# Interconnections between agricultural diversity, food supply diversity and native species and their impact on health in the European Union

Anna Stofa, s3403424

Campus Fryslan, University of Groningen

BSc. Global Responsibility and Leadership

CFB063A10: Capstone Project

Dr. Carol Garzon Lopez

10 June, 2022

**Abstract**

The number of species cultivated over the past centuries has drastically decreased and 90% of calories consumed today comes from 30 plant species out of the 30.000 known. A diverse diet is beneficial for health, however, it is not clear if the origin matters. First, this paper investigates whether the number of crops found in 27 EU countries' agriculture and supply impact health measured by life expectancy. Second, a subset study examines whether a crop being native or not might also have an impact on life expectancy and whether there are any trends or patterns between the countries. The results of the correlation analysis show a negative correlation between the number of crops found in a country's supply and agriculture, however the multiple regression analysis shows a positive (non significant) relationship. The subset study found some patterns that support that the consumption of native species might positively affect health, however, the results are not conclusive.

Keywords: Agriculture, Supply, Native, Species, Diversity, Biodiversity, Health

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## Introduction

Agriculture is a critical and major contributor of change in both human health and environmental change throughout the Anthropocene (Foley, 2011;  Bennett. et al, 2014). The Anthropocene is a new epoch, where it is believed that the Earth's state has been substantially transformed by human activities (Lewis & Maslin, 2015). One of the main challenges of agriculture has been providing an ever increasing population with nutrient rich and sustainable diets (Shelef et al., 2017). Modern agriculture has attempted this mostly by improving the yield of a small number of crop species, where according to the Food and Agriculture Organization, the majority of calories consumed by humans, about 90%, is sourced from about 30 plant species of the approximately 30,000 species known (Hammer et al., 2003; Shelef et al., 2017). In addition, most of the limited crops produced today are transported great distances from the place of production to the country where it is consumed, forming the culture of the global food economy as based on those few plant species (Shelef et al., 2017). Increasing the number of species cultivated and learning to use wild plants increases the possibility to diversify the global food production, leading to better local adaptation of crops to the environments of the geographical location of where they are consumed (Provenza, 2008; Shelef et al., 2017). A wide variety of species would also lead to a greater stability in the Earth's system and improve the resilience of agricultural and natural systems (Tsioumani, 2019; IPBES, 2019).

Moreover, a large and growing body of evidence supports the idea that nutrition and a healthy, balanced and diverse diet positively influence human health and can help prevent non-communicable diseases, such as heart disease, stroke, diabetes, and cancer (WHO, 2018a).

For example, Hanley-Cook et al. (2021) found that a diverse diet with species richness has a positive effect on life expectancy. A safe and nutritious diet should be based on food ingredients produced in a sustainable manner  within the framework set out by dietary recommendations and the food-based dietary guidelines in order to have positive impacts not only on human health but also on the environment (Hanley-Cook et al., 2021; WHO, 2018b).

However, there is a lack of research on to what extent the diversity of a diet is supported by local produce or by imported food products  (e.g., fruits and vegetables grown overseas). Agriculture can be viewed in two ways: the first being the use of native plant species (plants found naturally in a particular ecosystem without human interface) that is not well studied or commercialized, and second being commercial food production, that sees a short life cycle of crop from production to consumption (Shelef et al., 2017).

The native ecosystem consists of indigenous species within the country's borders, agricultural diversity consists of crops, vegetables, and fruits currently grown within the country's borders, and supply diversity refers to all foods available for consumption, including imported foods within the country's border.

This research aims to examine the interconnections between food supply and agriculture diversity, as whether there are interconnections between food supply, agriculture diversity and native ecosystem through answering the following research questions.

RQ1: Are there interconnections between agricultural and food supply biodiversity in the EU and do they influence life expectancy?

RQ2: Are there interconnections between ecosystem, agricultural, and food supply biodiversity in the EU and do they influence life expectancy?

RQ3: What are the dynamics of these interconnections across the EU, as well as differences and similarities?

The research carried out in this paper consists of two parts, the first of which is an analysis on connections between agriculture and supply and impact on life-expectancy in all 27 countries in the European Union. The major impacting variables that can have an influence on life expectancy (GDP per capita, government health expenditure and education) were examined as well, in order to determine the individual effect of agriculture, by subtracting the effects of these variables.  The second part of the study examines the interconnections between food supply, agriculture diversity and native ecosystems in the case of a subset of 6 countries in the European Union.

This research is scientifically relevant, as it fills in the knowledge gap, as the topic has not been yet addressed in a novel way. The interconnections between supply and nutritional diversity and their impact on health has already been researched by Remans, Wood, Saha, Anderman and DeFries (2014), where the study looked at 7 key nutrients for dietary intake. However, this research looks at the number of species instead of key nutrients, emphasizing the effects of diversity in species, containing macro and micro nutrients, not limited to the 7 key nutrients in the aforementioned research. Also, the control socio-economic variables chosen to be examined after a literature review are different in this paper and they might influence the outcome of the results and patterns. The interconnections between supply, agriculture and ecosystem diversity have not yet been studied, adding additional scientific relevance to the research. The results obtained are also socially relevant, as they can provide insight for policymakers to integrate the importance of ecological diversity to agricultural practices and policies.

The structure of the paper is as follows: firstly, a thorough literature review will be given in order to explain all definitions needed to answer the research questions and showcase research already carried out with relevance to this paper. Secondly, a methodology section will outline the steps taken in the data collection and analysis, which is followed by the results found. Then a discussion, connecting back to existing literature, the research questions, and the data found will ensue. Finally, a conclusion is given and a recommendation for future research is made.

## Literature review

### Agriculture

According to Dawson et al. (2019), environmentally and nutritionally sustainable food supply is dependent on biodiversity, the variety of plants, animals and other organisms, both wild and cultivated that are intended for consumption by humans (FAO, 2021; Golden et al., 2011). However, the beneficial role that biodiversity plays is mostly based on context, meaning the specific production system and the given environment (Dawson et al., 2019). This, coupled with the global food system moving towards a more homogenized range of species cultivated, challenges the supporting ability of biodiversity of the food supply in the future.

To properly map the biodiversity of the countries, the history of how non-indigenous species were introduced and the extent to which they are cultivated should be examined. The current geologic time period characterized by the dominance of human activity in shaping the Earth's abiotic and biotic environmental processes is known as the Anthropocene Epoch (Mariani et al. 2021). This epoch is defined in part by changes to the Earth's biogeography caused by humans, including in the introduction and domestication of indigenous species, as well as the changes in climate, land use and species distribution (Young, 2014; Capinha et al., 2015;  Parmesan & Yohe, 2013). The development of agricultural crops occurred most significantly in certain regions in the world, those of which were determined by researching the origin of food plants comprising crops in countries across the world (Khoury et al., 2016). One of the most noteworthy, large-scale anthropogenic changes in crop biodiversity came about with the Columbian Exchange in the early 1500s, where massive exchanges of crops and animals occurred between the Americas, Europe, and West Africa, during the new world colonization (Mariani et al. 2021). Another worldwide introduction of new species happened after the 1950s when the range of cultivated crops began to show similar patterns in most regions around the world (Martin et al., 2019). This was followed by other periods of increase in the number of crops up until today. These changes in the biodiversity of agricultural produce have had a great impact on food supplies and diets (Mariani et al., 2021). This has actually led to the homogenization of these food supplies and diets globally and has led to greater food security interdependency in agricultural trade between countries (Nelson et al., 2019; Hessenauer et al., 2021).

Countries can be viewed as interconnected by the degree of which they produce crops that originate from regions other than their own (Khoury et al., 2016). A high and ever increasing degree of interconnection has been found among food supplies and production systems over the last 50 years, even in countries where there is a large diversity on native crops (Khoury et al., 2016). Protecting and encouraging food biodiversity conservation and exchange is important, as increase in the biodiversity of crops produced also leads to increased diversity in the consumption of crops from different geographical regions (Khoury et al., 2016).

One challenge that humanity has had throughout history is feeding the ever growing population, in an increasingly healthier and more sustainable way (Shelef et al. 2017). The emphasis has mostly been on increasing the productivity of a select few crops, rather than increasing crop diversity. Attention has been put mostly on local food production and the advantages that it has on the environment due to the fact that less transportation is necessary, but even so about 90% of the calories consumed by humans come from a limited number, around 30, of species (Shelef et al., 2017; Hammer et al., 2003). There are approximately 30,000 known edible species, yet only about 150 are cultivated (Shelef et al., 2017). Even variations within species have diminished greatly, leading to a higher susceptibility to global change stressors on food production and human population (Shelef et al. 2017). However, increasing the diversity of crops, especially with native and/or wild plants, increases potential to diversify the world's food production and be better adapted to the increasingly diverse habitats that people inhabit (Provenza, 2008).

Agriculture is essential in providing the aforementioned nutrients as well as fibre, shelter, medicinal plants and livelihood for many people (Hawkes & Ruel, 2006). However, simultaneously it can have a negative effect as it can lead to malnutrition, chronic disease and death (Lipton & Kadt, 1988).

When crop diversity is limited, it raises the risk of diseases and also limits the ability to respond to climate change (Shelef et al., 2017). Introducing new local crops helps diversify the diets and increase the income of local communities relying on agriculture (Shelef et al., 2017). The agricultural practices and response of local communities to climate change is a key part for food security (FAO, 2016). Native plants have evolved to their native environment and are therefore better able to thrive and produce phytochemically rich crops with reduced need for inputs such as water, fertilizer, and pest and disease control and are hence a better better option for health than non-local crops (Provenza et al., 2015). Moreover, native plants and local agriculture can aid in the reduction of human conflicts, the reduction of labor exploitation and the enhancement of fair trade (Shelef et al., 2017).

Provenza et al. (2015) found that crops grown locally are a fresher and healthier food source, due to the reduced use of preservatives leading to higher amounts of nutritional content preservation. Fresh foods are also less likely to be highly processed in short-chain manufacturing systems, unlike processed foods that can not only lead to negative health consequences, but they can also influence appetitive states and food preferences (Provenza et al., 2015). Moreover, local production promotes well-being by fostering small-scale entrepreneurship, cultural diversity, a sense of belonging to a community, cultural and physiological connections between a local population, and seasonal availability of varied foods (Little & Horowitz, 1987).

Wheat, rice and corn alone make up approximately 50% of the world's calorie intake, and these species have been bred specifically to increase yield more than for any other aspect (Reeves et al., 2016). This has led to a number of problems for the environment, including water pollution, soil degradation and increased crop susceptibility and loss of biodiversity (Pingali, 2012). This in turn has also led to a decrease in dietary diversity, losing many traditionally consumed crops that were a crucial source of many micronutrients, especially in poorer communities (Webb & Eiselen, 2009). The importance of reintroducing native crops to ensure sustainable food production and promote health is gaining recognition and popularity (FAO & WHO, 2018). These neglected and under-utilized species (NUS) include wild and domesticated plants that are less recognised than the mainstream crops (Ulian et al. 2020). However they are valuable in terms of traditions of the people of the indigenous places of these plants and in terms of their adaptation to those regions. Implementing NUS species in mainstream agriculture would most likely have a significantly positive effect on the resilience and sustainability of global food production, while increasing the health of those that consume them (FAO, 2018; Padulosi et al., 2019; Raneri et al., 2019). The use of native species has a positive impact on human health (Shelef et al., 2017). The adaptation to the western diet has altered the nutritional characteristics of diets globally, and the selective process of the food industry in terms of grown fruits and vegetables has favored more flavourful variants over more nutritious ones (Reeve et al., 2016). Modern agricultural practices also favor quantity over quality and led to less nutritious produce (Shelef et al., 2017). Reintroducing native plants and traditional farming practices would add nutrients to diets once again (Provenza et al., 2015). Remans et al. (2014) have found a strong association between the biodiversity in food supplied by agriculture and imports, and human health, controlling socio-economic factors, stated as, "gross national income (GNI) per capita, calories available per capita per day, Gini index, percent of the population with access to an improved water source, percent of the population living in urban areas, literacy rate, number of physicians per 1000 people, export of goods and services as percent of gross domestic product (GDP), import of goods and services as percent of GDP, agricultural import/export, and food import/export as percent of GDP". The strong relationship between human health and diversity in food, was more based on the food produced locally in low income countries and food imported and traded in middle and high income countries (Remans et al., 2014). The outcome of this study is important in showing the connection between diversity in national food systems and human health, and as critical as nutrition is to human health, it has not yet been integrated in planning of agriculture and food systems. The ways in which agricultural production is connected to population health is complex (Hawkesworth et al., 2010). Production patterns are closely linked to patterns of availability, price and distribution of food resources. Raw foods are processed in a variety of ways, and complexities, which influence the end consumers, and therefore the population's health in a combination of ways  (Hawkesworth et al., 2010).

It is well known that a diverse and well balanced diet, including all or most macro and micro nutrients, is key to good health (Hawkesworth et al., 2010). In a large-scale study carried out by Hanley-Cook et al. (2021) food biodiversity or Dietary Species Richness (DSR) has been found to have a positive effect on life expectancy, where 451,390 adults were enrolled in the European Prospective Investigation of Cancer and Nutrition (EPIC) study between 1992 to 2013. The effect of DSR and all-cause and cause-specific mortality of the participating individuals over 9 European countries (Denmark, France, Germany, Greece, Italy, the Netherlands, Norway, Spain, Sweden, and the United Kingdom) and 46,627 deaths were recorded over the time span of the study. In addition, the study also gives insight into the usual food biodiversity of diets of the countries studied. It was found that a higher DSR, regardless of other components of diet quality, resulted in lower mortality rates and cause-specific deaths caused by cancer, heart-, respiratory-, and digestive diseases (Hanley-Cook et al., 2021) . This supports the food biodiversity in public health and environmental conservation. The large sample size of disease free participants from different European countries and long follow-up period with a comprehensive perspective on the approximately 250 species comprising European diets.

Food diversity gives a unique perspective when it comes to developing guidelines for a sustainable healthy diet (WHO, 2021; FAO, 2021). Dietary diversity, which is the measure of consumption between nutrient-dense food groups, rather than within nutrient-dense food groups, is well known and documented to promote healthy and balanced diets (Herforth et al., 2019).

The United Nations 2030 Agenda for Sustainable Development, set out in 2015 also emphasizes sustainable agriculture through 2 goals. First, the goal of Sustainable Development Goal 2 is to eliminate hunger, ensure food security, enhance nutrition, and promote sustainable agriculture by 2030. Sustainable Development Goal 3, "Good health and well-being", has several nutrition-related targets, for example target 3.2 which aims to end malnutrition related deaths for children under the age of 5 (UN, 2020). Generally speaking, poor quality diets such as those high in processed foods and added sugars compared to whole foods are associated with chronic diseases and higher mortality rates globally (Afshin et al., 2019).

Nutrition is a key component of achieving the goals as it is a marker and maker of development (WHO, 2018).  Pertaining to sustainability, SDG 15, has set out targets to "Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss", to which biodiversity and sustainable practices in agriculture are inevitable (UN, 2020).

Global evidence suggests a close link between a higher economic standard of living and dietary diversity, and therefore disease and health patterns (Hawkesworth et al., 2010). The 'nutrition transition' is the trend of diets moving away from the high fibre and low fat/sugar diets of hunter-gatherers, to the high sugar and fat diets of highly processed foods of the developed world (Drewnowski & Popkin 1997; Popkin 2006). This move towards less healthy foods was due to availability and marketing of processed foods and moving away from the agricultural to the urban lifestyle (Popkin, 2006).

**Dependent Variable**

*Life expectancy*

To see the effects of diversity of crops, fruits and vegetables, on a population's overall health, is best carried out with longevity indicators, such as life-expectancy at birth, which is the mean number of years a person at birth is expected to live (Joumard et al., 2010; Bilas et al., 2014). As life expectancy is an important indicator of a country's economic and social development (Bilas et al., 2014), the difference in socio-economic backgrounds, as well as that attained through education, of certain populations, and is thought to be the main factor in the disparity seen in the life expectancy of these groups they are to be the control variable in this study (Bilas et al., 2014). Other factors include health care expenditure, lifestyle factors, such as smoking, alcohol consumption, diet, and pollution (Joumard et al., 2010).

**Control Variables**

As life expectancy might be dependent on the aforementioned variables, and not solely on the biodiversity of the food supply, these will be considered the control variables in this study**.**

*Education*

The relationship between the level of education and health has been previously studied by the National Bureau of Economic Research in 2006, where the education gradient was found in both the health status and health behaviors of the participants (Cutler & Lleras, 2006). A higher education generally pointed to subjects smoking and consuming alcohol less, they were less likely to be overweight and had better health care coverage and access to health care (Cutler & lleras, 2006). The more highly educated were also less likely to suffer from health conditions, such as cardiac problems, stroke, diabetes and asthma, and also less likely to report mental issues such as anxiety or depression (Cutler & lleras, 2006). Even though the extent of the relationship between education and health varies greatly, it is generally to a large extent (Bilas et al., 2014). It was found that an additional 4 years of education lowered five-year-mortality by 1.8 , and the risk of heart disease by 2.16, and diabetes by 1.3 percentage points (Cutler & lleras, 2006).

*Healthcare Expenditure*

Healthcare expenditure is also a key factor in increasing life expectancy and is defined by the percentage of domestic general government health expenditure to the general government expenditure (WHO, 2019). Studies show that with a higher investment in good healthcare, productivity and GDP increases leading to better overall health and higher life expectancy, following Grossman's (1972) health investment theory (Han & Rizzo, 2017; Kim & Lane, 2013). Comparing European Union countries with higher healthcare expenditures to those with lower expenditures show lower infant mortality, and mortality in general (Kim & Lane, 2013, Nixon & Ulmann, 2006; Budhdeo et al., 2015). This was also found to be true in developing countries in a worldwide analysis.

*GDP per Capita*

The effect of economic development on life expectancy is supported by empirical evidence that GDP per capita has a non monotonic relationship with a decrease in mortality rates (Cruz & Amaia, 2005). The population of a country with a higher GDP has higher living standards and lives longer on average and has lower mortality rates (Bilas et al., 2014).

**Hypotheses**

H1: Agriculture and supply diversity increases life expectancy

H2: Life expectancy increases with more diversity in native species

## Methodology

**Part 1 of the study**

In the first part of the research data is collected from all 27 EU countries, on whether certain edible fruits, vegetables or crops are present in the country's agriculture and supply and whether there is a correlation between these values and the overall health of the population measured by life-expectancy. There are other variables taken into account in this research that affect life expectancy the effects of which are subtracted to show the individual effects of agriculture. Other variables that are examined are GDP per capita, education index and healthcare, which is calculated by Domestic general government health expenditure of general government expenditure.

Data for food supply and agriculture is collected from the database of the Food and Agriculture Organization of the United Nations (FAO), which is national data on food production per capita compiled for most countries (Hawkesworth et al, 2010). The data is freely available online and is used mainly to inform agricultural and food policies. In the FAO database, "crops primary" is selected for production quantity, export quantity, and import quantity for the years 2017, 2018, 2019 and downloaded from the list in the supply utilization accounts.

The control variables are also sourced from reputable outlets: GDP per capita was sourced from Eurostat (2021), as the indicator of the real GDP of the average population of a country for a given year. It is the measure of the total final output of goods and services within a given time frame, averaged to the population. Life expectancy at birth was also sourced from Eurostat (2022). It is defined as the mean number of years a child at birth is expected to live given the age specific mortality probabilities (Eurostat, 2022). Data on the education level in a given country used in this research comes from The Education Index which combines average number of years adults have spent in education and with expected years children are to spend in schooling weighting each at 50%, where the higher the value the better. The Education Index is one part of the Human Development Index and is measured by the United Nations Educational, Scientific and Cultural Organization (UNDP, 2020). Finally, data on healthcare was sourced from WHO World Health 2022 statistics report, which is a percentage of the domestic general government health expenditure to the overall general government expenditure.

For both dependent (life expectancy) and control variables (GDP per capita, healthcare expenditure, education) data from 2019 is used, as from 2020 the data might have been influenced by the measures of COVID-19 restrictions. For agriculture and supply data, 2017, 2018 and 2019 were all looked at, due to crop rotation practices, and lack of data of a country for a certain year, it is more comprehensive to look at multiple years. After downloading the three datasets for agriculture and supply, data cleaning is carried out in Microsoft Excel to remove duplicates and blanks, as well as standardize species nomenclature. The two datasets are then combined into a single file by country and arranged as a presence-absence table for agricultural and supply levels. Finally, a multiple linear regression analysis is carried out in SPSS to test the hypotheses.

**Part 2 of the study**

The scope of the second part of the research is also the European Union, however, only 6 countries are examined due to the extensiveness of looking at all EU countries individually. The 6 countries are based on the life expectancy at birth per country in the 2019 list by WHO, including the countries scoring both high and low on life expectancy. The selection of countries was also based on the previously mentioned research on "The European Prospective Investigation into Cancer and Nutrition (EPIC) study which looked at 10 European Countries and their associations between food biodiversity and total mortality rates.“ The list in this research includes 4 countries from the EPIC study that showed significance between food biodiversity and total mortality rates (Italy, The Netherlands, Denmark, Germany). However, these countries have a relatively high life-expectancy and all score above the 78,5 years average life expectancy at birth in Europe (Statista, 2020). In order to be more representative of the entire European Union, this study also included 2 countries with lower than average life expectancies (Hungary, Bulgaria).

As a result, the second part of the research looks at countries looks at the following list of countries (with the corresponding life expectancy in years in the year 2019 according to the WHO): Italy (83), The Netherlands (81.8), Denmark (81.3), Germany (81.7), Hungary (76.4) and Bulgaria (75.1).

Data for supply and agriculture, life expectancy, as well as data for independent variables (GDP per capita, healthcare expenditure, education) come from the same sources as in the case of the first part of the research. Data looking at whether a certain crop is native or not comes from the Kew plant database providing the dataset of “Species naturally found in each EU country”.

After downloading the three datasets for agriculture, supply, and ecosystem, data cleaning is carried out in Microsoft Excel to remove duplicates and blanks, as well as standardize species nomenclature. The two datasets are then combined into a single file by country and arranged as a presence-absence table for agricultural, supply, and native species. Following this, results are explored, visualized and analyzed. Finally, the study investigates whether there is a correlation between the results and the life expectancy in countries, taking into account the dependent variables (healthcare, GDP per capita, education).

## Results

*Part 1 of the study*

*Correlations*

| | Agro | Supply | SupNoAgr | AgriSup |
|---|---|---|---|---|
| Austria | 58 | 123 | 65 | 58 |
| Belgium | 46 | 128 | 82 | 46 |
| Bulgaria | 75 | 123 | 48 | 63 |
| Croatia | 62 | 114 | 52 | 62 |
| Cyprus | 67 | 120 | 53 | 67 |
| Chechia | 56 | 126 | 70 | 56 |
| Denmark | 39 | 120 | 81 | 39 |
| Estonia | 35 | 111 | 76 | 35 |
| Finland | 36 | 119 | 83 | 36 |
| France | 82 | 129 | 47 | 82 |
| Germany | 50 | 127 | 77 | 50 |
| Greece | 88 | 124 | 36 | 88 |
| Hungary | 81 | 119 | 38 | 81 |
| Ireland | 34 | 120 | 86 | 34 |
| Italy | 79 | 130 | 51 | 79 |
| Latvia | 45 | 110 | 65 | 45 |
| Lithuania | 52 | 117 | 65 | 52 |
| Luxembourg | 34 | 117 | 83 | 34 |
| Malta | 42 | 112 | 70 | 42 |
| Netherlands | 57 | 128 | 71 | 57 |
| Poland | 65 | 122 | 57 | 65 |
| Portugal | 74 | 124 | 50 | 74 |
| Romania | 68 | 123 | 55 | 68 |
| Slovakia | 67 | 117 | 50 | 67 |
| Slovenia | 69 | 120 | 51 | 69 |
| Spain | 97 | 130 | 33 | 97 |
| Sweden | 41 | 123 | 82 | 41 |

*Table 1. Number of crop species found for all 27 countries in the EU in 1) Agriculture, 2) Supply, 3) in the supply but not in agriculture and 4) both supply and agriculture*


*Figure 1. Scatterplot visualization of the correlation to life expectancy with species found in 1) Agriculture, 2) Supply, 3) in the supply but not in agriculture and 4) both supply and agriculture*

**Correlations**

| | | lifeex | edu | healthcare | gdpreal | agris |
|---|---|---|---|---|---|---|
| lifex | Pearson Corr | 1 | .188 | .450* | .624** | -.015 |
| | Sig. (2-tailed) | | .348 | .018 | <.001 | .940 |
| | N | 27 | 27 | | 27 | 27 |
| edu | Pearson Corr | .188 | 1 | .619** | .306 | -.508** |
| | Sig. (2-tailed) | .348 | | <.001 | .121 | .007 |
| | N | 27 | 27 | 27 | 27 | 27 |
| healthcare | Pearson Corr | .450* | .619** | 1 | .452* | -.379 |
| | Sig. (2-tailed) | .018 | <.001 | | .018 | .051 |
| | N | 27 | 27 | 27 | 27 | 27 |
| gdpreal | Pearson Corr | .624** | .306 | .452* | 1 | -.489** |
| | Sig. (2-tailed) | <.001 | .121 | .018 | | .010 |
| | N | 27 | 27 | 27 | 27 | 27 |
| agris | Pearson Corr | -.015 | -.508** | -.379 | -.489** | 1 |
| | Sig. (2-tailed) | .940 | .007 | .051 | .010 | |
| | N | 27 | 27 | 27 | 27 | 27 |

*Table 3. Correlation table*

As seen in Table 3, the correlation results show a negative, not statistically significant relationship (0.940) between life expectancy and Agrisup value, meaning life expectancy decreases when the value of Agrisup increases. Agrisup and education have a statistically significant (0.007) negative correlation. Agrisup and GDP per capita have a negative, statistically significant (0.010). Healthcare expenditure and Agrisup have a non-significant (0.051) negative correlation. Regarding the relationship between the control variables and life expectancy, education has no relationship with life expectancy, healthcare has a non-significant positive relationship with life expectancy, GDP per capita has a significant positive relationship with life expectancy.

As the result of the correlation analysis opposes the literature, control variables are added in the multiple regression analysis to control for other factors that can influence the relationship. Examining only the correlation between single variables can be flawed due to not controlling the variables that were found to be influencing life expectancy in the literature review.

*Multiple regression Analysis*

**Model Summary** [b]

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .754[a] | .568 | .490 | 1.98348 |

a. Pedictors: (Constant), agris, healthcare, gdpreal, edu
b. Dependent Variable: lifeex

*Table 4.*

**ANOVA** [a]

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| | Regression | 113.882 | 4 | 28.470 | 7.237 | <.001[b] |
| | Residual | 86.552 | 22 | 3.934 | | |
| | Total | 200.434 | 26 | | | |

a. Dependent variable: lifeex
b. Predictors: (Constant), agris, healthcare, gdpreal, edu

*Table 5.*

Table 5 shows the model is statistically significant meaning that the independent variables (agris, healthcare, gdpreal, edu) can predict dependent variables (life expectancy). The significance is smaller than .001 which indicates that the significance is really high.

**Coefficients** [a]

| Model | | Unstandardized B | Coefficients Std. Error | Standardized Coefficients Beta | t | Sig. |
|---|---|---|---|---|---|---|
| 1 | (Constant) | 68.537 | 8.940 | | 7.666 | <.001 |
| | edu | 1.303 | 10.624 | .024 | .123 | .903 |
| | healthcare | .260 | .173 | .287 | 1.501 | .148 |
| | gdpreal | .000 | .000 | .708 | 4.124 | <.001 |
| | agris | .071 | .028 | .452 | 2.533 | .019 |

a. Dependent variable: lifeex

*Table 6. Coefficients table*

The coefficients table (Table 6.) shows that there is a positive relationship between agrisup and life expectancy and it is significant. Furthermore, there is a statistically significant positive relationship between GDP per capita and life expectancy. There is also a positive relationship between education and life expectancy, as well as healthcare expenditure and life expectancy, however these are not statistically significant. Due to the positive relationship between Agrisup and life expectancy, we can confirm H1, stating Agriculture and supply diversity increases life expectancy.

The results of the regression analysis are not in line with the correlation results which is likely the result of including all of the control variables. The multiple regression analysis shows a positive relationship between agrisup and life expectancy and besides this positive correlation, it can also be seen that GDP per capita positively influences life expectancy, whereas education and healthcare have no effects on life expectancy. The results of the multiple regression analysis are different from correlation results, showing the importance of including control variables.

*Part 2 of the study*

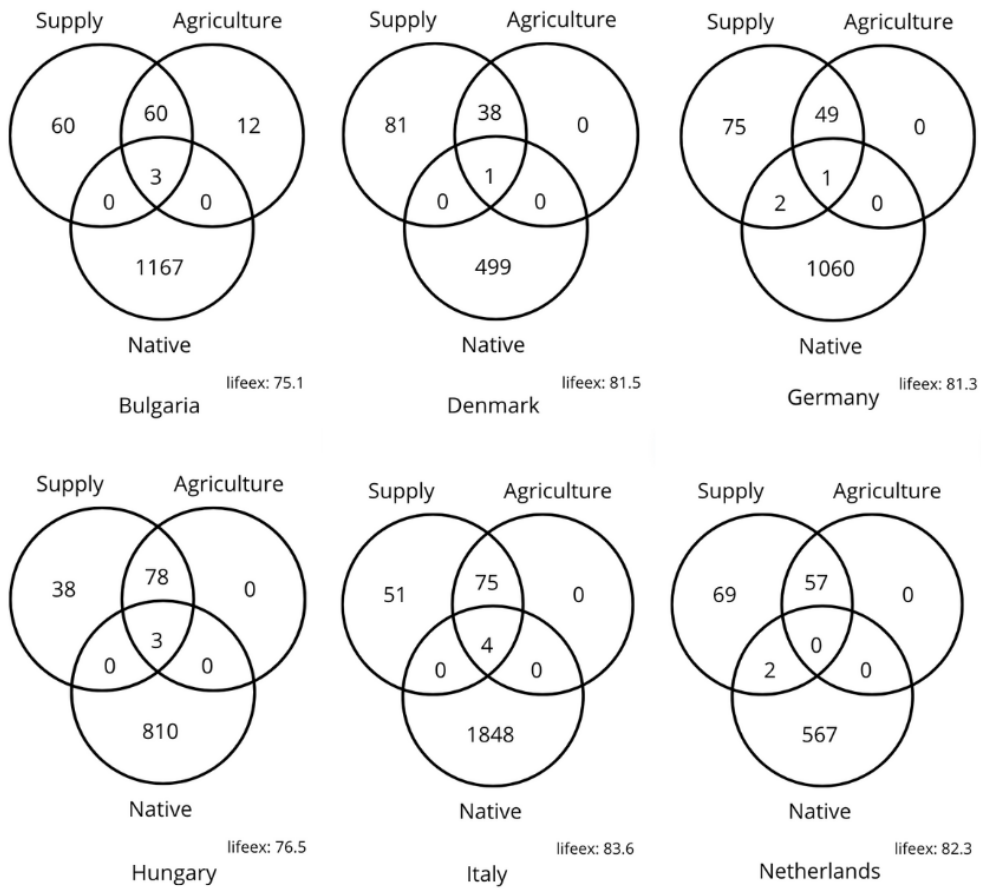


*Figure 2. Venn diagrams of the overlaps of the number of 1) native crops 2) crops found in agriculture 3) crops found in the supply of 6 countries in the EU*

| | lifex | edu | healthcar | gdpreal | agrisup |
|---|---|---|---|---|---|
| Bulgaria | 75.1 | 0.81 | 11.6 | 6630 | 63 |
| Denmark | 81.5 | 0.92 | 16.8 | 49270 | 39 |
| Germany | 81.3 | 0.94 | 20.1 | 35980 | 50 |
| Hungary | 76.5 | 0.82 | 9.4 | 13270 | 81 |
| Italy | 83.6 | 0.79 | 13.2 | 27230 | 79 |
| Netherlands | 82.3 | 0.91 | 16 | 41980 | 57 |
| | | | | | |
| Average | 80.05 | 0.865 | 14.51666667 | 29060 | 61.5 |

*Table 7.*

Figure 2 visualizes the interconnections between supply diversity, ecosystem diversity and native species diversity. It depicts that native species are rarely used in the supply or agriculture within a given country's borders. In the case of all 6 countries, the highest value of natives species found in either agriculture, supply or both was found to be in Italy with a value of 4. Italy also has the highest value of native species overall within its borders compared to other countries. In terms of life expectancy, Italy is also on top of the list as having the highest metric, in spite of being below average on the control variables of education, GDP per capita and healthcare expenditure. The lowest value of life-expectancy of the 6 observed countries was Bulgaria, even though it had a high agriculture and supply diversity, and the highest native species count second only to Italy. What is evident from all examined countries, is that the number of native species that overlap with supply and agriculture are very low. Due to this, and due to the small sample it was best not to do a statistical analysis in SPSS and instead the decision was made to visualize the relationship and see if there are any patterns. Because of the limitations of the sample the results for this part of the study are inconclusive, and H2 can not be confirmed, nor rejected. It is not possible to identify patterns conclusively.

## Discussion

For the first part of the study two types of analyses were carried out, first a Pearson's correlation analysis, where the relationship of Agrisup versus life expectancy was looked at without taking into account the control variables, and second, a multi regression analysis that did include the effect of 3 control variables (GDP per capita, healthcare expenditure, education) that according to the literature review would potentially influence the results. When taking into account the controlling factors, the overlap of agriculture and supply was found to have a positive and significant relationship to life expectancy. These result correspond to the findings of a number of studies, including a large-scale study carried out in 9 European countries (Denmark, France, Germany, Greece, Italy, the Netherlands, Norway, Spain, Sweden, and the United Kingdom) by in Hanley-Cook et al. (2021) who found that diversity in diets or Dietary Species Richness (DSR) positively influences life expectancy.

The exploration of the relationship of agriculture, native and supply to life-expectancy show mixed results. In the case of Italy the results correspond to previous literature as Italy scored the highest in the number of native plants found in the supply and agriculture and also has the highest life-expectancy, despite scoring relatively low on control variables. This is also seen in the study carried out by Shelef et al. (2017), where the use of more native species, and hence consuming more nutrients, extend life-expectancy. However the results for life expectancy of the other countries of the subset were not measurably dependent on the number of native species or diversity of supply and agriculture. It was difficult to derive conclusions as the number of native species found in each country was 4 or less, yet this low number corresponds to what Shelef et al. (2017) has stated, where of the 30,000 known edible species of plants, only around 150 are grown, which in turn leads to a low level of diversity in diets. The sample taken in this study is small and therefore has limited reliability and it is difficult to determine a correlation of diversity in diets to the life expectancy of a country. The research on the topic of native species in diets and their effects on health are very limited, which could also result in limited or unreliable related data. Further research is recommended to investigate the effect the increase in the diversity of native species in diets affects life-expectancy on a larger scale.

*Limitations*

This research encounters several limitations. First, data available on agricultural production from FAO are inherently incomplete, as the food availability estimates have a range of possible errors from miscalculations of the level of production and trade and determining what percentage of what is produced is available for consumption. The data has been criticized by academics, such as Svedberg (1997) as well as independent evaluators (Hawkesworth et al., 2010). The second potential error in the FAO database is the discrepancy between available data and realized life observations. Some crops were not present in the supply according to the data and they had to be manually added based on internet searches. However, only those most apparently incorrect and readily available online were added, as going through each possible crop for each country would have been too extensive and not all is available online. In the case of some exotic crops, that are only found in small quantities in stores with no online presence, their produce is not listed on FAO and adding them manually is also not realistic. For this reason some crops might be excluded from this study and are therefore a source of error that might influence the results.

Other than problems that arise from the data, the use of the dependent variable of life expectancy and the control variables is also not without error. Due to the complexity of the connection of health to life expectancy, it can not be considered a perfect indicator (Joumard et al., 2010). The measure of overall health is often criticized such as in the case of the Institute of Medicine's Committee on Summary Measures of Population Health for not taking into account psychological illnesses and disabilities (Field & Gold, 1998). Life expectancy is dependent on a vast number of factors other than the control variables listed in this research. Variables, such as cultural differences, genetics, daily habits, unforeseen circumstances, pollution, mental health are not looked at in this study and others too numerous to list all add to the complexity and inherent errors. In addition, the data on the control variables that were listed in this research are not completely reliable and are not unanimously agreed to have a significant impact on life expectancy. For example, although many support the idea that the relationship between GDP and life expectancy is positive, disagree and found that the relationship follows a U pattern or even an inverted U pattern (Ehrlich & Lui, 1991; Hu, 1999).

There is also no unanimous agreement whether healthcare expenditure impacts life expectancy, as for example, Deshpande et al. (2014) found the correlation to be present in developed countries, however, no correlation was found in developing countries (van den Heuvel & Olaroiu, 2017). This may be due to the fact that in developed countries spending goes to improving quality, increasing the effectiveness of healthcare that is mainly dependent on high quality healthcare technology (Shang & Goldman, 2008). In addition, the correlation of healthcare expenditure to life-expectancy is difficult to quantify as many other factors other than longevity increase spending, such as alcohol consumption, smoking and obesity (van den Heuvel & Olaroiu, 2017).

Similarly, the effects of education on life-expectancy can not be universally stated as it was pointed out that the relationship between them could be due to the effect of other variables on both (Bloom, 2007, Feinstein 1993). Bilas et al. (2014) also found no positive effect of education on health and life expectancy, and in fact the opposite was found. This negative effect can potentially be explained by the general lifestyle of those who reach a higher education: more stress, bad nutrition, long working hours and less physical activity.

## Conclusion

Regardless of the general agreement of that a diverse diet is beneficial for health, the past centuries have seen a dramatic decrease in the diversity of cultivated crops, and it is estimated that over 90% of the calories consumed by humans come from only around 30 species (Shelef et al., 2017; Hammer et al., 2003). The cultivation and consumption of native species - species that are naturally found in a given country's ecosystem are even lower, even though their consumption is believed to have positive effects on health due to being more nutritious and fresh (Provenza et al.,2015). As they are naturally found in specific regions, their cultivation requires less chemical and pesticide use, being a more sustainable option both in terms of health and environmental criteria (Provenza et al., 2015). Nevertheless, this topic of interrelation between agriculture, supply and native species has limited research, and the information of health benefits might not reach policymakers working in the agricultural industry. For this reason, this paper investigated whether crop diversity really had a positive effect on health in the European Union and whether a crop being native or not could also have an effect on health. The results of a simple correlation analysis between the overlap of agriculture and supply (agrisup) to life expectancy found a negative relationship, meaning the higher the agrisup value, the lower the life expectancy, which opposes the findings in the reviewed literature. However, when control variables (GDP per capita, healthcare expenditure, education) were added to a multiple regression analysis, the results showed that agriculture, independent of the effects of the control variables, indeed had a positive effect on life expectancy, hence H1 was accepted. In the case of the second part of the study where the interconnection of agriculture, supply, and native species was analyzed in a subset of 6 EU countries, and some patterns were identified, such as that Italy had both the highest amount of native species found in its agriculture and supply and the highest amount of life expectancy, regardless of scoring below average for the other variables influencing life expectancy. However, this trend was not this clearly seen in the example of the other countries. All countries scored below 5 for the amount of native species found in their agrisup. A low number was expected as also literature stated that the number of native cultivated crops has drastically decreased over the past centuries, however, the low number could have also stem from limitations in the data, such as native crops not being present in the agriculture tables due to their low popularity and low cultivated values. Furthermore, in some cases the data used showed a crop is not available in a country's supply, however, personal investigations showed otherwise. Due to the low sample size of the second part of the study and low numbers of native crops found within the countries' agriculture, the results were inconclusive and H2 (Life expectancy increases with more diversity in native species) could not be accepted or rejected. However, due to some patterns still present, it is recommended to do further research on the topic and increase data availability for more accurate results.

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**Appendix**

Link to data:
https://drive.google.com/drive/folders/1bZc9N0NcBmXEVVtVdEvpXTpiVCmIPCj2?usp=sharing