HSLU Lucerne University of Applied Sciences and Arts

The Impact of Urbanisation on Agricultural Area

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Geospatial Data Analysis for Smart Communities

HSLU Hochschule Luzern

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Figure 1 - Symbolic picture for urbanisation

(Source: https://pixabay.com/de/photos/geb%c3%a4ude-stadt-horizont-stadtbild-1842205/)

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List of acronyms and abbreviations

BFS	Bundesamt für Statistik
CSV	Comma-separated values
EC	European Commission
e.g.	exempli gratia
FAO	Food and Agriculture Organisation of the United Nations
NUTS	Nomenclature des unités territoriales statistiques
EU	European Union

1. INTRODUCTION

In this group work, we will address the question of whether the amount of land used for agriculture is influenced by urbanization.

The intuitive approach is to expect a negative effect of urbanization on agricultural land. Higher urbanization is often accompanied by population growth, which would automatically convert more agricultural zones into construction zones. In addition, it could be argued that urbanization causes former agricultural land to be used for unproductive recreational pursuits, e.g. hobby gardening, or horse keeping.

On the opposite side, it could be argued that an opposite effect could also occur: Higher urbanization could also mean that more people move from rural to urban areas due to the poor labour market situation, thus accumulating the population in the city and freeing up more land in the countryside. With this view, a positive effect of urbanization on agricultural land could be plausible.

The idea and the motivation for this topic came up during the input in the lectures. The lecturer showed maps of different time periods on https://map.geo.admin.ch. What made it clear to us was the strong growth of urbanized agglomerations and the decrease of the former agricultural zones. This observation motivated us to take a closer look at this topic. We do not want to limit ourselves to Switzerland, but to look at other European countries in comparison. A global comparison seems to us too far-reaching since the European countries are still rather comparable with each other in their structure.

The term paper is structured as follows: In chapter 2, we start the analysis for the urbanization dimension. For this purpose, the data of two time periods 2007 and 2016 are compared in two maps. The time-related question to be answered is whether there are differences between the maps for the two chosen time periods. Data from the European Statistics from the European Commission (ec.europa) is used.

The time periods 2007 and 2016 were not chosen arbitrarily. 2007 is the first common data cut point with the data for the Agricultural Land analysis. The year 2016 is the last available data for Agricultural Land on ec.europa.eu.

As a second step, the data are analysed from the point of view of the agricultural area. "Are there differences between the map's land area used for agriculture for the 2 chosen time periods?".

For the agricultural area and for urbanization, the focus is initially on the country level of the European countries. This is followed by a more detailed breakdown of the countries at Nomenclature des unités territoriales statistiques (NUTS) 2 level.

In chapter 4, we focus on Switzerland and look at the development for the two chosen time periods of agricultural land and urbanization at the cantonal level. Data from the Federal Statistical Office bfs.admin.ch is used as the data set.

In last chapter 5 the thematic question is addressed, whether urbanization has an influence on agricultural land. The Food and Agriculture Organization of the United Nations (FAO) serves as the data source. For this purpose, the data is transformed into R so that correlation coefficients for the years 2007-2016 can be determined per country. The FAO data set was selected for this because ec.europe does not have any data per year, but only shows them for certain years. Since FAO does not have data per NUTS 2 level, the analysis and visualization were limited to country level. In order to improve the linear model, another variable "used forest area" was added and the correlation coefficient with Agricultural Area was visualized.

Finally, the results are brought together and reflected upon in a Conclusion. In addition, we also go into what the next meaningful steps could be if the project were to continue.

In the appendix the metadata and non-essential visualizations and maps that would unnecessarily disrupt the reading flow and clear structure of the document are also attached. In a separate Appendix the required R-code is attached so that the study can be reproduced if necessary.

2. URBANISATION

In 2020, about 72% of the European Union population lived in cities and urban areas, but this proportion conceals marked differences between countries. Urbanisation rates vary from about 50%, for countries like Romania and Croatia, to beyond 80% for countries like Italy, Netherlands or the UK.

Europe’s urban system today consists of a mixture of different city sizes, which can be seen to have distinctive impacts on the agricultural areas as they stand at different points in their life cycles. By most definitions, Europe has no megacity. There is no single municipal area with more than 10 million people. But the city-regions of Paris and Milan each have more than 10 million.

To measure the urbanization we were using household as the main indicator, for this purpose we have defined this concept in the following way:

> *A household consists of one or several persons who live in the same dwelling and share meals. It may also consist of a single family or another group of people. The household is the basic unit of analysis in many social, microeconomic and government models, and is important to economics and inheritance. Household models include families, blended*

families, shared housing, group homes, boarding houses, houses of multiple occupancy, and single room occupancy.

For our analysis we have selected and joined two data sets, one with the households per NUTS 2 region and a shape file containing all the NUTS levels. They are structured as follows:

1. ***'Number of households by degree of urbanisation and NUTS 2 regions'***, which consist of 481 geopolitical entities and 3 main variables that we had used. The degrees of urbanization were consolidated in the 'households' variable.
2. ***'NUTS_RG_20M_2021_3035.shp'***, it contains the NUTS levels from zero to 3. We had used level '0' for country level and level NUTS 2.

To get a first impression of how urbanization is developing in Europe at a major scale, we have visualized the household units (by thousands) per country, comparing the year 2007 with the year 2016.

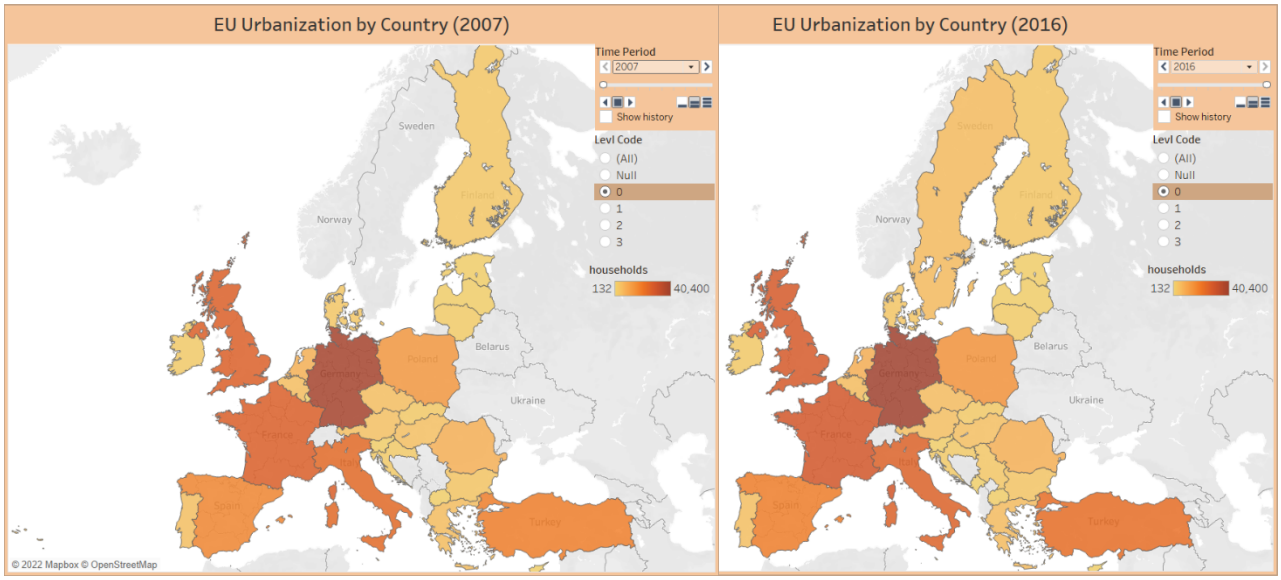

Figure 2 - EU Urbanization Map, Household Units (1000's) - Country Level

We can observe a couple of things. First, we can notice how some countries get some colour as we obtain data from them. This is due to the integration of new nations into the EU over these years, like Sweden and countries coming from the Ex-Yugoslavia.

Secondly, we can see which countries have the higher household rates as a whole region, we see Germany taking the lead, followed by France, UK and Italy.

At country level, no change in the number of households is to be seen in the time comparison. Therefore, we switched to a more granular approach by visualizing the households by NUTS 2 level.

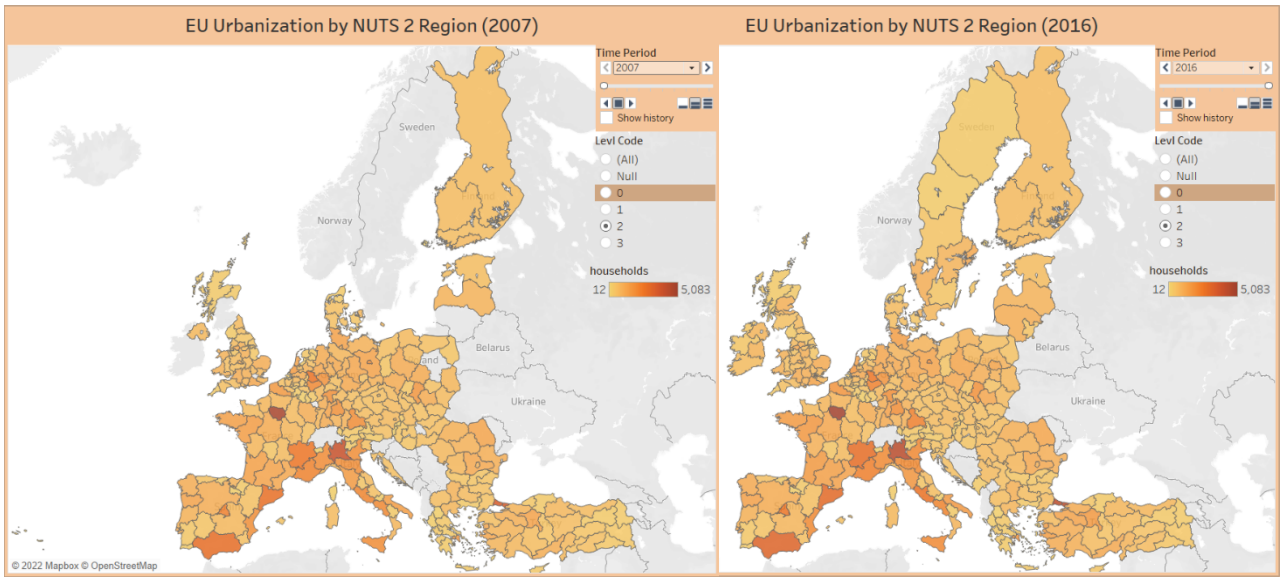

Figure 3 - EU Urbanization Map, Household Units (1000's) - NUTS 2 Level

We can again observe the same effect of the EU integration of new nations and not much of a change in the household units in function of time. But more importantly, we can visually identify more accurately the regions with the highest household rates.

For example, the initial assumption of Germany being more urbanized, is only true from the point of view of Germany as a whole region or country. However, we can confirm the statistic from 2020, which mentions that the city-regions of Paris and Milan, to have the highest urbanization rate.

3. AGRICULTURAL LAND

In 2020 France had the largest amount of organic farmland in Europe with around 2.55 million hectares, followed by Spain with roughly 2.44 million hectares. These numbers are clearly visible on the maps below. France and Spain show the highest in green coloring, which indicates the amount of utilized farmland. In this dataset it was not distinguished between farmland for life stock or crops, just farmland in general. Overall, there seems not to be a vast difference between 2007 and 2016. When we have a closer look at the actual numbers it can be discovered that France and Germany show an increase of farmland, while Spain in contrast shows a slight decrease.

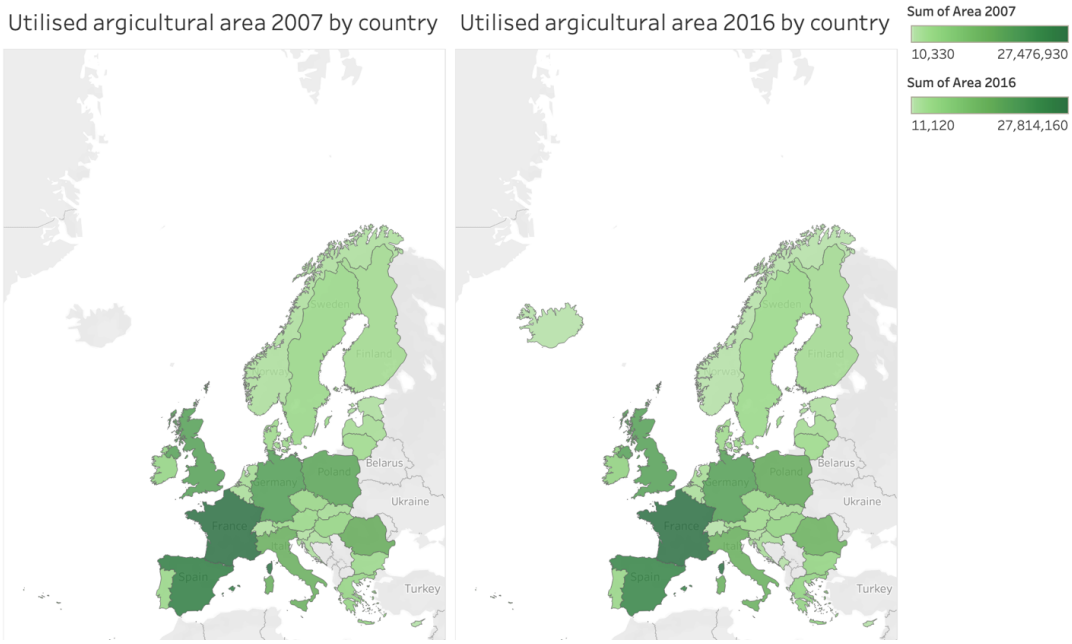

Figure 4 - EU Agricultural Land - Country Level

When we look at the NUTS 2 level, we get a more detailed picture of the topic. Especially, by looking at the Iberian peninsula. In Spain, three main areas can be identified, where most of the agricultural industry is settled: Andalucía, Castilla-la Mancha and Castilla y Léon. These three regions make in total nearly ¾ of Spain's total agricultural land in use. All these three regions show a slight decrease from 2007 to 2016 (on the map in dark green).

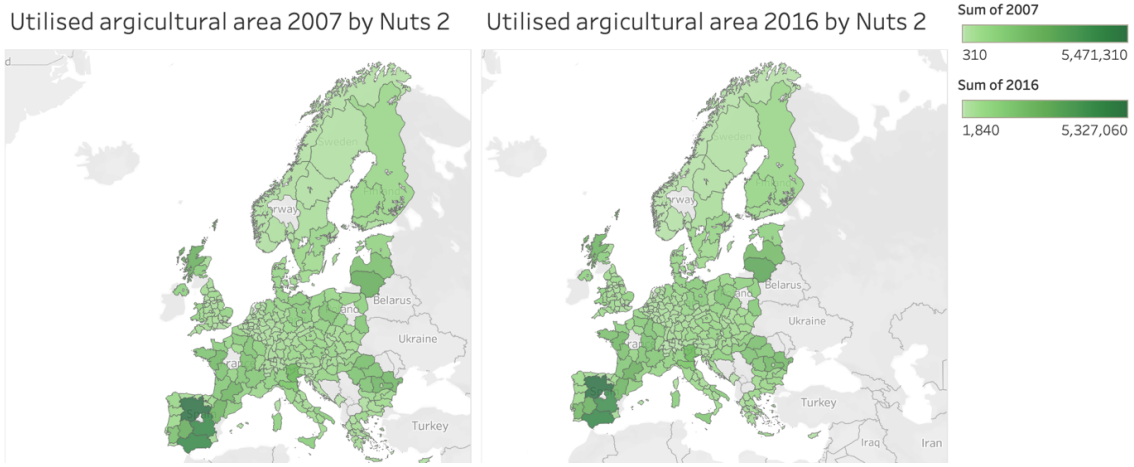

Figure 5 - EU Agricultural Land - NUTS 2 Level

4. URBANISATION VS AGRICULTURAL LAND IN SWITZERLAND

The goal of this section is to analyse whether the amount of land used for agriculture in Switzerland is influenced by urbanization. For this purpose, we have used the Federal Statistical Office as a data source, where we have obtained the data for each of the cantons of Switzerland. Specifically, for this analysis, we have taken 2009 data as a reference and compared it with 2018 data. After data preparation and cleaning of the data, the datasets were loaded into Tableau for visual analysis.

In the first instance, we have analysed the agricultural land for each canton. Below we can see a comparison of the hectares of land devoted to agriculture in 2009 and in 2018. For more detailed visualizations of this section, see Appendix A.

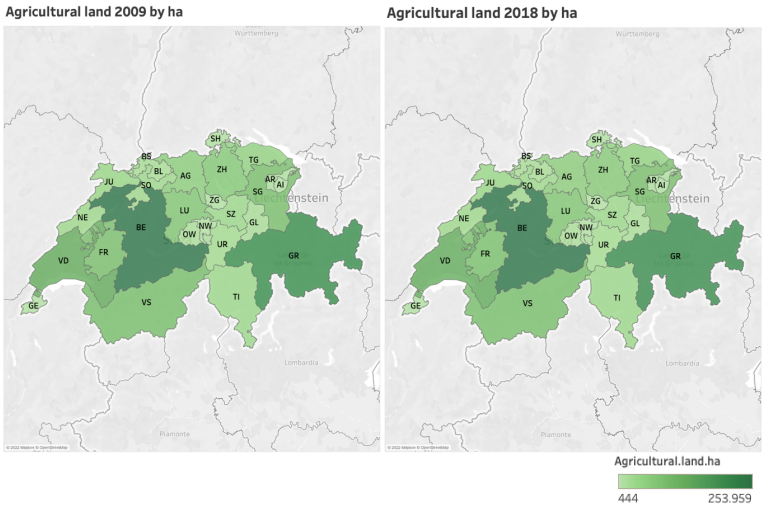

Figure 6 - Agricultural Land 2009 vs 2018 by ha (Switzerland)

At first glance, we see that the cantons with the most hectares devoted to agriculture are Bern and Graubünden. At the same time, we also see that they are 2 of the largest cantons. Therefore, we believe that this information is not entirely accurate and have proceeded to calculate the % of hectares of agricultural land in each canton out of its total area.

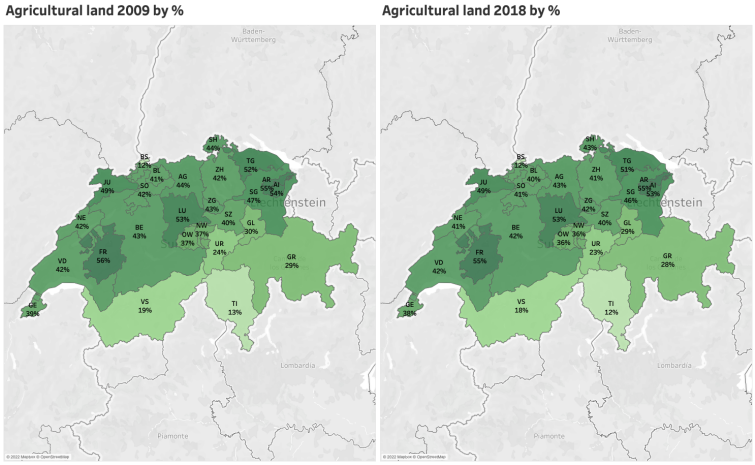

Figure 7 - Agricultural Land 2009 vs 2018 by % (Switzerland)

In this case, the situation is completely different, and we can see that the cantons with the highest percentage of land dedicated to agriculture are:

Canton	2009	2018
Freiburg	56%	55%
Appenzell Ausserrhoden	55%	55%
Appenzell Innerrhoden	54%	53%
Luzern	53%	53%

Table 1 - Cantons with the highest % of Agricultural Land

We can see that in both Freiburg and Appenzell Innerrhoden there has been a decrease of 1% in agricultural land. This led us to make a visualization of the evolution of each canton.

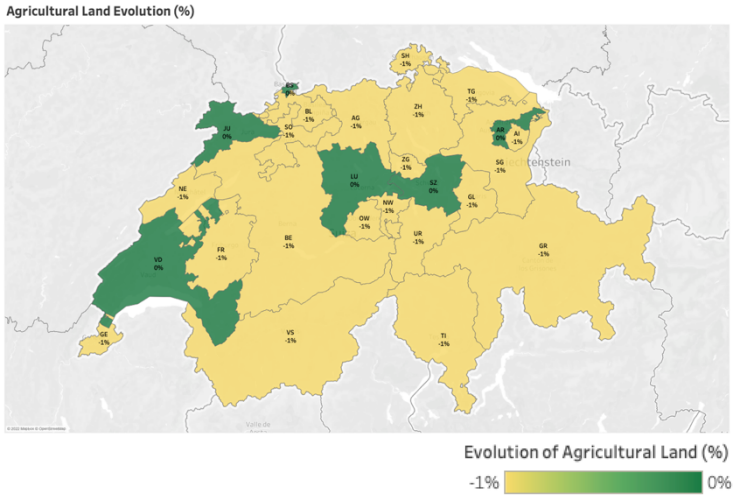

Figure 8 - Evolution Agricultural Land 2009-2018 by % (Switzerland)

In a conclusion from the above visualization, we can conclude that in most cantons of Switzerland there has been a 1% decrease in land devoted to agriculture. Only in very few cantons have the % of agricultural land remained the same. Specifically, Switzerland has gone from having 1.482.667 hectares in 2009 to 1.452.451 in 2018, a difference of 30.216 hectares.

Once the agricultural land has been analysed, we proceeded to study the evolution of urbanization in Switzerland.

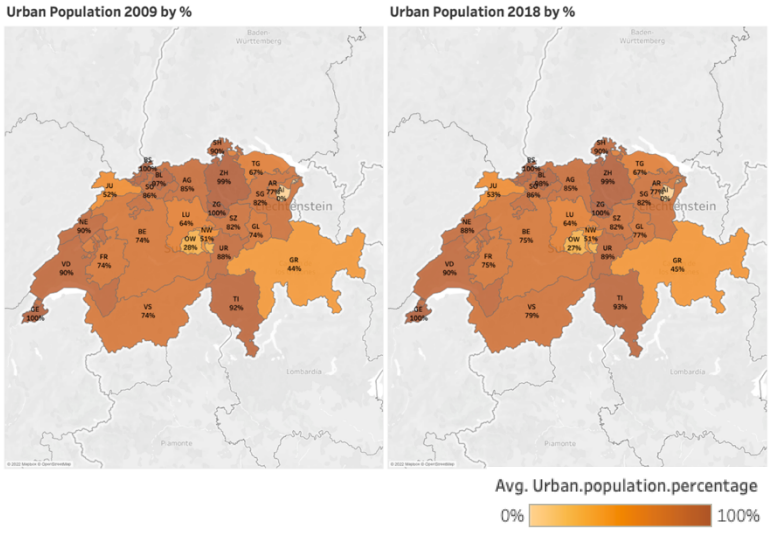

Figure 9 - Urbanization 2009 vs 2018 by % (Switzerland)

As we can observe in the map above, we see that the cantons with the highest percentage of the urban population are the same in both 2009 and 2018. Among the cantons with a higher percentage, we would highlight Zürich, Zug, Genf, Basel-Stadt and Basel-Landschaft, where their values range between 97% and 100%. On the other hand, the cantons with the highest percentage of the urban population are Appenzell Innerrhoden (0%), Obwalden and Graübunden.

If we visualize on a single map the difference in % of the urban population between 2009 and 2018, the result is as follows:

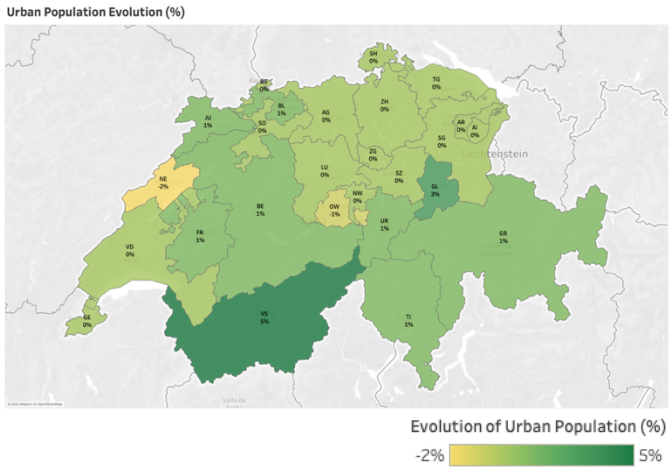

Figure 10 - Urban Population 2009-2018 by % (Switzerland)

From the above visualization, we can confirm that there has been an increase in the urban population in most of the cantons. In particular, the cantons with the highest % growth are Wallis (5%) and Glarus (3%). On the contrary, the cantons that have experienced a decrease in their urban population are Neuenburg (-2%) and Obwalden (-1%). Specifically, Switzerland has gone from having an urban population in 2009 of 6,562,902 to 7,241,546 in 2018, a growth of 678,644 urban people.

Finally, to see if the amount of land used for agriculture in Switzerland is influenced by urbanization, we have made the following visualization:

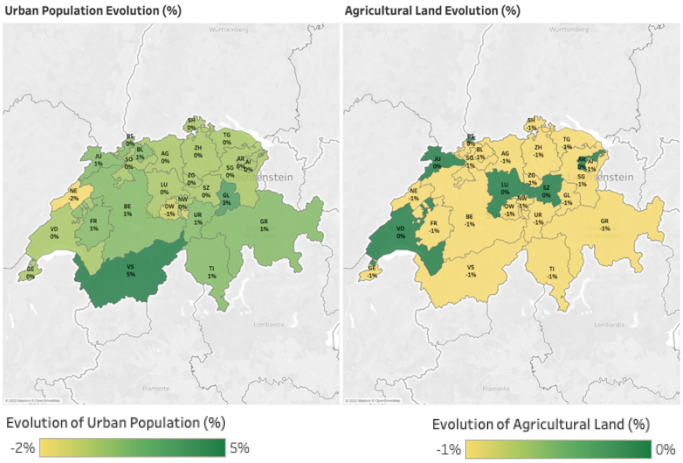

Figure 11 - Evolution of Urban Population and Agricultural Land 2009-2018 by % (Switzerland)

In a conclusion, we can see that while the urban population has been growing, the agricultural land has been decreasing in most cantons of Switzerland. A clear example is the canton of Wallis, where the urban population has grown by 5% while the agricultural land has decreased by 1%.

5. CORRELATIONS

In this chapter, the different dimensions are put in relation to each other. The descriptive correlation coefficient according to Bravais-Pearson can take values from -1 to 1. The value 1 means a perfect, strong positive linear correlation: If variable X increases, then variable Y also increases. Or another interpretation is variable X decreases and variable Y decreases as well. The value -1 means a perfect, strong negative linear correlation: If variable X increases, then variable Y decreases (the opposite direction is also possible). A correlation coefficient of 0 means that variable x has no linear relationship with the other variable. [1] The formula can be described as: $r_{x,y} = \frac{\sigma x,y}{\sigma x * \sigma y}$

Absolute value of r	Strength of the relationship
r < 0.25	No relationship
0.25 < r < 0.75	Weak / moderate relationship
r > 0.75	Strong relationship

Table 2 - Rule of thumb for interpreting the correlation coefficients of two variables[2]

In this project, the correlation coefficient between Agricultural Land and Urbanization, and between Agricultural Land and Forest Area were calculated and then visualized on different maps using the rules of thumb which are shown in Table 1.

6. CORRELATION BETWEEN URBANISATION AND AGRICULTURAL LAND

In a first step a correlation between Urbanisation and Agricultural Land was calculated. Two different CSVs were extracted from FAO. In order to merge them into one join, the data had to go through some preparation steps. For this it was filtered to the desired time period (2007-2016), furthermore only the necessary attributes and countries were selected. [3] In addition, the data structure was changed, so that Agricultural Land and Urbanization became their own attributes and at last the following two relative variables

[1] Vgl. Weigand, 2019, S. 115-119

[2] Vgl. Fabian, 2020, https://statologie.de/starke-korrelation/

[3] The definition which country belongs to Europe is highly controversial. In this analysis Russia, Turkey and the Caucasian countries as Armenia, Azerbaijan and Georgia was included. For Kosovo no data are available therefore the complete area is excluded.

were calculated: Agricultural Land / Total Land and Urban Population / Total Population (see: Appendix C).

Based on the data preparation it was possible to implement a loop in R which produced stepwise correlations for each country. Furthermore, the correlation coefficient for different European Areas (Northern, Southern, Eastern, Western) were calculated. The decision which country belongs to which region was based on the metadata of FAO, where the countries are assigned to the respective area (see: Appendix B). Lastly, a correlation coefficient was also calculated for all 27 European Union States. At the end the data was loaded into Tableau.

With longitude and longitude as geographic coordinates the map can be interpreted as follows:

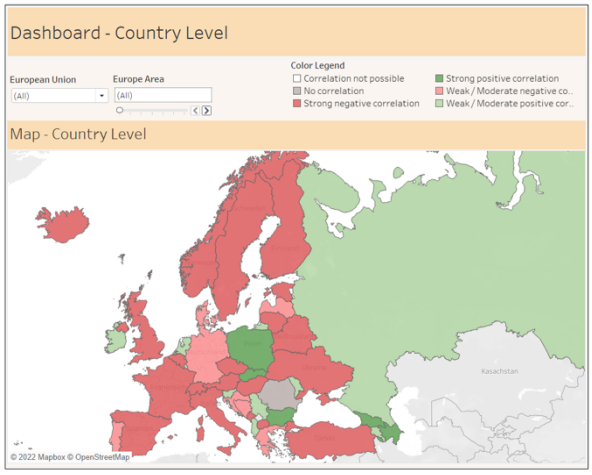

Figure 12 - Map with correlations between Agriculture Land and Urban Population - Country level

Dark green: A Strong positive correlation between agricultural land and urban population can be observed in some countries, e.g. Poland and Slovakia. By plotting Urban and Agricultural Land over time we see that the decrease of urbanisation has a relationship with the decrease of the agricultural land. [4]

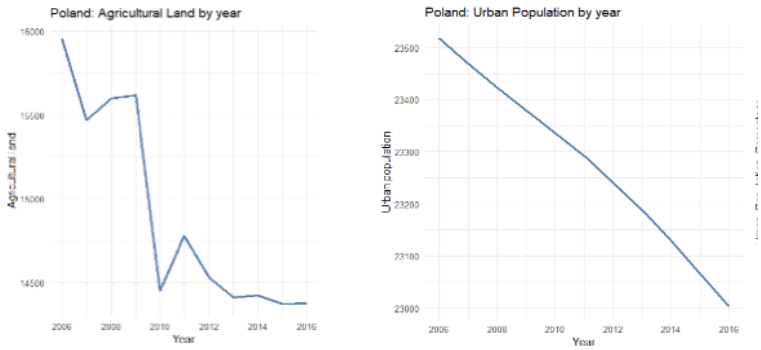

Figure 13 - Agricultural Land and Urban Population by Year for Poland

[4] Note: The values on the plots must be multiplied by 1000. For example, it means that the agricultural area in Poland in 2010 was 14500*1000 ha. For the urbanized population, the interpretation for the year would be about 23150 *1000 people.

There seems to be a trend in some Eastern European countries to reduce the proportion of the population living in cities. It speaks for an urban exodus. This urban exodus has a significant impact on agricultural land, as more residential areas are built on the basis of previously used agricultural land. However, by plotting different positively correlated countries there was no behaviour observable that an increase of urban population also leads to an increase of agricultural land.

Dark red: A Strong negative correlation between agricultural land and urban population can be observed in other countries, e.g. Sweden and Switzerland. By plotting Urban and Agricultural Land over time we see that the increase of urbanisation has the opposite effect and it leads to a reduction of agricultural land.

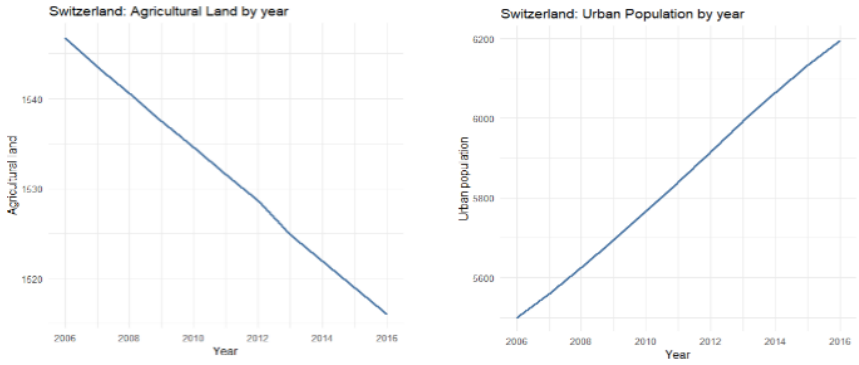

Figure 14 - Agricultural Land and Urban Population by Year for Switzerland

For many Western and Northern Europe countries this is a general trend. The percentage of Urban Population increases, while the Agricultural Land decreases. One reason for this could be that urban agglomeration continues to expand and former agricultural land is used to expand urban habitat. Or another possible cause could be that former agricultural land is now used for hobby activities of the urban population, as mentioned in the introduction.

Ukraine shows a negative correlation coefficient as well. In this case, however, the interpretation is the opposite: A reduction in the urbanized population has led to an increase in the area used for agriculture. The urbanized population has a strong negative linear trend in absolute numbers, whereas in relative numbers exactly the opposite happens and the urbanized population increases. This is since the ukrainian population has decreased 46.47 millions in 2006 to 42.42 millions in 2016.[5]

[5] vgl. Urmersbach, 2022, https://de.statista.com/statistik/daten/studie/232387/umfrage/gesamtbevoelkerung-in-der-ukraine/

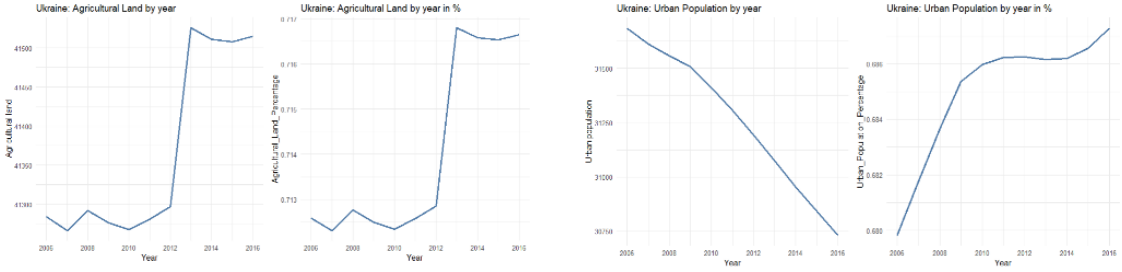

Figure 15 - Agricultural Land and Urban Population in Total and in % by Year for Ukraine

Grey: The country Romania shows no correlation. This is also an interesting situation. By plotting Agriculture by year it can be read out that the agriculturally used area has an undulating course and the mean value remains constant over the years at about 13,000 ha * 1000, but there is only an upward and downward swing, but no general trend. For Romania we see the same problem with a decreasing population as in Ukraine therefore the plot in absolute numbers and relative number shows differently.[6]

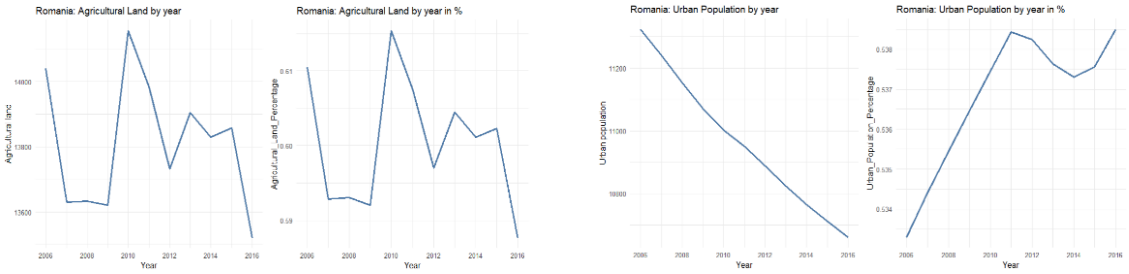

Figure 16 - Agricultural Land and Urban Population in Total and in % by Year for Romania

A last interesting view is on the **European Area level**. As we have already seen, there are eastern European countries with positive correlation coefficients. These are Poland, Slovakia, Russia and Moldova. By contrast, Ukraine, Belarus, the Czech Republic and Hungary have a negative coefficient. At the aggregate level, the trends cancel each other out and a grey colour is assigned.

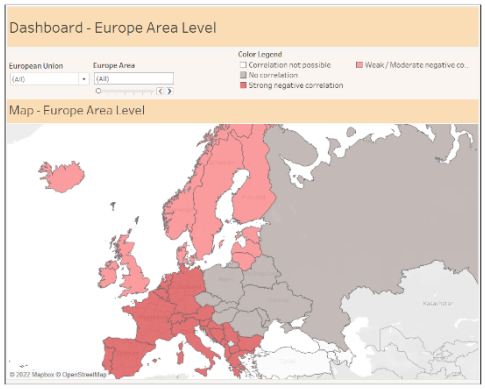

Figure 17 - Map with correlations between agriculture land and urban population - Area Level

[6] vgl. Urmersbach, 2022, https://de.statista.com/statistik/daten/studie/270708/umfrage/gesamtbevoelkerung-von-rumaenien/

7. CORRELATION BETWEEN FOREST AREA AND AGRICULTURAL LAND

In a second step a correlation between Forest Area and Agricultural Land was calculated. According to the FAO metadata the Forest Land is defined as: “Land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 per cent, or trees able to reach these thresholds Excludes land that is predominantly under agricultural or urban land use…”

To determine the correlation coefficient, the R script was adapted. Subsequently, the following map was generated in Tableau. Again, there are some strong correlation coefficients to be seen.

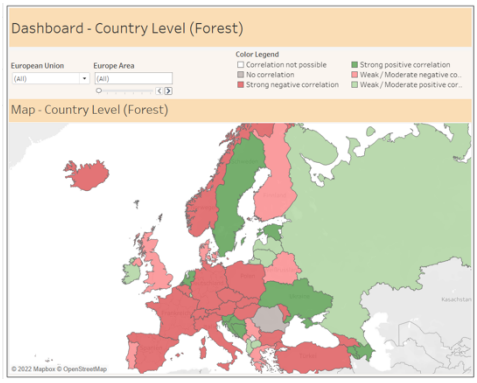

Figure 18 - Map with correlations between agriculture land and forest area - Country Level

Dark green: A Strong positive correlation between agriculture land and forest area can be observed in countries, e.g. Sweden. The loss of agricultural land was additionally accompanied by a loss of forest land. For Sweden this strongly suggests that this loss of land was invested exclusively in the expansion of urbanization.

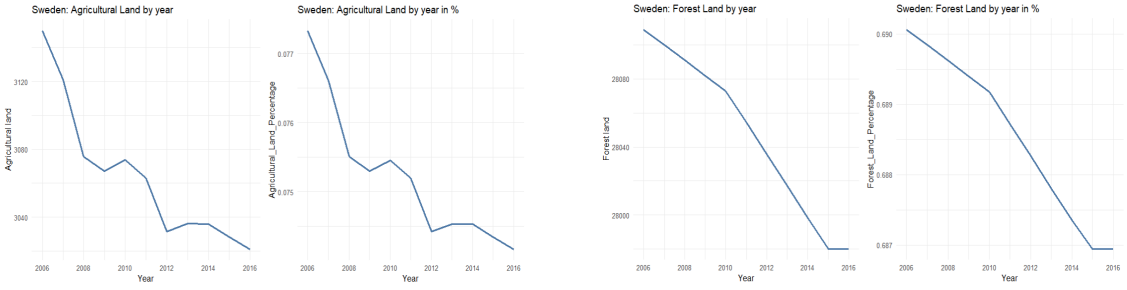

Figure 19 - Agricultural Land and Forest Land in Total and in % by Year for Sweden

Dark red: A Strong negative correlation between agriculture land and forest area can be observed in countries, e.g. Germany. For Germany we can conclude that the loss of agricultural land was only partly invested in the expansion of urbanized habitat. In the other part, the development of new forest areas was pushed forward.

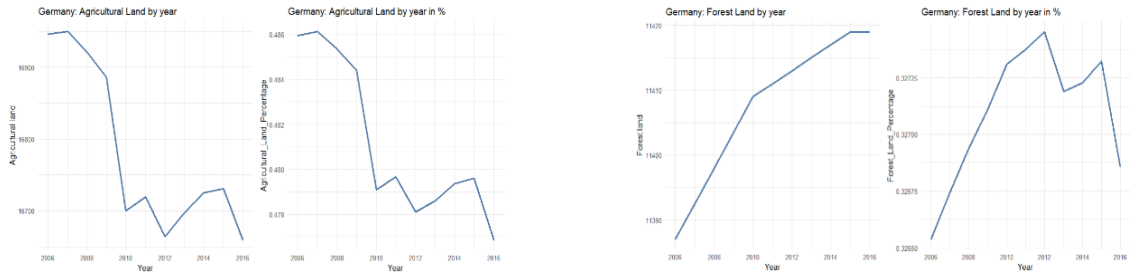

Figure 20 - Agricultural Land and Forest Land in Total and in % by Year for Germany

8. CONCLUSION

Urbanization: The urbanization maps by country does not provide much meaningful information, more than just pointing at the countries with the highest population density. But once we close up to a more granular area of measurement, like the NUTS 2, we observe clearly where the main focus of urban population have been. Which would set the direction to take for further and deeper analysis, this may be achieve by levelling up to a NUTS 3 and expanding the time frame to analyse.

Agriculture: The agriculture maps by country show very clearly, which countries have the most agricultural area overall, in use. In the NUTS 2 maps, it is clearly visible that mainly three regions in Spain have the highest utilized agricultural area. This was to be expected since for example Andalucía is considered to be the “Green house of Europe”. Overall there are no big differences between 2007 and 2016 regarding utilized agricultural land.

Urbanization vs Agricultural Land in Switzerland: On one hand, the agricultural land maps provide us with the information that there has been a decrease in most cantons in Switzerland. Specifically, in Switzerland, there were 30.216 fewer hectares in 2018 than in 2009, a decrease of 2%. On the other hand, the maps related to the urban population show that Switzerland's main cities are home to the highest percentages. In addition, we can confirm that there has been an increase in the urban population in most of the cantons. The urban population in Switzerland has increased from 2009 to 2018 by 678,644 million people, an increase of 10%.

We could think that the decrease in agricultural land in Switzerland is actually caused by the strong growth of the urban population. But to be able to affirm this idea, we recommend a deeper analysis, since there may be other factors, not analysed in this study, that also have a direct relationship with agricultural land.

Correlation: It can be concluded that in all cases except for Rumania urbanization shows a correlation with the agricultural land. Therefore, it can definitely be assumed that both variables are related to each other and that urbanization has an impact on the agricultural area. Some examples of very strong correlation coefficients were considered in chapter 5. The following interpretations can be concluded:

- In some Eastern European countries, such as Poland, there is the effect of an urban exodus, which leads to a decrease in urbanized population and, at the same time, a decrease in agricultural land.

- In the Northern and Western European countries, we see the trend that has been waiting: The urbanized population increases, and the agricultural area decreases, due to the expansion of the urban habitat. However, when the Forest Area variable is added, some of the Western European countries, such as Germany, have compensated for the decrease in agricultural area by building up more forest area.

- The second hypothesis put forward in the introduction, that higher urbanization would possibly lead to an increase in agricultural land, could not be confirmed. In contrast, however, Ukraine has shown an interesting behaviour, where the urbanized population decreases, but the agricultural area increases.

Overall Conclusion: The research question of whether urbanization has an impact on agricultural land can be answered clearly: Agricultural land and variables are related to each other and urbanization has an impact on the agricultural area. But it's hard to say how strong that influence is.

Additionally, another variable called Forest Area was already introduced as an extension in Chapter 5, which has a significant impact on the agricultural area. If the project were to be continued, our next steps would be to analyse the political, environmental and geographical conditions of the countries with the most interesting behaviours. These are Poland, Ukraine, Romania, Germany and Sweden. Based on the analysis, we could then add more factors and make the model more complex to experience more certainty about the strength of the influence of urbanization on agricultural land. Conceivable factors would be: Number of farms and farmers, Production of agricultural products in € and in % of GDP and number in tons, Imports of agricultural products in € and in % of GDP and number in tons, and the level of the state's subsidies to agriculture in €.

9. REFERENCES

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APPENDIX A

URBANISATION VS AGRICULTURAL LAND IN SWITZERLAND

Figure 6 - Agricultural Land 2009 vs 2018 by ha (Switzerland)

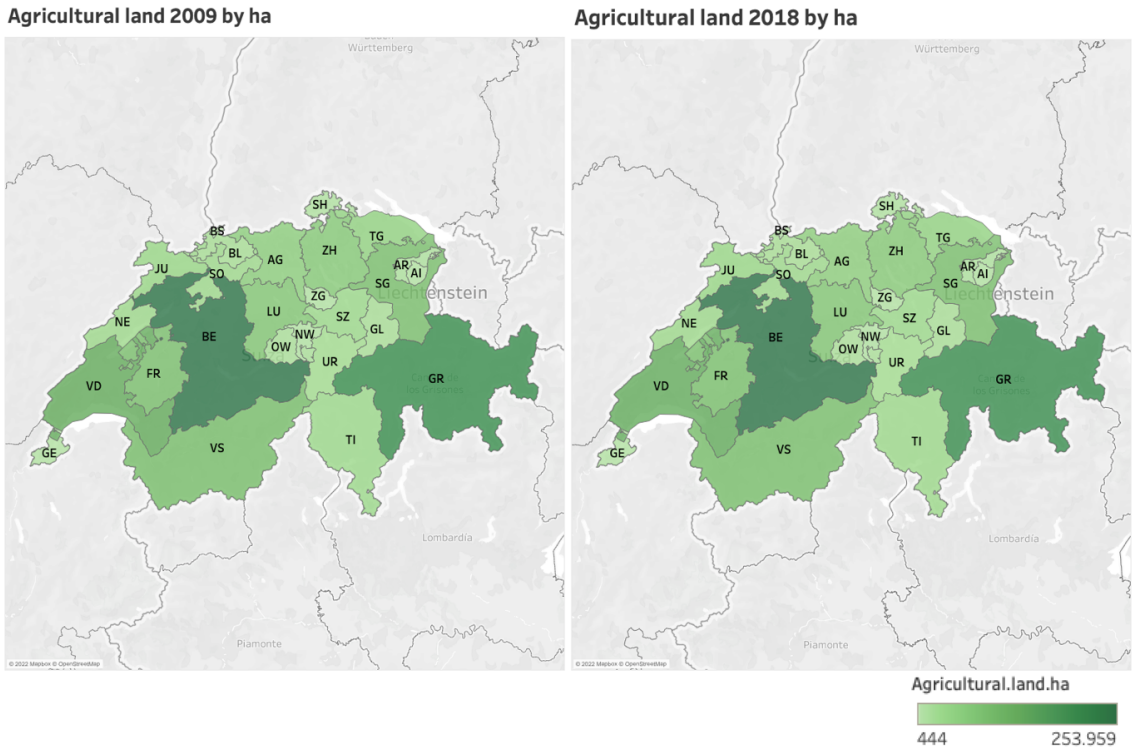


Figure 7 - Agricultural Land 2009 vs 2018 by % (Switzerland)

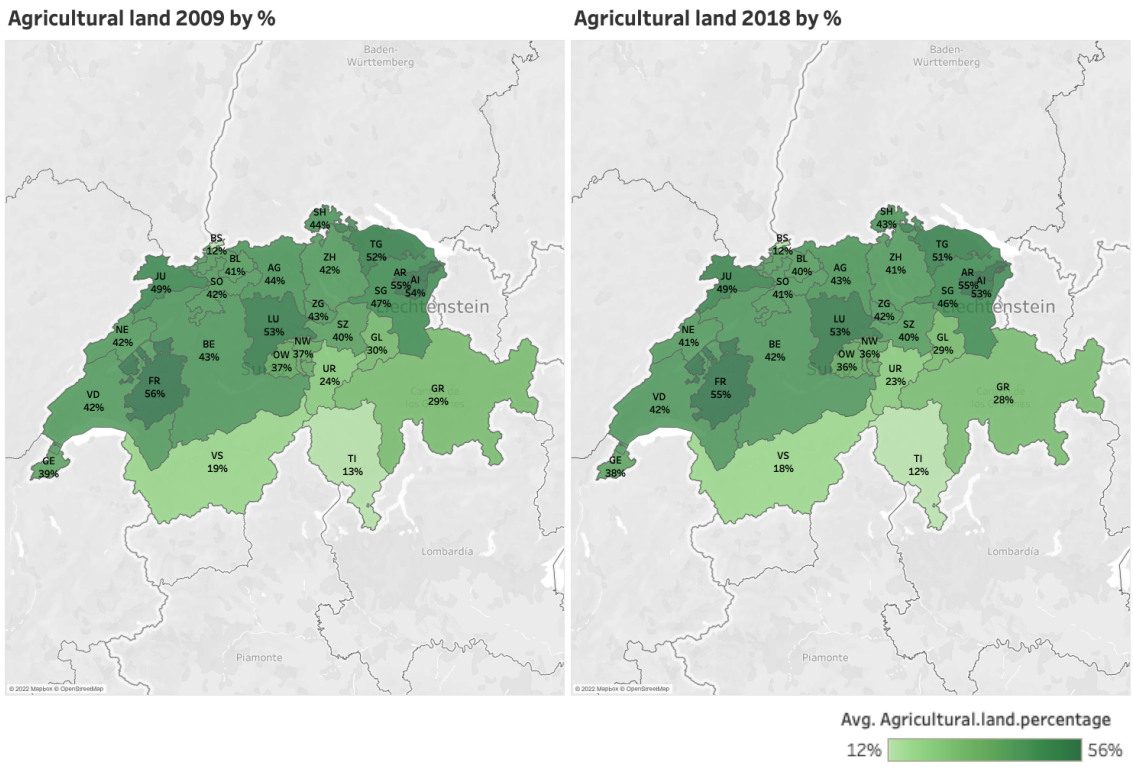


Figure 8 - Evolution of Agricultural Land 2009-2018 by % (Switzerland)

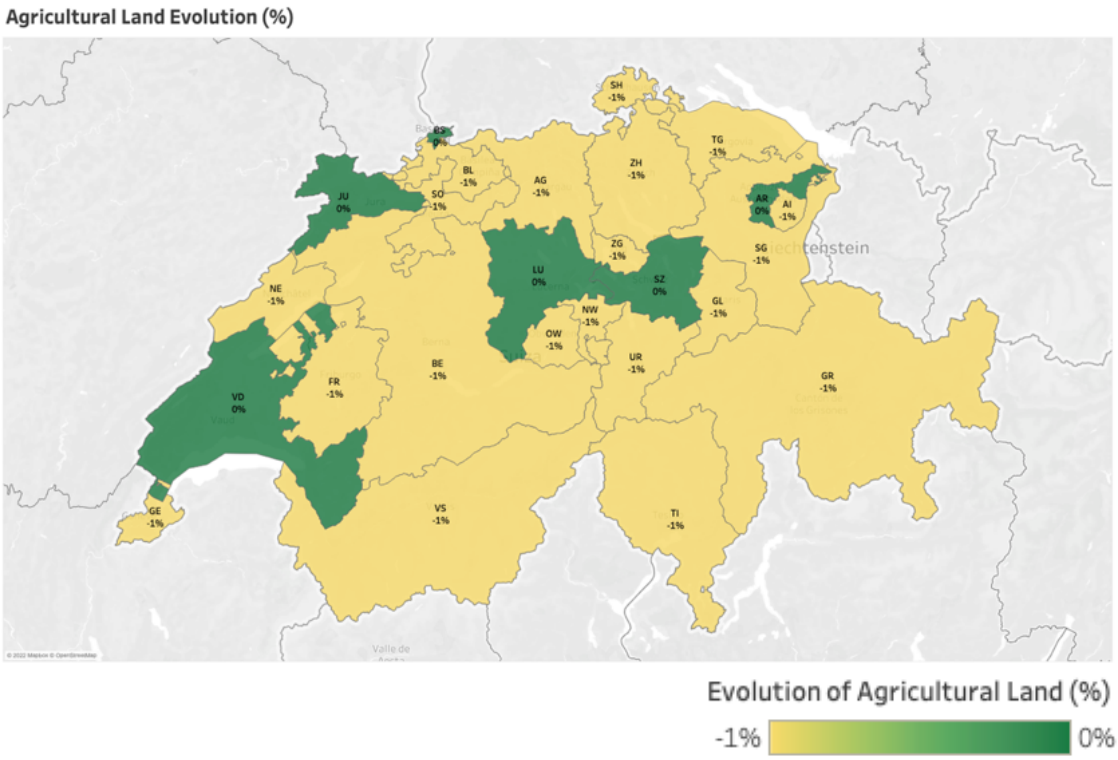


Figure 9 - Urbanization 2009 vs 2018 by % (Switzerland)

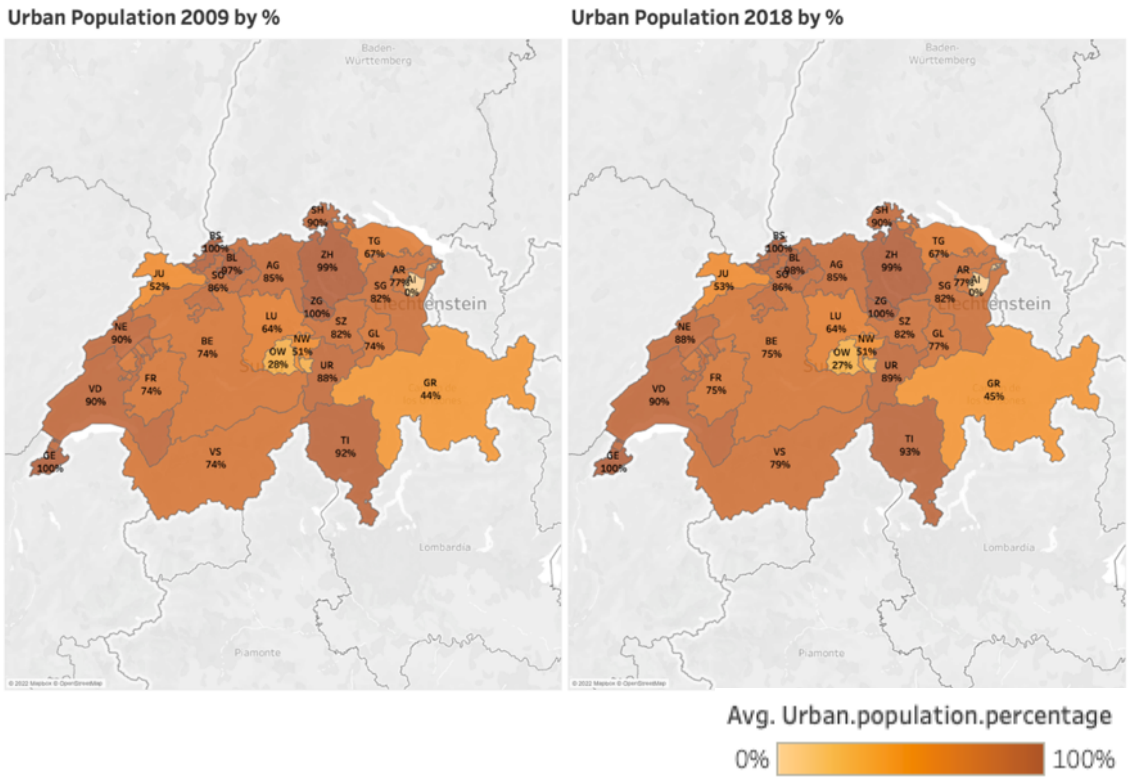


Figure 10 - Urban Population 2009-2018 by % (Switzerland)

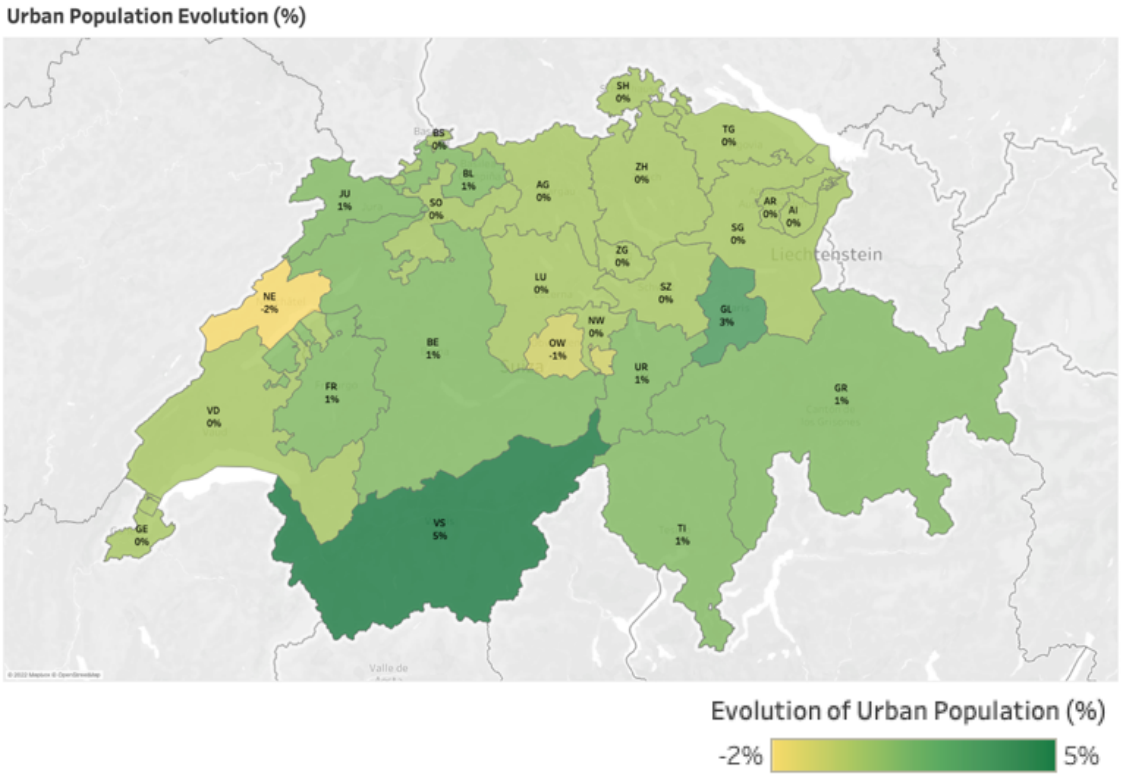
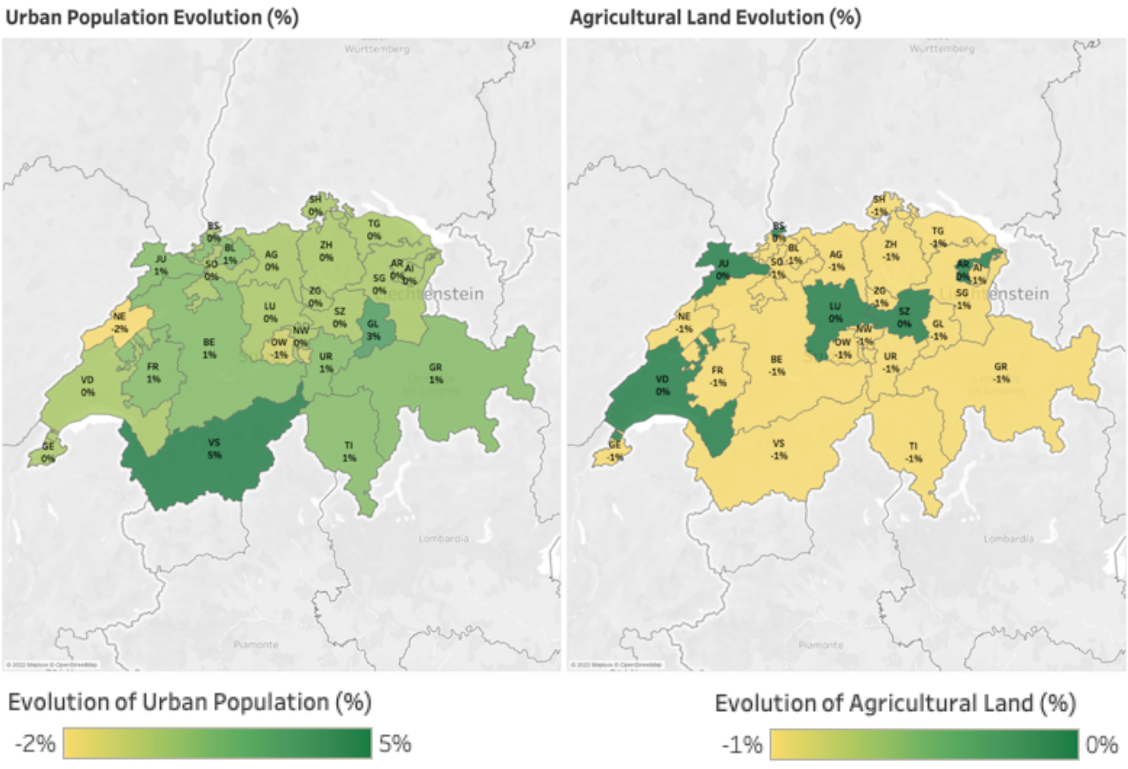
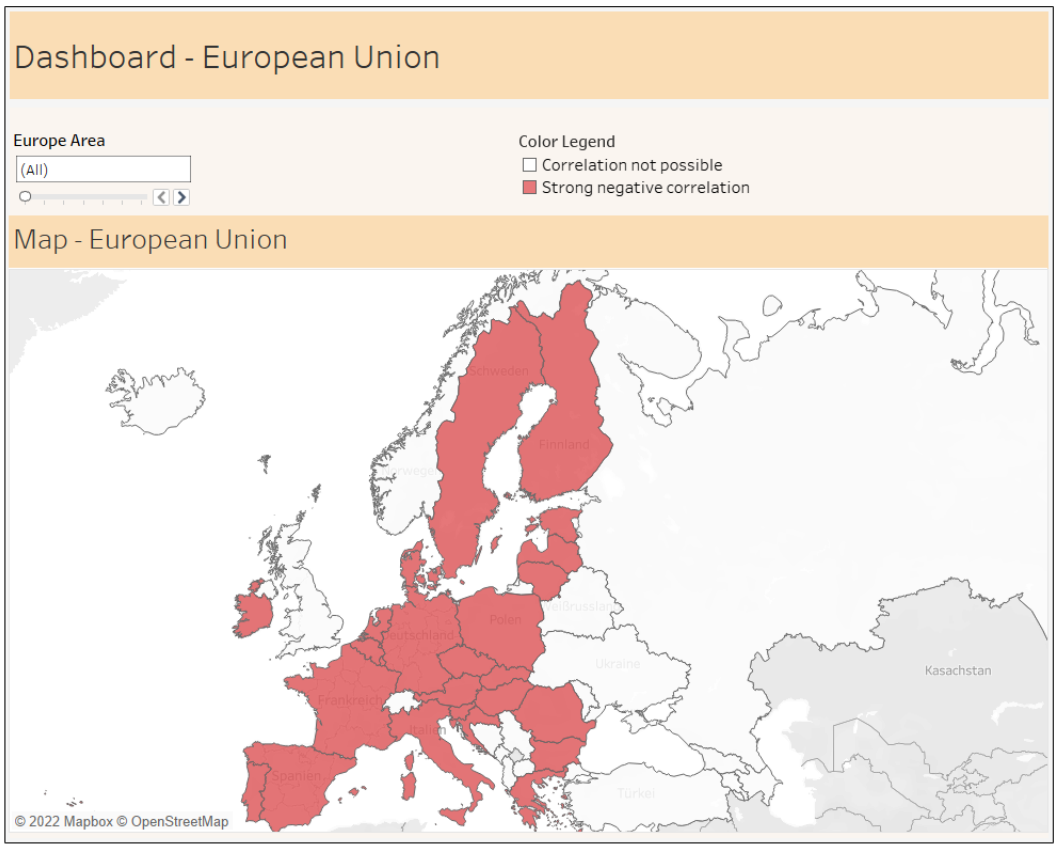


Figure 11 – Evolution of Urban Population and Agricultural Land 2009-2018 by % (Switzerland)



APPENDIX B

Additional Visualisation and Maps



For the states in the European Union the overall relationship between Urbanisation and Agricultural Land is strong negative.

APPENDIX C

METADATA

Southern Europe	Albania
Southern Europe	Andorra
Western Europe	Austria
Eastern Europe	Belarus
Western Europe	Belgium
Southern Europe	Bosnia and Herzegovina
Eastern Europe	Bulgaria
Southern Europe	Croatia
Eastern Europe	Czechia
Northern Europe	Denmark
Northern Europe	Estonia
Northern Europe	Faroe Islands
Northern Europe	Finland
Western Europe	France
Western Europe	Germany
Southern Europe	Greece
Eastern Europe	Hungary
Northern Europe	Iceland
Northern Europe	Ireland
Southern Europe	Italy
Northern Europe	Latvia
Western Europe	Liechtenstein
Northern Europe	Lithuania
Western Europe	Luxembourg
Southern Europe	Malta
Western Europe	Monaco

Southern Europe	Montenegro
Western Europe	Netherlands
Southern Europe	North Macedonia
Northern Europe	Norway
Eastern Europe	Poland
Southern Europe	Portugal
Eastern Europe	Republic of Moldova
Eastern Europe	Romania
Eastern Europe	Russian Federation
Southern Europe	San Marino
Southern Europe	Serbia
Eastern Europe	Slovakia
Southern Europe	Slovenia
Southern Europe	Spain
Northern Europe	Sweden
Western Europe	Switzerland
Eastern Europe	Ukraine
Northern Europe	United Kingdom of Great Britain and Northern