 0.5918 |
| Ankara | 0.8937 | 0.5025 | 0.4961 |
| Antalya | 0.9523 | 0.1961 | 0.1936 |
| Aydın | 0.7859 | 0.3701 | 0.3281 |
| Balıkesir | 0.8651 | 0.4501 | 0.3983 |
| Batman | 0.1374 | 0.5448 | 0.5188 |
| Bayburt | 0.4504 | 0.4705 | 0.4705 |
| Bilecik | 0.6366 | 0.5082 | 0.4802 |
| Bingöl | 0.5815 | 0.3562 | 0.3264 |
| Bitlis | 0.8392 | 0.2548 | 0.2526 |
| Bolu | 0.5705 | 0.1998 | 0.1752 |
| Burdur | 0.8695 | 0.1232 | 0.1048 |
| Bursa | 0.9259 | 0.5150 | 0.4497 |
| Denizli | 0.9699 | 0.4528 | 0.4045 |
| Diyarbakır | 0.9047 | 0.5129 | 0.5117 |
| Edirne | 0.7190 | 0.3648 | 0.2670 |
| Elazığ | 0.4485 | 0.4618 | 0.3902 |
| Erzurum | 0.4308 | 0.9107 | 0.7046 |
| Eskişehir | 0.9680 | 0.3319 | 0.2611 |
| Gaziantep | 0.7988 | 0.5524 | 0.5518 |
| Giresun | 0.7303 | 0.3356 | 0.3068 |
| Gümüşhane | 0.5022 | 0.2301 | 0.2166 |
| Hatay | 0.4410 | 0.5400 | 0.4108 |
| Isparta | 0.7817 | 0.3328 | 0.3286 |
| Iğdır | 0.9130 | 0.5090 | 0.4636 |
| Karabük | 0.6904 | 0.6177 | 0.6068 |
| Karaman | 0.8990 | 0.4765 | 0.3426 |
| Kars | 0.5921 | 0.1734 | 0.1629 |
| Kastamonu | 0.7191 | 0.5164 | 0.5151 |
| Kayseri | 0.8849 | 0.2023 | 0.1624 |
| Kilis | 0.8380 | 0.5227 | 0.3931 |
| Kocaeli | 0.8266 | 0.5935 | 0.5580 |
| Konya | 0.7708 | 0.2214 | 0.1615 |
| Kütahya | 0.9380 | 0.6164 | 0.5510 |
| Kırklareli | 0.8655 | 0.4913 | 0.4048 |
| Kırıkkale | 0.8382 | 0.6000 | 0.5732 |
| Kırşehir | 0.9414 | 0.6073 | 0.5052 |
| Malatya | 0.6854 | 0.5187 | 0.5078 |
| Manisa | 0.9349 | 0.3426 | 0.2792 |
| Mardin | 0.8703 | 0.6356 | 0.6348 |
| Mersin | 0.8999 | 0.1986 | 0.1829 |
| Muğla | 0.7924 | 0.5810 | 0.4998 |
| Muş | 0.9091 | 0.4171 | 0.3576 |
| Nevşehir | 0.0827 | 0.3465 | 0.3430 |
| Niğde | 0.5168 | 0.2871 | 0.2126 |
| Osmaniye | 0.9033 | 0.5229 | 0.5119 |
| Sakarya | 0.8777 | 0.5548 | 0.5093 |
| Samsun | 0.4672 | 0.6168 | 0.5781 |
| Siirt | 0.6661 | 0.4927 | 0.4179 |
| Sivas | 0.9310 | 0.5882 | 0.4903 |
| Tokat | 0.1947 | 0.1155 | 0.1139 |
| Trabzon | 0.5477 | 0.3312 | 0.3215 |
| Tunceli | 0.3873 | 0.5599 | 0.5171 |
| Uşak | 0.8602 | 0.5778 | 0.4642 |
| Van | 0.8035 | 0.7042 | 0.6966 |
| Yalova | 0.7994 | 0.2444 | 0.2422 |
| Yozgat | 0.8965 | 0.5259 | 0.4036 |
| Zonguldak | 0.7381 | 0.5076 | 0.3853 |
| Çanakkale | 0.9271 | 0.4474 | 0.4112 |
| Çankırı | 0.8876 | 0.3071 | 0.2583 |
| Çorum | 0.9535 | 0.2401 | 0.2196 |
| İstanbul | 0.0497 | 0.3960 | 0.3894 |
| İzmir | 0.8738 | 0.3023 | 0.2850 |
| Şanlıurfa | 0.9281 | 0.4857 | 0.4697 |
| Şırnak | 0.8701 | 0.6175 | 0.5288 |
|  |  | Mean RMSE 0.4539 | Mean MAE: 0.4078 |

**Conclusion**

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