**Agricultural Production and Nutrient Balance:**

**Case of Ireland, Spain, and France**

# **Introduction**

## **Background**

Agricultural production is one of the significant economic activities, not only in the EU but also in all the countries across the globe. Crop production provides employment, food, industrial raw materials, medicinal products, etc. Agricultural production generally provides the livelihood for over ten million grams and over forty-four million jobs across the EU (WEF, 2022). In some cases, agriculture is cultural because people plant some crops due to their cultural significance. The importance of agriculture is further emphasized by the size of land it occupies, with WEF (2022) claiming that over 40% of land in the EU is occupied by agricultural production. With agriculture and crop production having vast importance for the economy, health, culture and food security, a measure of optimizing crop production has always been invented and implemented. Such measures include disease and pest control, weed control, nutrient balancing, irrigation, farm machinery use, optimization of human labor productivity, temperature controls, and research on favorable crop conditions. This research studied the EU agricultural production, nutrient balance, and labor input from 1991 to 2017, basing the study on Ireland, Spain, and France.

## **Objectives, Research Questions and Hypotheses**

* **Objective 1:** To compare Ireland, Spain, and France regarding change in agricultural production, nutrient balance, and labor input.
* **Objective 2:** To test the relationship impact of nutrient balance and labor input on agricultural production in Ireland, Spain, and France.
* **Research Question 1:** Is there a difference between Ireland, Spain, and France in terms of change in agricultural production, nutrient balance, and labor input?
* **Null Hypothesis:** There is no difference between Ireland, Spain, and France regarding change in agricultural production, nutrient balance, and labor input.
* **Alternative Hypothesis:** There is a difference between Ireland, Spain, and France in terms of change in agricultural production, nutrient balance, and labor input.
* **Research Question 2:** Is there a relationship or association between agricultural production, nutrient balance, and labor input?
* **Null Hypothesis:** There is no relationship or association between agricultural production, nutrient balance, and labor input.
* **Alternative Hypothesis:** There is a relationship or association between agricultural production, nutrient balance, and labor input.

# **Literature**

## **Nutrient Balance and Plant Yield**

Nutrient balances give information regarding environmental stressors. A nutrient deficiency (a negative nutrient balance) implies deteriorating soil fertility (OECD, 2023). An excess of nutrients implies a potential for soil, water, and air pollution. The term "nutrient balance" refers to the discrepancy that exists between the amount of nutrients that are introduced into an agricultural system (mainly in the form of manure from animals and fertilizer) and the amount of nutrients that are removed from the system, i.e. "the uptake of nutrients for crop and pasture production" (OECD, 2023). Nutrient balance is computed for the two primary nutrients, phosphorus, and nitrogen, and is quantified in nutrients (in tones and Kilograms) per hectare of farmland. Nitrogen is shown first, followed by phosphorus (OECD, 2023). Nutrient inputs are required in agricultural systems since these substances are essential for sustaining and enhancing the amount of crop and pasture yield. Therefore, there should be a balance in nutrient input and output to attain an optimum Nutrient balance conducive to agricultural production.

The nutrient balance dramatically impacts the environment, directly affecting agricultural yields and other life aspects like health (OECD, 2023). An accumulation of surplus excessive nutrients exceeding the instant crop and grassland needs leads to nutrient failures (OECD, 2023). Such losses cause economic disadvantages in using nutrient content by farmers damaging the environment through air and water pollution, most notably greenhouse gas or ammonia emissions (OECD, 2023). Therefore, the need to keep the optimal nutrient balance aims to optimize immediate agricultural yield and conserve the environment, which plays a significant role in agriculture in the long run.

## **Labor Input in Agriculture**

There has been a decrease in the utilization of human labor in agriculture across the EU countries. Since 2000, agricultural labor in the EU has declined by 24.9%, which, per the AWU, implies a loss of 3.7 million (Eurostat, 2015). This decrease brought the total number of AWUs in the EU-27 down to 11.2 million in 2009 (Eurostat, 2015). The number of individuals working in the agricultural sector is higher than the number of yearly labor units since many farm workers and owners only work in agriculture part-time. Therefore, the decrease in the use of labor in agriculture in the EU countries is quite notable.

The agricultural labor input change did not significantly impact the agricultural production for EU states based on EU agricultural sector data. The data is accessible through EU Database, specifically under the agriculture section (<https://ec.europa.eu/eurostat/web/agriculture/data/database>). According to the indices generated from the data in the accounts at constant agricultural prices since 2000, the amount of agricultural output in the EU has been relatively consistent overall (Eurostat, 2015). According to the data, the total goods produced in 2009 was 4% greater than in 2000 (Eurostat, 2015). During the same period, there was a 24.9% drop in the amount of labor that was put in, which resulted in a considerable improvement in the volume produced per yearly work unit (Eurostat, 2015).

Regarding the amount of production, the EU-15 and the 12 recently joined Member Countries have shown two very distinct trajectories. The output volume for the EU-15 has remained relatively consistent over time, while the output volume for the 12 states has increased. According to the indices' average for 2007 to 2009, the volume has grown by 15% for the 12 new states since 2000 (Eurostat, 2015). The comparison between the EU-15 and the 12 states indicates that the decrease in agricultural labor in the EU had no significant impact on agricultural production.

Evaluations of the growth in volume per AWU show more apparent contrasts between the two nations. Still, they indicate that the EU agricultural sector has gained optimal output from the little labor used. Based on the average indices for 2007-09, the EU-15 shows a slightly less than 20% gain since 2000, whereas the increase for the 12 members is over 60% since 2000 (Eurostat, 2015). However, there is a significant gap between the two sets of EU Members regarding the output volume generated per yearly labor unit. The production in constant agricultural prices (prices in 2005) per AWU in the EU-15 was about 6.4 times larger than in the 12 states from 2007 to 2009 on average (Eurostat, 2015). Only a tiny portion of this significant change in level may be explained by differences in agricultural items sold in the 12 states and relatively lower pricing overall. Therefore, despite the contrast between the two sets of nations, EU countries seem to have maintained a high output volume per labor unit.

# **Study Methodology**

## **Data Collection and Analysis**

The data was downloaded from the EU agricultural sector database accessible: <https://ec.europa.eu/eurostat/web/agriculture/data/database>. The data were transferred to Microsoft Excel for tabulation and exported to Jupiter notebook using the pandas function for further analysis. The first step was to obtain descriptive statistics. From there, five inferential statistical tests were conducted to test the difference between the three countries regarding production, nutrient balance, and labor input. Independent sample t-test, paired sample t-test, one sample t-test, and Wilcoxon test compared Ireland and Spain, while ANOVA compared Ireland, Spain, and France. A correlation matrix and regression analysis were also conducted to establish the relationship and association between various variables. Lastly, GridSearchCV was conducted for Gradient Boosting Regressor and XGB Regressor to examine further the impact of nutrient balance and labor input on agricultural production.

## **Output Visualization and Presentation**

The analysis process used Matplotlib to create the graphical presentations needed. The figures obtained were copy-pasted to this report. Additionally, the figures obtained from various analyses (the t-statistic and p-value for t-test analysis) were tabulated and provided in the results section of this report. Each figure and table have a clear caption stating what it presents.

# **Results and Discussion**

## **Descriptive Statistics**

### ***Statistics***

Table

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Fig 1: The Descriptive Statistics as Obtained from the Dataset

### ***Histograms***

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Fig 2: Histogram on Ireland %Change in Production: Skewness = -0.25904688514299185

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Fig 3: Histogram and Skewness Statistic for Spain % Change in Production

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Fig 4: Histogram and Skewness Statistic for France % Change in Production

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Fig 5: Histogram and Skewness Statistic for Ireland % Change in Nutrient Balance

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Fig 6: Histogram and Skewness Statistic for Spain % Change in Nutrient Balance

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Fig 7: Histogram and Skewness Statistic for France % Change in Nutrient Balance

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Fig 8: Histogram and Skewness Statistic for Ireland % Change in Labor Input

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Fig 9: Histogram and Skewness Statistic for Spain % Change in Labor Input

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Fig 10: Histogram and Skewness Statistic for France % Change in Labor Input

### ***Boxplots***

Chart, box and whisker chart

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Fig 11: A Boxplot on % Change in Production

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Fig 12: A Boxplot on % Change in Nutrient Balance

Chart, box and whisker chart

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Fig 13: A Boxplot on % Change in Labor Input

### ***Kurtosis***

Table 1: Kurtosis Statistics for the nine Variables Used

|  |  |  |
| --- | --- | --- |
| *Kurtosis Statistics* | | |
|  | Kurtosis |
| Ireland % Change in Production | 0.6870645241773632 |
| Spain% Change in Production | -0.19461395566756323 |
| France % Change in Production | -0.5167448084946358 |
| Ireland % Change in Nutrient Balance | 0.7123391583171998 |
| Spain % Change in Nutrient Balance | -0.24566089464822793 |
| France % Change in Nutrient Balance | -0.3125633364343643 |
| Ireland % Change in Labor Input | 1.4946699239889467 |
| Spain% Change in Labor Input | 0.06882370896729695 |
| France % Change in Labor Input | 0.8808588615279809 |

***Findings Implication***

The main focus is descriptive statistics to measure the dispersion and the normality. The data does not seem to have significant dispersion from the standard deviation and mean statistics. This insignificant dispersion is also indicated by a considerably slight difference between the maximum and minimum values for the variables. On normality, skewness and kurtosis statistics were computed. Although the data was found to be a little skewed and kurtotic, the values of the two statistics were not significantly large enough to rule the data as abnormally distributed. The fairly bell-shaped curve in the Histograms and the minimal outliers in the boxplots visualized the dataset's normality.

### **Differential Statistical Tests** ***Paired Sample t-test***

|  |
| --- |
|  |

Table 2: Paired Sample t-test Analysis Results to Compare Ireland and Spain concerning % Change in Production, Nutrient Balance, and Labor Input

|  |  |  |  |
| --- | --- | --- | --- |
| *Paired Sample t-test Statistics* | | | |
|  | Statistic | P-Value |
| % Change in Production | .048640114225444474 | .9615778230515271 |
| % Change in Labor Input | 0.7543805184346148 | 0.45739946629591544 |
| % Change in Nutrient Balance | 0.209917091401485 | 0.8353686575553475 |

### ***Independent Sample t-test***

Table 3: Independent Sample t-test Analysis Results to Compare Ireland and Spain with Regard to % Change in Production, Nutrient Balance, and Labor Input

|  |  |  |  |
| --- | --- | --- | --- |
| *Independent Sample t-test Statistics* | | | |
|  | Statistic | P-Value |
| % Change in Production | 0.03429139216001633 | 0.9727760831845589 |
| % Change in Labor Input | 0.17633655389634448 | 0.8607145176558175 |
| % Change in Nutrient Balance | 0.6869762511163178 | 0.49515013906293703 |

### 

### ***One Sample t-test***

Table 4: One-Sample t-test Analysis Results to Compare Ireland and Spain with Regard to % Change in Production, Nutrient Balance, and Labor Input

|  |  |  |  |
| --- | --- | --- | --- |
| *One Sample t-test Statistics* | | | |
|  | Statistic | P-Value |
| % Change in Production | 0.043628599234602654 | 0.9655338005799113 |
| % Change in Labor Input | -0.2327092432964251 | 0.817809371488665 |
| % Change in Nutrient Balance | -0.8454475876207341 | 0.4055745209750492 |

### 

### ***Wilcoxon Test***

Table 5: Wilcoxon Test Analysis Results to Compare Ireland and Spain with Regard to % Change in Production, Nutrient Balance, and Labor Input

|  |  |  |  |
| --- | --- | --- | --- |
| *Wilcoxon Test Statistics* | | | |
|  | Statistic | P-Value |
| % Change in Production | 171.0 | 0.6789510101079941 |
| % Change in Labor Input | 157.0 | 0.6384532010547104 |
| % Change in Nutrient Balance | 156.0 | 0.44104358553886414 |

### ***ANOVA***

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Fig 14: One-way ANOVA Results for % Change in Production

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Fig 15: One-way ANOVA Results for % Change in Nutrient Balance

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Fig 16: One-way ANOVA Results for % Change in Labor Input

### ***Findings Implication***

The differential statistical tests were conducted in the pursuit of the first study objective. The tests aimed at answering the first research question by testing its null hypothesis. All the tests took 0.05 as the Alpha Value. Therefore, from the results presented here, the P-Values obtained in all the tests were more than the Alpha Value (0.05). Hence, the null hypothesis was accepted. Acceptance of this null hypothesis indicates no statistically significant differences between Ireland, Spain, and France regarding change in production, nutrient balance, and labor input.

## **Relationship Analysis: Correlation, Regression, and GridSearchCV**

### ***Correlation***

Timeline

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Fig 17: A Correlation Matrix for the Dataset

### ***Linear Regression***

Table 6: Linear Regression Analysis Statistics for % Change in Production against % Change in Nutrient Balance

|  |  |  |
| --- | --- | --- |
| *Linear Regression Analysis Statistics for % Change in Production against % Change in Nutrient Balance* | | |
|  | Value |
| Intercept | 1.6474948 |
| Coefficient | 0.01176621 |
| R-Squared | 0.0014696115110522934 |

Chart, scatter chart

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Fig 18: A Scatterplot for Linear Regression Analysis for % Change in Production against % Change in Nutrient Balance

Table 7: Linear Regression Analysis Statistics for % Change in Production against % Change in Labor Input

|  |  |  |
| --- | --- | --- |
| *Linear Regression Analysis Statistics for % Change in Production against % Change in Labor Input* | | |
|  | Value |
| Intercept | 2.55778306 |
| Coefficient | 0.46665807 |
| R-Squared | 0.08200840599813708 |

Chart, scatter chart

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Fig 19: A Scatterplot for Linear Regression Analysis for % Change in Production against % Change in Labor Input

### ***GridSearchCV***

#### **Gradient Boost Regressor** **GridSearchCV**

Table 8: Best Score and Parameters for Gradient Boost Regressor GridSearchCV

|  |  |  |
| --- | --- | --- |
| *Best Score and Parameters for Gradient Boost Repressor* *GridSearchCV* | | |
|  | Value |
| Score | 0.018662755024537514 |
| Learning Rate | 0.03 |
| Max Depth | 10 |
| N Estimator | 25 |
| Subsample | 0.1 |

#### **XGB Regressor GridSearchCV**

Table 9: Best Score and Parameters for XGB Regressor GridSearchCV

|  |  |  |
| --- | --- | --- |
| *Best Score and Parameters for XGB Regressor* *GridSearchCV* | | |
|  | Value |
| Score | -0.07143775300683734 |
| Learning Rate | 0.01 |
| Max Depth | 6 |
| N Estimator | 100 |
| Gamma | 0.01 |

### ***Findings Implication***

The Relationship analyses were conducted in pursuit of the second study objective. The correlation matrix shows that most variables did not have a significant association. Very low correlation coefficients denote this weak association. However, as for the % Change in Production, the three countries demonstrated a relatively fair association compared to other variables. Each pair of the three countries has a positive Correlation coefficient, with the least being between Spain and France (0.41). This positive Correlation Coefficient implies that a change in the % production was witnessed in one of the countries in a particular year. There was a high probability of having a similar change in the other two countries. For instance, in a year where Ireland witnessed a drop in production, there is a possibility that Spain and France witnessed a drop too. As well, in a year where Ireland witnessed an increase in production, there is a probability that Spain and France witnessed an increase too.

The linear regression results showed an insignificant relationship between % Change in production and % Change in Nutrient Balance and Labor Input. This insignificant relationship is indicated by very low R-Squared Statistics and visualized by the line of best fit in the scatterplots. Furthermore, the results for the two GridSearchCV show very low best Score values, with one being a negative value. Therefore, from the correlation matrix and the regression and GridSearcgCV results, the null hypothesis for the second research question was accepted. This acceptance implies that the study concluded that % Change in Nutrient Balance and Labor Input did not significantly impact the % Change in production. The findings agree with Eurostat's (2015) findings that the reduction of labor input did not impact agricultural production in the EU.

# **Conclusion, Challenges /Limitations and Recommendation**

## **Conclusion**