A study on economic growth related carbon dioxide damage and forest area damage across the world, for the period of 2012 to 2013.

1. Research Question and motivation:

In an era where environmental sustainability and economic stability are increasingly intertwined, understanding the impact of natural resource management on national income is crucial. This analysis focuses on the relationship between *Forest Area Percentage* and *Carbon Dioxide Damage*, as well as their effects on *Adjusted Net National Income Per Capita* across various countries during the years 2012 and 2013. For the study, the "World Bank Database" was utilized.

The motivation for researching this topic stems from the growing discourse surrounding environmental issues in the news and social media. As climate change and deforestation continue to dominate global conversations, it is imperative to understand the economic implications of these environmental challenges. By analyzing the interplay between forest conservation and economic indicators, contribution to valuable insights that can inform policy decisions and promote sustainable practices shall be achieved.

The findings from this research could hold societal benefits, as they can guide the development of effective policies that promote sustainable practices while fostering economic growth. Furthermore, by raising public awareness of the critical link between environmental health and economic prosperity, we can encourage collective action towards conservation efforts.

Summing up the above, the following research question can be fomulated:

“What is the impact of *Forest Area Percentage* and *Carbon Dioxide Damage* on the *Adjusted Net National Income Per Capita* across different countries from 2012 to 2013?“

2. Methods:

2.1 Samples:

In the used dataset there are 198 observations for each of the studied variables (*Forest Area Percentage*, *CO_2 Damage*, and *Adjusted Net National Income per Capita*) for the years 2012 and 2013. These observations represent the number of countries, involved in the world bank data. 247 countries are available in total, but with missing data for at least one of the variables. To ensure further processing, these values have been cleaned out.

2.2 Measures:

The *Forest Area Percentage* indicates the proportion of land covered by forests in a country for 2012 and 2013. This measure is crucial for assessing natural resource management and environmental health, as forests contribute to carbon sequestration and biodiversity. Values range from 0% to nearly 98.4%, reflecting significant global variation.

The *Carbon Dioxide Damage* measures the economic costs linked to carbon dioxide emissions in a country for 2012 and 2013. This metric accounts for the financial impacts of environmental degradation and health issues caused by CO_2 emissions. Understanding CO_2 damage is essential for evaluating the economic consequences of

environmental policies. Countries with higher CO_2 damage may encounter significant economic challenges, potentially influencing their adjusted net national income.

The *Adjusted Net National Income per Capita* reflects a country's economic well-being by accounting for the depreciation of natural resources and the impacts of environmental degradation. This measure offers a more sustainable view of economic performance, highlighting the interplay between environmental factors, such as forest area and CO_2 damage. A higher adjusted net national income per capita indicates stronger economic health and effective sustainability practices. Values range from approximately 140 to 78,000, illustrating significant disparities among countries. The measures were not binned any further for the analysis.

2.3 Descriptive Statistics:

The following table provides an overview of all variables and their descriptive statistics.

Table 1: Descriptive statistics of the chosen variables

	FOREST_AREA _PCT_2012	FOREST_AREA _PCT_2013	CO2_DAMAGE_ 2012	CO2_DAMAGE_ 2013	ADJ_NAT_ GPA_2012	ADJ_NAT_ GPA_2013
Count	198	198	198	198	198	198
Mean	31.716	31.703	0.483	0.491	10389.064	10750.837
STD	22.633	22.639	0.371	0.379	14401.763	14837.418
Min	0.000	0.000	0.048	0.051	140.283	154.823
25 %	12.411	12.438	0.239	0.247	1246.590	1351.589
50 %	30.923	31.111	0.347	0.359	4189.441	4424.458
75 %	45.988	46.132	0.633	0.646	11192.652	11851.326
Max	98.355	98.331	2.509	2.485	78441.338	80588.455

Forest Area Percentage (2012 and 2013): The mean *Forest Area Percentage* is around 31.7%, with a standard deviation of approximately 22.6%. This indicates a wide variation in *Forest Area* across the considered countries.

CO_2 Damage (2012 and 2013): The mean *CO_2 Damage* is around 0.48 to 0.49, with a standard deviation of approximately 0.37. This suggests that there are countries with significantly higher *CO_2 Damage*.

Adjusted Net National Income per Capita (2012 and 2013): The mean adjusted net national income per capita is around 10,389 to 10,751, with a large standard deviation, indicating significant income disparity among countries.

To gain a visual overview over the data, histograms were created for each variable (see figure 1).

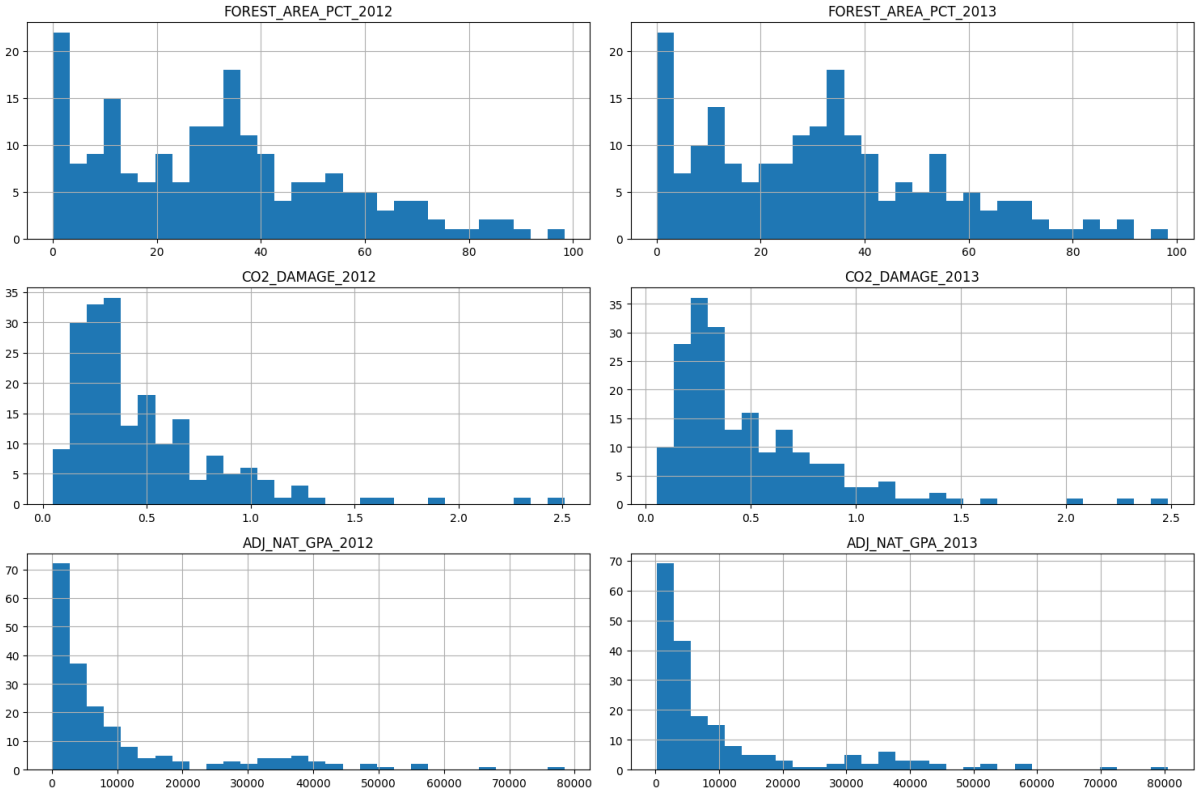

Figure 1: Visualization of statistics for each of the parameters in histograms.

2.4 Analyses:

In the following, the approach in context of the research topic is described. To understand the strength and direction of the relationships between the variables, a correlation matrix is created. In the next step, a multiple regression is performed, to check for statistical significance among the variables. In the last step, a linear regression to forecast the 2013 data based on the 2012 data is being performed, to model the relationship between the independent variables (*Forest Area Percentage* and *CO_2 Damage*) and the dependent variable (*Adjusted Net National Income Per Capita*).

3. Evaluation:

3.1 Correlation Matrix:

To evaluate the strength and direction of the relationships between the variables, a correlation matrix was created (see figure 2).

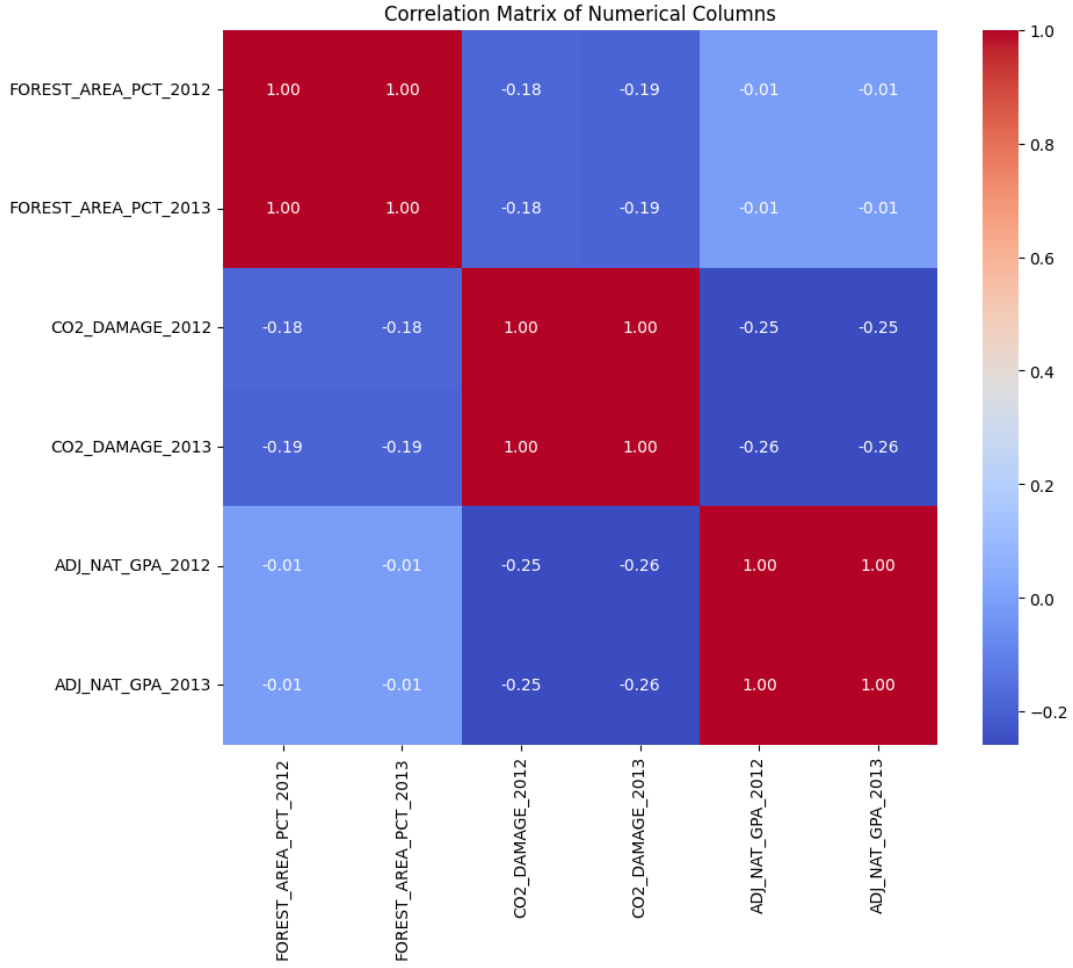

Figure 2: Correlation matrix of the parameters

The variables *CO2_DAMAGE_2012* and *FOREST_AREA_PCT_2012* have a correlation of -0.183780, suggesting a weak negative correlation. This means that as *CO_2 Damage* increases, the forest area percentage tends to decrease slightly.
The correlation factor between *Adjusted Net National Income per Capita 2012* and *CO_2 Damage 2012* is -0.25 as well as -0.26 for the respective values of the year 2013, indicating a moderate negative correlation. This indicates, that with increasing *Adjusted Net National Income per Capita,* the CO_2 damage slightly decreases.
Nevertheless, there seems to be no correlation between the *Adjusted Net National Income per Capita* and the forest area for both years.

Concluding the above findings, the matrix suggests that forest area percentages are stable over the two years measured. Further, CO_2 damage appears to have a weak negative relationship with forest area percentages, indicating that higher CO_2 damage may be associated with lower forest area percentages. The adjusted national GPA shows a strong consistency between the two years.

3.2 Multiple Linear Regression:

A multiple linear regression was performed to check for statistical significance among the variables. The results were separated for both years of observation, 2012 (see figure 3) and 2013 (see figure 4). The CO_2 damage was chosen as the dependent variable and the dependence of the *Forest Area Percentage* as well as the *Adjusted Net National Income per Capita* was analyzed.

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Multiple Regression Results for 2012
                            OLS Regression Results
==============================================================================
Dep. Variable:        CO2_DAMAGE_2012   R-squared:                       0.099
Model:                            OLS   Adj. R-squared:                  0.090
Method:                 Least Squares   F-statistic:                     10.74
Date:                Wed, 23 Apr 2025   Prob (F-statistic):           3.76e-05
Time:                        10:05:42   Log-Likelihood:                -73.671
No. Observations:                 198   AIC:                             153.3
Df Residuals:                     195   BIC:                             163.2
Df Model:                           2
Covariance Type:            nonrobust
============================================================================================
                               coef    std err          t      P>|t|      [0.025      0.975]
--------------------------------------------------------------------------------------------
const                     0.6486      0.047     13.760      0.000       0.556       0.742
FOREST_AREA_PCT_2012     -0.0030      0.001     -2.739      0.007      -0.005      -0.001
ADJ_NAT_GPA_2012     -6.587e-06   1.75e-06     -3.764      0.000      -1e-05   -3.14e-06
==============================================================================
Omnibus:                      117.385   Durbin-Watson:                   2.246
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              744.147
Skew:                           2.258   Prob(JB):                    2.57e-162
Kurtosis:                      11.355   Cond. No.                     3.32e+04
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
[2] The condition number is large, 3.32e+04. This might indicate that there are
strong multicollinearity or other numerical problems.
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Figure 3: Results of the multiple linear regression for 2012.

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Multiple Regression Results for 2013
                            OLS Regression Results
==============================================================================
Dep. Variable:        CO2_DAMAGE_2013   R-squared:                       0.103
Model:                            OLS   Adj. R-squared:                  0.094
Method:                 Least Squares   F-statistic:                     11.20
Date:                Wed, 23 Apr 2025   Prob (F-statistic):           2.49e-05
Time:                        10:05:46   Log-Likelihood:                -77.402
No. Observations:                 198   AIC:                             160.8
Df Residuals:                     195   BIC:                             170.7
Df Model:                           2
Covariance Type:            nonrobust
============================================================================================
                               coef    std err          t      P>|t|      [0.025      0.975]
--------------------------------------------------------------------------------------------
const                     0.6634      0.048     13.806      0.000       0.569       0.758
FOREST_AREA_PCT_2013     -0.0032      0.001     -2.816      0.005      -0.005      -0.001
ADJ_NAT_GPA_2013     -6.629e-06   1.73e-06     -3.830      0.000      -1e-05   -3.22e-06
==============================================================================
Omnibus:                      111.931   Durbin-Watson:                   2.216
Prob(Omnibus):                  0.000   Jarque-Bera (JB):              637.099
Skew:                           2.174   Prob(JB):                    4.53e-139
Kurtosis:                      10.637   Cond. No.                     3.43e+04
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
[2] The condition number is large, 3.43e+04. This might indicate that there are
strong multicollinearity or other numerical problems.
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Figure 4: Results of the multiple linear regression for 2013.

The regression model for 2012 has an R-squared value of 0.099, indicating that approximately 9.9% of the variability in *CO_2 Damage* can be explained by the independent variables included in the model. The F-statistic is 10.74 with a p-value of 3.76e-05, suggesting that the overall model is statistically significant.
The coefficient for the *Forest Area Percentage* is -0.0030, indicating that as the percentage of forest area increases, *CO_2 Damage* decreases, and this relationship is statistically significant (p = 0.007). The coefficient for *Adjusted Net National Income per Capita* 2012 is -6.587e-06, suggesting a negative relationship with *CO_2 Damage*, which is also statistically significant (p = 0.000)

The regression model for 2013 has an R-squared value of 0.103, indicating that approximately 10.3% of the variability in *CO_2 Damage* can be explained by the independent variables included in the model. The F-statistic is 11.20 with a p-value of 2.49e-05, suggesting that the overall model is statistically significant. The coefficient for *Forest Area Percentage 2013* is -0.0032, indicating that as the *Percentage Of Forest Area* increases, *CO_2 Damage* decreases. This relationship is statistically significant (p = 0.005). The coefficient for *Adjusted Net National Income per Capita* 2013 is -6.629e-06, suggesting a negative relationship with *CO_2 Damage*, which is also statistically significant (p = 0.000).

3.3 Prediction of 2013 values, based on 2012 values using linear regression:

In the last step, a linear regression to forecast the 2013 data based on the 2012 data is being performed, to model the relationship between the independent variables (*Forest Area Percentage* and *CO_2 Damage*) and the dependent variable (*Adjusted Net National Income Per Capita*). For this, two models were set up, one for the prediction of *CO_2 Damage* in 2013 (see figure 5) and one for the prediction of *Adjusted Net National Income Per Capita* (see figure 6).

CO2 Damage Model Summary:

OLS Regression Results

Dep. Variable:	CO2_DAMAGE_2013	R-squared:	0.993
Model:	OLS	Adj. R-squared:	0.993
Method:	Least Squares	F-statistic:	1.431e+04
Date:	Wed, 23 Apr 2025	Prob (F-statistic):	2.84e-212
Time:	10:55:25	Log-Likelihood:	406.43
No. Observations:	198	AIC:	-806.9
Df Residuals:	195	BIC:	-797.0
Df Model:	2		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	0.0003	0.004	0.067	0.947	-0.008	0.009
CO2_DAMAGE_2012	1.0168	0.006	163.496	0.000	1.005	1.029
ADJ_NAT_GPA_2012	-9.328e-08	1.6e-07	-0.583	0.561	-4.09e-07	2.23e-07

Omnibus:	59.249	Durbin-Watson:	1.715
Prob(Omnibus):	0.000	Jarque-Bera (JB):	620.709
Skew:	0.754	Prob(JB):	1.64e-135
Kurtosis:	11.542	Cond. No.	5.77e+04

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
[2] The condition number is large, 5.77e+04. This might indicate that there are strong multicollinearity or other numerical problems.

Figure 5: Results of the linear regression model for prediction of 2013 CO_2 Damage.

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Adjusted Net GPA Model Summary:
                            OLS Regression Results
==============================================================================
Dep. Variable:       ADJ_NAT_GPA_2013   R-squared:                       0.996
Model:                            OLS   Adj. R-squared:                  0.996
Method:                 Least Squares   F-statistic:                 2.753e+04
Date:                Wed, 23 Apr 2025   Prob (F-statistic):          7.94e-240
Time:                        10:55:25   Log-Likelihood:                -1623.2
No. Observations:                 198   AIC:                             3252.
Df Residuals:                     195   BIC:                             3262.
Df Model:                           2
Covariance Type:            nonrobust
===================================================================================
                      coef    std err          t      P>|t|      [0.025      0.975]
-----------------------------------------------------------------------------------
const               70.2855    124.322      0.565      0.572    -174.902     315.473
CO2_DAMAGE_2012     -7.0348    176.009     -0.040      0.968    -354.161     340.091
ADJ_NAT_GPA_2012     1.0284      0.005    226.930      0.000       1.019       1.037
==============================================================================
Omnibus:                      148.844   Durbin-Watson:                   1.926
Prob(Omnibus):                  0.000   Jarque-Bera (JB):            11315.440
Skew:                          -2.015   Prob(JB):                         0.00
Kurtosis:                      39.815   Cond. No.                     5.77e+04
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
[2] The condition number is large, 5.77e+04. This might indicate that there are
strong multicollinearity or other numerical problems.
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Figure 6: Results of the linear regression model for prediction of 2013 adjusted net national income per capita.

For better visualization of the results, plots for each model and the respective predicted variable were created (see figure 7)

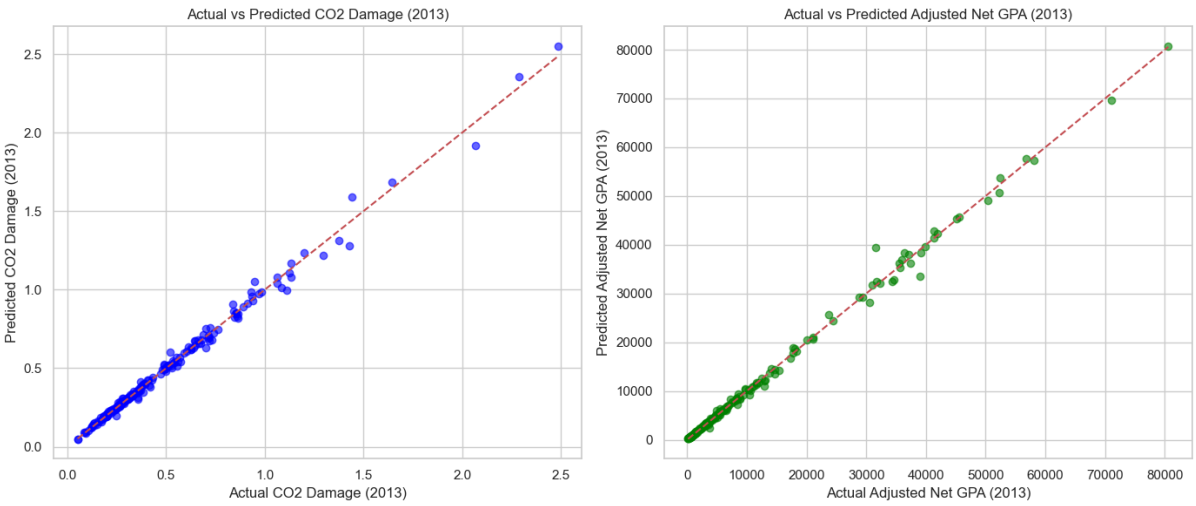

Figure 7: Results of the linear regression model for the purpose of prediction of CO_2 damage and adjusted net national income per capita for the year 2013.

The regression analysis for *CO_2 Damage* and *Adjusted Net National Income per Capita* yielded strong results. The model predicting *CO_2 Damage in 2013* explained approximately 99.3% of the variance (R-squared = 0.993), with *CO_2 Damage in 2012* being a statistically significant predictor ($p < 0.001$), indicating that a one-unit increase in *CO_2 Damage in 2012* results in an increase of about 1.017 units in *CO_2 Damage in 2013*.

However, *Adjusted Net National Income per Capita in 2012* did not significantly impact *CO_2 Damage in 2013* ($p = 0.561$). In the model for *Adjusted Net National Income per*

Capita in 2013, approximately 99.6% of the variance was explained (R-squared = 0.996), with *Adjusted Net National Income per Capita in 2012* being a significant predictor ($p < 0.001$), suggesting that a one-unit increase in *Adjusted Net National Income per Capita in 2012* leads to an increase of about 1.028 units in *Adjusted Net National Income per Capita in 2013*.
Conversely, *CO_2 Damage in 2012* did not show a statistically significant effect on *Adjusted Net National Income per Capita in 2013* ($p = 0.968$).

Overall, the findings highlight the strong predictive power of the models, particularly for *CO_2 Damage in 2013* and *Adjusted Net National Income per Capita in 2013* based on their respective 2012 values.

4. Discussion of results

The negative correlation between *CO_2 Damage* and *Forest Area Percentage* suggests that countries with higher forest coverage may experience lower economic costs associated with carbon emissions. Policymakers should prioritize forest conservation as a strategy to mitigate climate change impacts and enhance economic stability."

The moderate negative correlation between *Adjusted Net National Income per Capita* and *CO_2 Damage* indicates that as countries improve their economic performance, they may also reduce environmental degradation.

5. Conclusion:

This analysis highlights the relationship between *Forest Area Percentage*, *Carbon Dioxide Damage*, and *Adjusted Net National Income per Capita* across various countries from 2012 to 2013. The findings indicate that higher forest coverage is associated with lower *CO_2 Damage*, suggesting that effective natural resource management can contribute to economic stability. Furthermore, the negative correlation between *Adjusted Net National Income per Capita* and *CO_2 Damage* underscores the potential for economic growth to align with environmental sustainability.

Moving forward, it is essential for policymakers to consider these relationships when designing strategies for sustainable development. Future research should aim to use the whole available dataset to include additional years and variables, allowing for a more comprehensive understanding of these dynamics and their implications for global environmental and economic policies.