Feeding the City: A Foodshed Analysis for Freiburg

University College Freiburg: Geographic Information Systems

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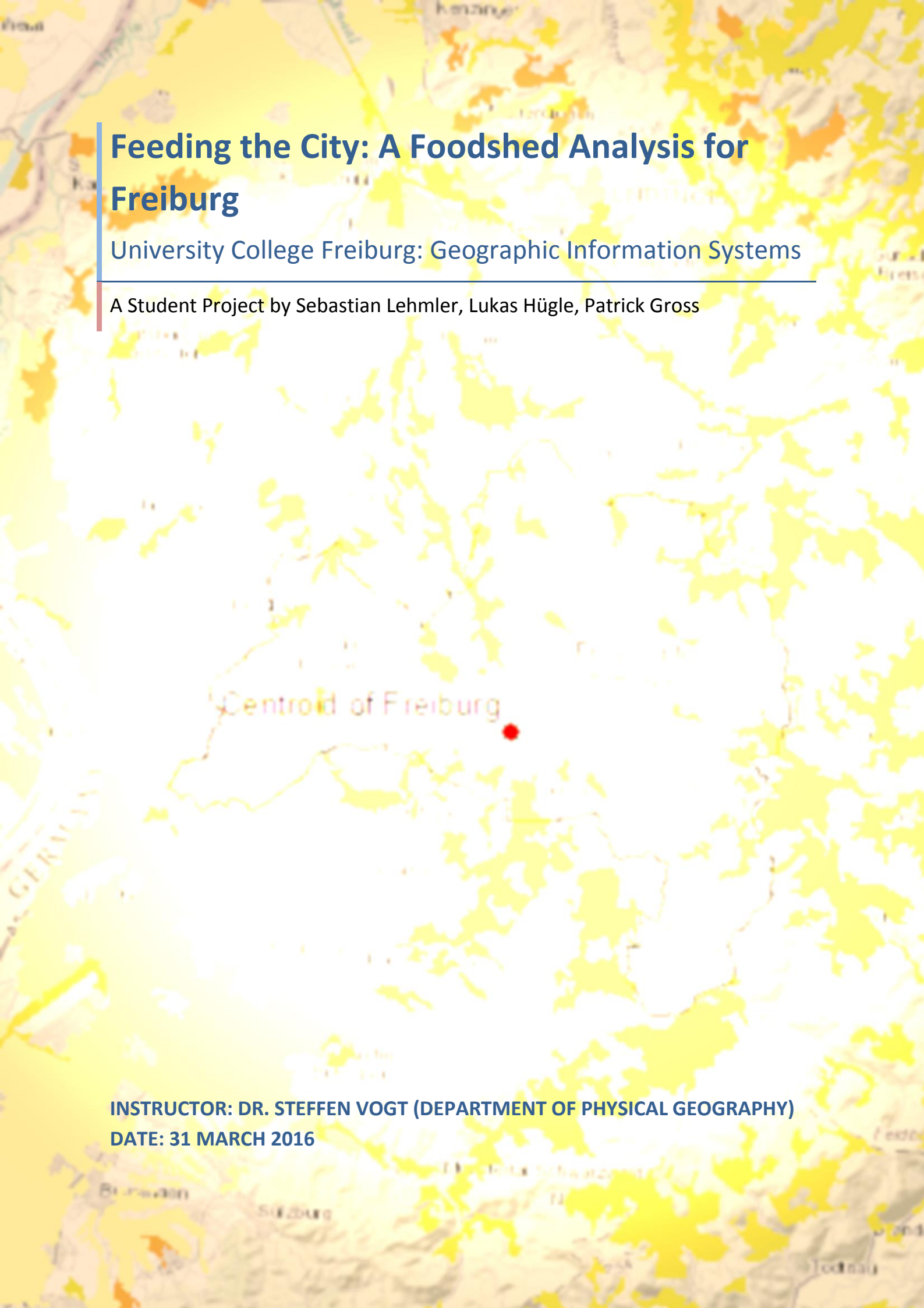

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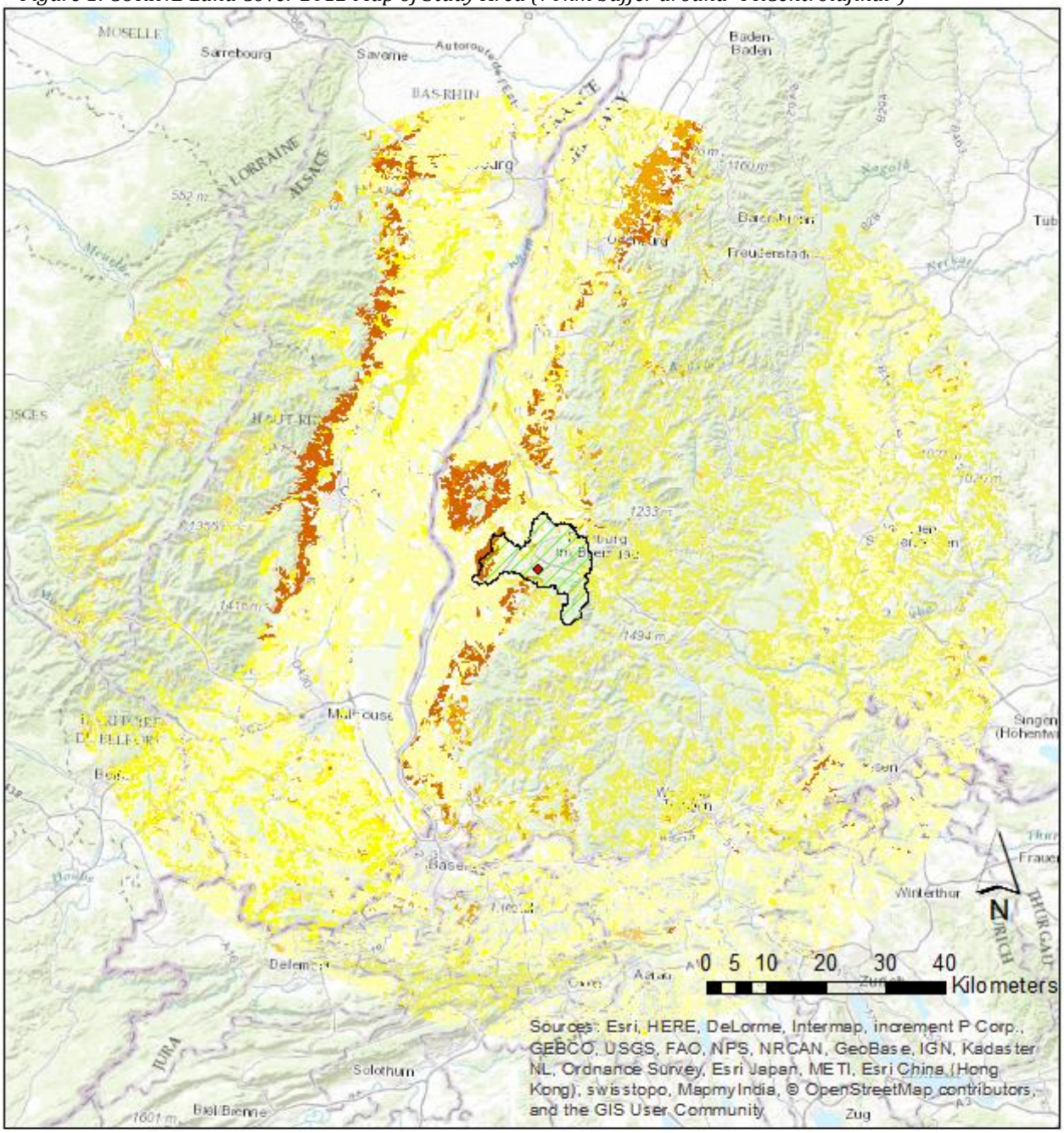
1. Introduction

Global food trade has endowed us with food diversity. We can buy almost any given food at any given time of the year, be it for instance scampi from Latin America, kiwi fruits from Australia, or sushi algae from Asia. Yet, long-distance transportation can have detrimental impacts on the environment as it requires the use of pesticides, the exploitation of fossil fuels, and the large-scale emission of greenhouse gases.

Creating more regional foodsheds is a possible strategy to confront these problems. A foodshed is the amount of land necessary to satisfy a population's food needs (Bowen, Martin, & Schuble, 2009). Besides limiting adverse environmental impacts, they establish more direct bonds between producers and consumers within the region. This increases accountability along the food supply chain (Fox, 1992). Promoting regional food systems requires data on regional resources, land use, and transportation networks. Based on this, extension and carrying capacity of a potential regional foodshed can be estimated. A research team at the University of Chicago employed geospatial analysis to calculate resource potential for promoting more regional agricultural activity around Chicago's urban area (Bowen, Martin, & Schuble, 2009). Drawing on their methodological approach, this project aims to map the potential land requirements for a regional food supply of Freiburg.

We deem Freiburg appropriate for such an undertaking, as it sets optimal preconditions to a successful role model for further promotion of a regionalization of food systems. The city is surrounded by much agricultural production and disposes of a large eco-minded consumer group. We therefore do not only focus on regionalization, but also build our model based on the advantages of purely organic food production (Fox, 1992; Badgley et al., 2007). First, we outline the methods applied for the analysis, and second, present our findings. Third, we discuss our results.

Figure 1: CORINE Land Cover 2012 Map of Study Area (70km buffer around "FRCentroidfinal")



Legend

Freiburg Urban Area (incl. Gundelfingen & Merzhausen)

Freiburg Urban Area Centroid

CLC Classification Agricultural Areas

211: Non-irrigated arable land

221: Vineyards

222: Fruit trees and berry plantations

231: Pastures

242: Complex cultivation patterns

243: Land principally occupied by agriculture, with significant areas of natural vegetation

2. Methodology

2.1. Task description

Our project is to assess the **land requirements for a regionalized and organic food supply** of Freiburg. There are manifold ways to approach this task. We decided to adopt the methodological approach from the Chicago research team (Bowen, Martin, & Schuble, 2009) and to adjust it to the scope of our project.

The concept of the foodshed encompasses the amount of land required to feed the population in a particular area. In the Chicago model, the foodshed is calculated on the basis of three variables: (i) the amount of food required by an individual, (ii) the total population to be fed, and (iii) the amount of available land needed for the food production.

2.2. Factors included in the analysis and underlying assumptions

The data we chose for each of these factors entail a number of assumptions which go into our model.

First, to determine the **amount of arable land** a single person requires for an organic diet we used an **average** estimated by Wakamiya (2011). Specifically, Wakamiya (2011) uses the yearly consumption of different foodstuffs (in kg) and calculates the area needed for their production. This area amounts to **2523 m²** needed to generate enough organic food to nourish an average German citizen for one year. In our model, each person is therefore assumed to require the same amount of food, respectively land for food production. The estimate includes the areal need for the production of: Grain, Vegetables & Potatoes, Fruit, Pork, Beef, Chicken, Eggs and Dairy products (Wakamiya, 2011).

Second, in order to account for the **population of Freiburg's entire urban area**, we chose to include the neighboring municipalities Merzhausen and Gundelfingen as they also belong to the continuous urban fabric in the area.

Third, we used CORINE land cover (CLC) classification for our assessment of **available arable land**. All land classified as "agricultural areas" (code_12: 2xx) was considered suitable for food production. In fact, many variables other than land use could potentially be considered as indicators for available arable land. Agricultural areas according to CLC, however, provide a first useful indicator for two reasons. First, land use data is categorized consistently. Second, relying on this one consistent variable keeps our model manageable within the scope of this project. The Minimum Mapping Unit (MMU) for CLC is 25 hectares for areal phenomena and 100 meter for linear phenomena. Despite this fairly large MMU, we decided on CLC data for its consistent land use classification across national borders in case Freiburg's foodshed would reach into France and or Switzerland. Furthermore, we excluded vineyards from the agricultural areas analysis for three reasons: Viniculture has an exceptional role within our study area (Appendix *Figure 5*), it adds little nutritional value to people's diet, and it is unlikely to make room for regional food production in the foreseeable future.

2.3. Data Preparation: Building a File Database

The first step was to create an ESRI geodatabase consisting of the layers required for our analysis. The files listed in tables 1 and 2 were used to create the foodshed maps.

Table 1: Layers and sources of shapefiles used in data preparation

Data Layer	Files / Supplier	Retrieved from
CLC Agricultural Areas	"CORINE Land Cover 2012" European seamless vector database (ESRI) v18.4 *Copernicus Land Monitoring Services*	http://land.copernicus.eu/pan-european/corine-land-cover/clc-2012
Municipalities Freiburg urban area (incl. Merzhausen & Gundelfingen)	"Administrative boundaries" Open Data - Vector data by *Landesamt für Geoinformation und Landentwicklung (LGL)*	https://www.lgl-bw.de/lgl-internet/opencms/de/07_Produkte_und_Dienstleistungen/Open_Data_Initiative/index.html#Verwaltungsgrenzen

Table 2: Statistical data and sources used in data preparation

Statistical Data	Files / Supplier	Retrieved from
Total population per municipality [225,582 inhabitants]	„Census Data Table" *Statistisches Landesamt B.W.*	http://www.statistik.baden-wuerttemberg.de/SRDB/?E=GS
Land requirements per person [2522.9 m^2/ inhabitant]	Wakamiya (2011)	http://www.lel-bw.de/pb/site/lel/get/documents/MLR.LEL/PB5Documents/lel/pdf/w/Wie%20viel%20Fl%C3%A4che%20braucht%20ein%20Mensch%20um%20sich%20zu%20ern%C3%A4hren%20-%20Wakamiya.pdf

2.4. Data processing

On the basis of this data, we undertook the following analytical steps:

1) **Creating relevant Freiburg urban area including its population:** First, we joined the census data table with the administrative boundaries layer. Then, we dissolved the administrative boundaries of Freiburg im Breisgau, Merzhausen, and Gundelfingen and merged them into one feature. The respective layer "Freiburg3Gunitedpro" now contains the total population to be fed by the foodshed.

2) **Creating Freiburg urban area centroid:** Using the "Freiburg3Gunitedpro"-layer we created a new layer: "FRCentroidfinal."

3) **Creating CLC area of interest:** Next we created a 70 km buffer around the centroid of Freiburg. Then we extracted the CLC data within this buffer using the clip tool.

4) **Creating CLC study areas of arable land (in- & excluding vineyards):** First, we deleted all features classified other than agricultural from the CLC layer. Then we erased all non-agricultural and all non-occurring agricultural (code_12: 212; 213; 223: 241; 244) labels from the symbology of the layer. On the basis of this "CLC_AgriAreas"-layer we created one layer only containing the vineyards ("CLC_Vineyards"), and a second one excluding the vineyards ("CLC_AgriAreas_woVY").

5) **Calculating the total amount of arable land necessary:** In the attribute table of the "Freiburg3Gunitedpro"-layer we created a new column "SUM_Flächenbedarf" for the total amount of required arable land. Using the field calculator and per capita land requirements as provided by Wakamiya (2011), we calculated the total amount of required arable land for the population of Freiburg: 569,120,828 m^2.

6) **Building model to determine foodshed and iterate execution of model (Figure 2):**
   a) **Create buffers with varying ranges:** The model iterates over a given start and ending value for the range of the buffer by a given value. In the first trial, we chose 15,000m for the lower and 25,000m for the upper bound and let the model create buffers in increments of 1,000m.
   b) **Clip agricultural areas within respective buffers:** The model deploys respective buffers to create new features from the "CLC_AgriAreas_woVY"-layer. These polygons contain varying amounts of available arable land.
   c) **Calculate amount of arable land within each polygon:** Using the summary statistics tool, the model calculates the amount of available arable land within the polygon and creates a host of

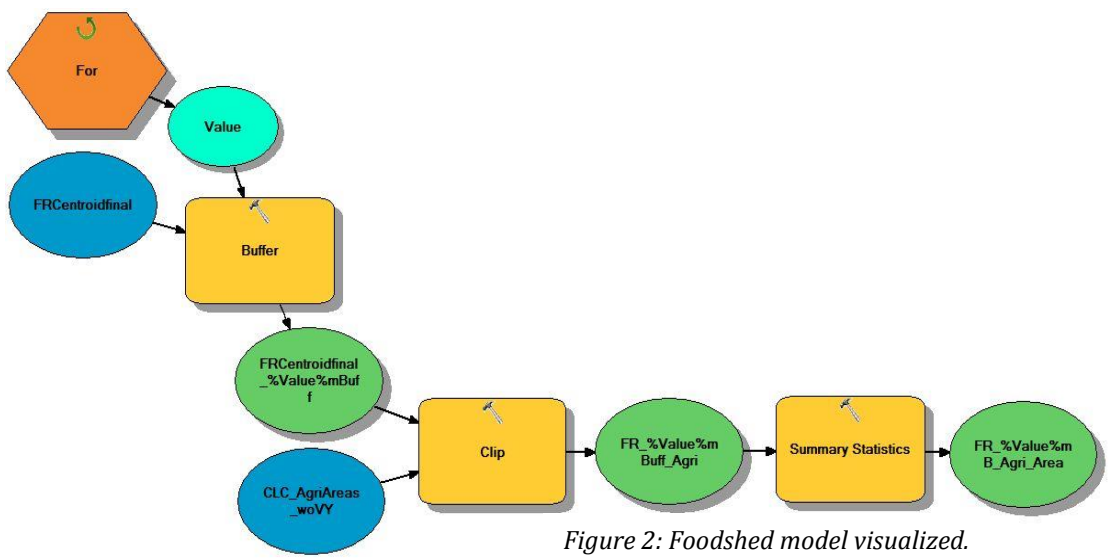


Figure 2: Foodshed model visualized.

tables "FR_%Value%mB_AgriAreas" supplying this information.

d) **Manually select value closest to the amount of arable land required:** After the first run of the model, we compared the values in the tables to the 569,120,828 m^2 of arable land required to feed Freiburg.

e) **Narrow down buffer ranges and re-run model:** In order to render our search more precise, we ran the model three times. Each time we adjusted upper and lower bound and chose smaller increments for the buffers to be created. The two values closest to our sought value of arable land would provide the new upper and, respectively, lower bound.

   i) **First trial:** 15,000m to 25,000m in increments of 1,000m

   ii) **Second trial:** 21,000m to 22,000m in increments of 100m

   iii) **Final trial:** 21,600m to 21,700m in increments of 10m.

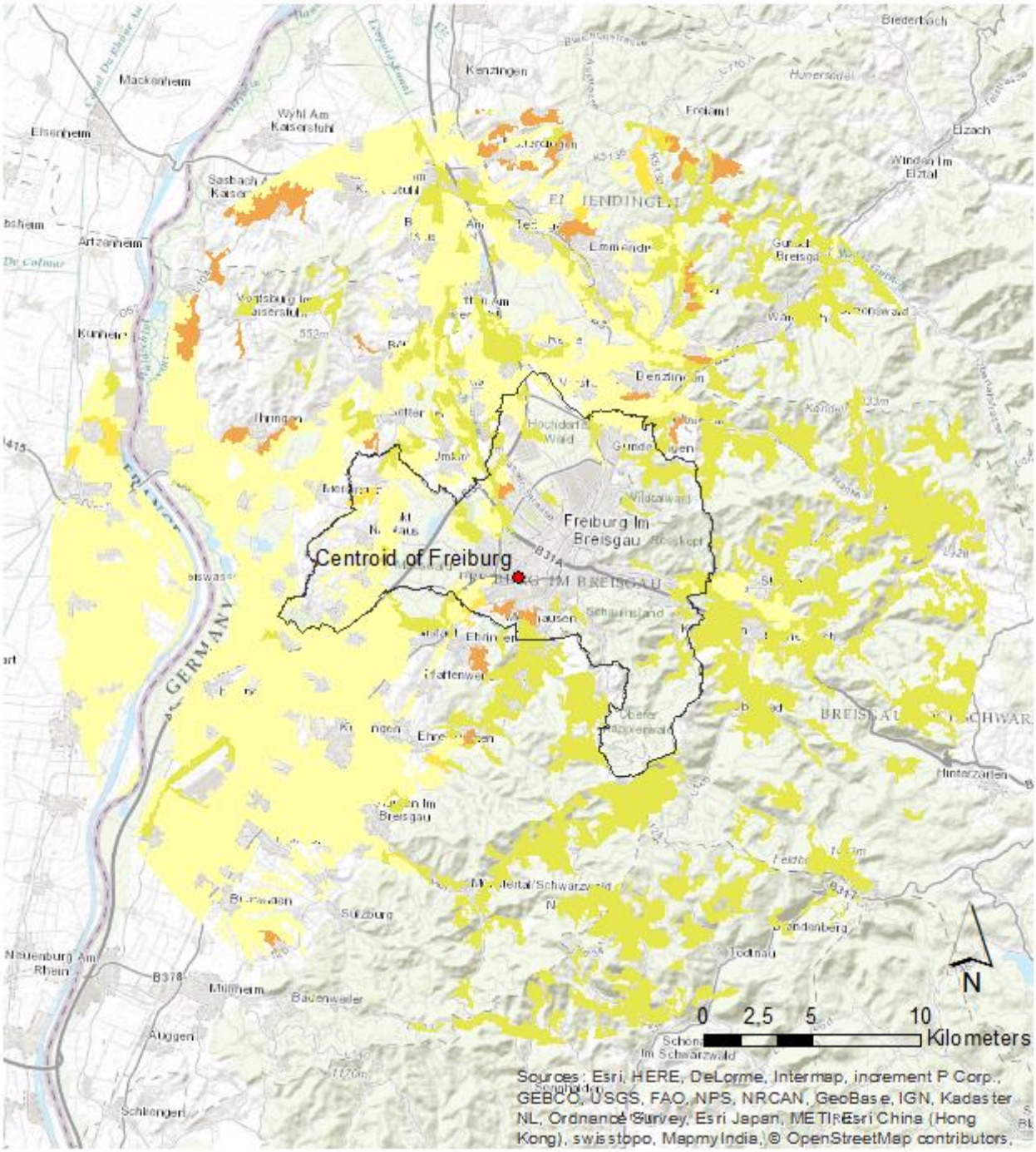
3. Results & Analysis

With the help of the model outlined above, we identified a circular area around the centroid of Freiburg that contains a sufficient amount of arable land to nourish the whole urban population. More specifically, there are 225,582 inhabitants in Freiburg of whom, according to our model, each needs 2522.9 m^2 of arable land to be nourished for one year. The area has a radius of 21.63 km in which 569,120,828 m^2 of arable land are contained.

Figure 3 shows the estimated foodshed and the amounts of different types of arable land contained within the foodshed. It stands out that the two most widespread types of arable land are "non-irrigated arable land" and "pastures". Whereas "non-irrigated arable land" is mainly found west of Freiburg in the Kaiserstuhl region, "pastures" are concentrated east of Freiburg in the southern Schwarzwald area. The two land types are followed by occasional occurrences of "Fruit trees and berry plantations" and very few areas with "Complex cultivation patterns." According to Wakamiya (2011), the largest amount of land needed for an organic diet would be non-irrigated arable land (primarily for vegetables and pork), followed by a significantly smaller amount of pastures (primarily for dairy products and beef). We can see that those land use types, are also the most common ones in our identified foodshed. In order to comply with the needs suggested by Wakamiya (2011), however, the ratio would have to be transformed towards more non-irrigated arable land at the expense of pastures.

In summary, the estimated foodshed points to the fact that, whilst deploying organic practices, the 225,586 citizens of Freiburg could be nourished for one year with the amount of arable land contained in an area of about 22 km around the city. Considering land types within our foodshed, the two most common types would principally match those required for producing the foodstuffs in the model. Thus, adjusting the ratio of land types in our Freiburg foodshed could lead to establishing a regionalized food supply.

Figure 3: Foodshed of Freiburg: Types of arable land



Legend

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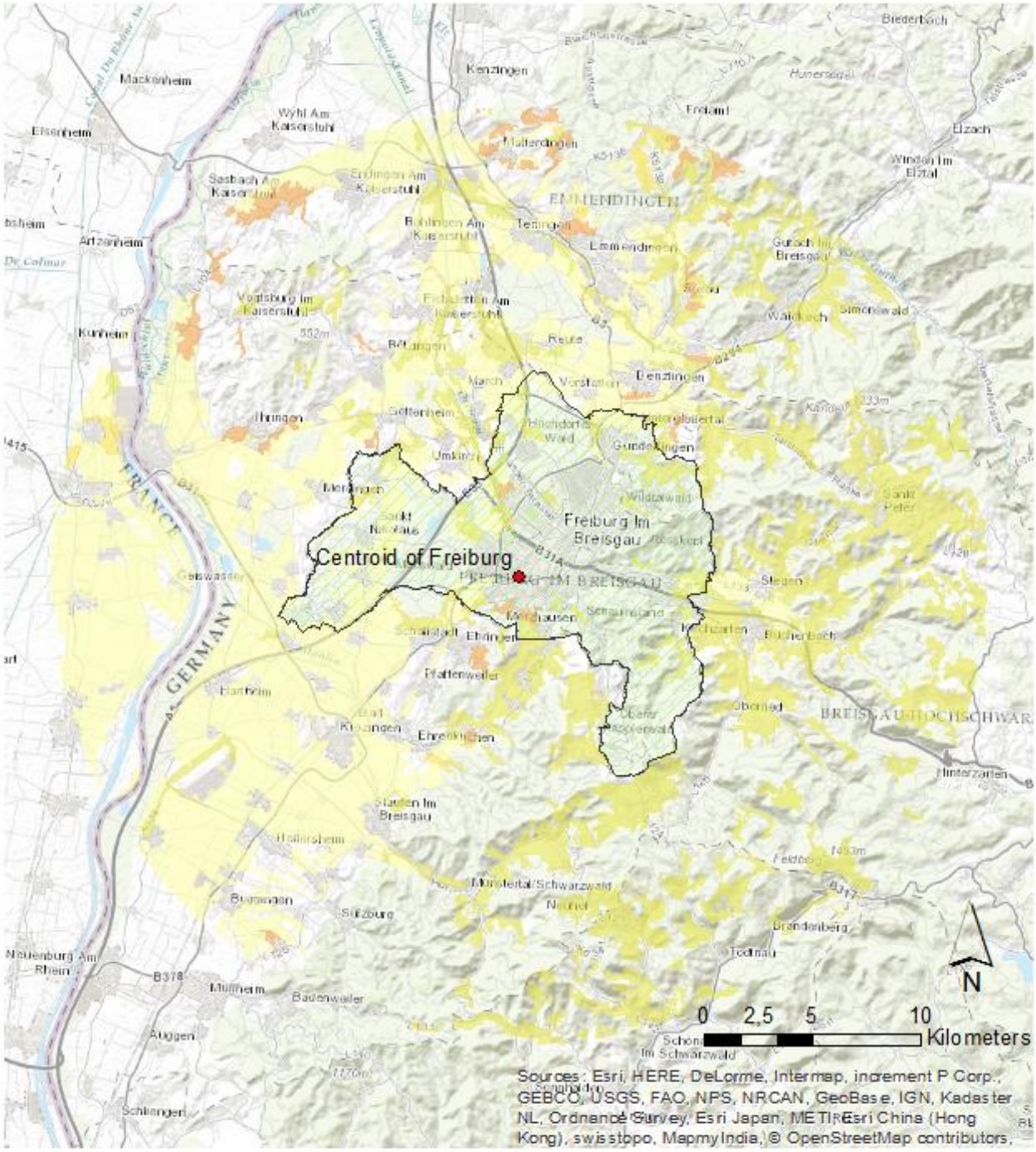
Figure 4: Foodshed of Freiburg: Types of arable land and topography



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4. Discussion

Our analysis has shown that a foodshed of 21.63 km radius could suffice to supply the population of Freiburg with organic foodstuff. Yet, we could have both, over- or underestimated the range of the foodshed. Various shortcomings limit the informative value of our finding and could be refined in future analysis.

Three dietary assumptions might influence the empirical accuracy of our results. **First**, our model assumes **all people in Freiburg to consume meat**. Yet, according to Statista data (2015), almost 10% of Freiburg's population advocates a vegetarian diet. Vegetarian diet matters for our model, given that vegetarian agriculture requires between four and ten times less arable land than meat production to produce the same amount of calories (Tilman et al., 2002). **Second**, the model presumes all people in Freiburg need **the same amount of food as an average citizen in Germany** according to Wakamiya (2011). The city's inhabitants, however, have a comparably low age with 3,5 years below the national mean value (Statistisches Landesamt Baden-Württemberg, 2016). Since younger populations tend to have more children, they can be expected to consume less food and hence require less arable land. **Third**, our **calculations are based on organic food consumption**. While this assumption cannot hold for all people in Freiburg, it proves particularly problematic as, on average, organic agriculture yields much lower crops than conventional agriculture per square meter (Harper & Makatouni, 2002). In short, these three dietary assumptions are simplifications that might render our results inaccurate. To build stronger hypotheses, a refinement of the model should thus better account for the specific dietary characteristics of Freiburg's population.

In addition to these constraints, we present three methodological considerations to improve our model. **First**, **another dataset could be used**. We used CORINE dataset since it covers the entire European land area with consistent land use categorizations and thus allows for an analysis across national borders. Yet, with 25 ha for aerial phenomena, the CORINE dataset has a comparably large MMU, which might hinder detailed analysis of land use capacities especially in urban or sub-urban areas. The ATKIS (Amtlich Topographisch-Kartografisches Informationssystem) model could provide an alternative with a smaller MMU. However, it was unavailable for this student project and is limited to the administrative boundaries of Germany. **Second**, **more data could be included**. We exclusively used CORINE data due to the limited scope of this project in terms of time and resources. This focus renders our model fairly abstract. For example, it is unclear in how far the detected foodshed and its land use types (e.g. pastures) can actually yield the different types of foodstuff required. More data, for instance on soil types and fertility, the local climate, land ownership, etc. could add information to CORINE land use data and hence allow us to determine the actual yield potential of the arable land. Moreover, our model detects the potential arable land based on geographic proximity - not on actual accessibility. It could thus be fruitful to include data on transportation routes (e.g. streets, railway). In fact, we included OSM (OpenStreetMap) data, but failed to create a functional network data set. Due to time constraints, we did not pursue this technical challenge any further. *Figure 4* highlights topography within the foodshed. The map indicates that accessibility in terms of topographical conditions may also be a relevant factor in determining the most effective foodshed.

Third, the **iterative process of our foodshed model could be automatized**. We, for instance, manually selected the two values closest to the amount of arable land required to narrow down the buffer ranges and rerun the model. An automatization of this process would enhance transferability by allowing for easier adaptation of the model to different regions and cities. This, in turn, facilitates usability and hence increases the potential to provide our model as "open source technology" for further promotion of regional agriculture.

Apparently, there are various shortcomings which render our results imprecise. Still, our findings are relevant in many ways. They can serve as a starting point for building more intensive and extensive models. Moreover, they reveal where the potential for agricultural transformation lies geographically. In addition, our results can function as a baseline measure for policy designs aiming at regionalization of food supply. Ultimately, they can detect future areas of research, which for instance need to assess the realistic applicability of a politically-induced regionalization of agriculture with respect to other factors, such as landowner participation and economic feasibility.

5. Conclusion

This study project aimed to assess what a regionalized and organic food system might imply in terms of land requirements for Freiburg and its surroundings. The establishment of such a foodshed may present a possible strategy to confront the adverse environmental effects resulting from a globalized food supply system (Fox, 1992; Badgley et al., 2007). Drawing on the methodology of a similar analysis conducted in Chicago (Bowen et al., 2009), we designed a GIS-based model that involves calculating a circular area around Freiburg. Considering the favorable conditions Freiburg provides for establishing such a regionalized food supply, we constrained our study area to a buffer of 70 km around the city centroid. We found that a foodshed with a 21.63 km radius could suffice to nourish Freiburg's population. In fact, closer analysis has shown that the land types occurring in our foodshed may be capable of producing the specific foodstuffs required. Still, our model is considerably abstract and we could have both over- or underestimated the range of the foodshed. Our set of dietary assumptions and methodological simplifications limit the explanatory power of our findings. Yet, we succeeded in creating a first preliminary foodshed for a regionalized and organic food supply of Freiburg. Our results prove relevant in many aspects: besides serving as a basis for more intensive and extensive analysis, they can serve as a baseline measure for policy designs and help to detect future areas of research. In short, this study project has contributed to better understand the potential for a more sustainable food supply of Freiburg.

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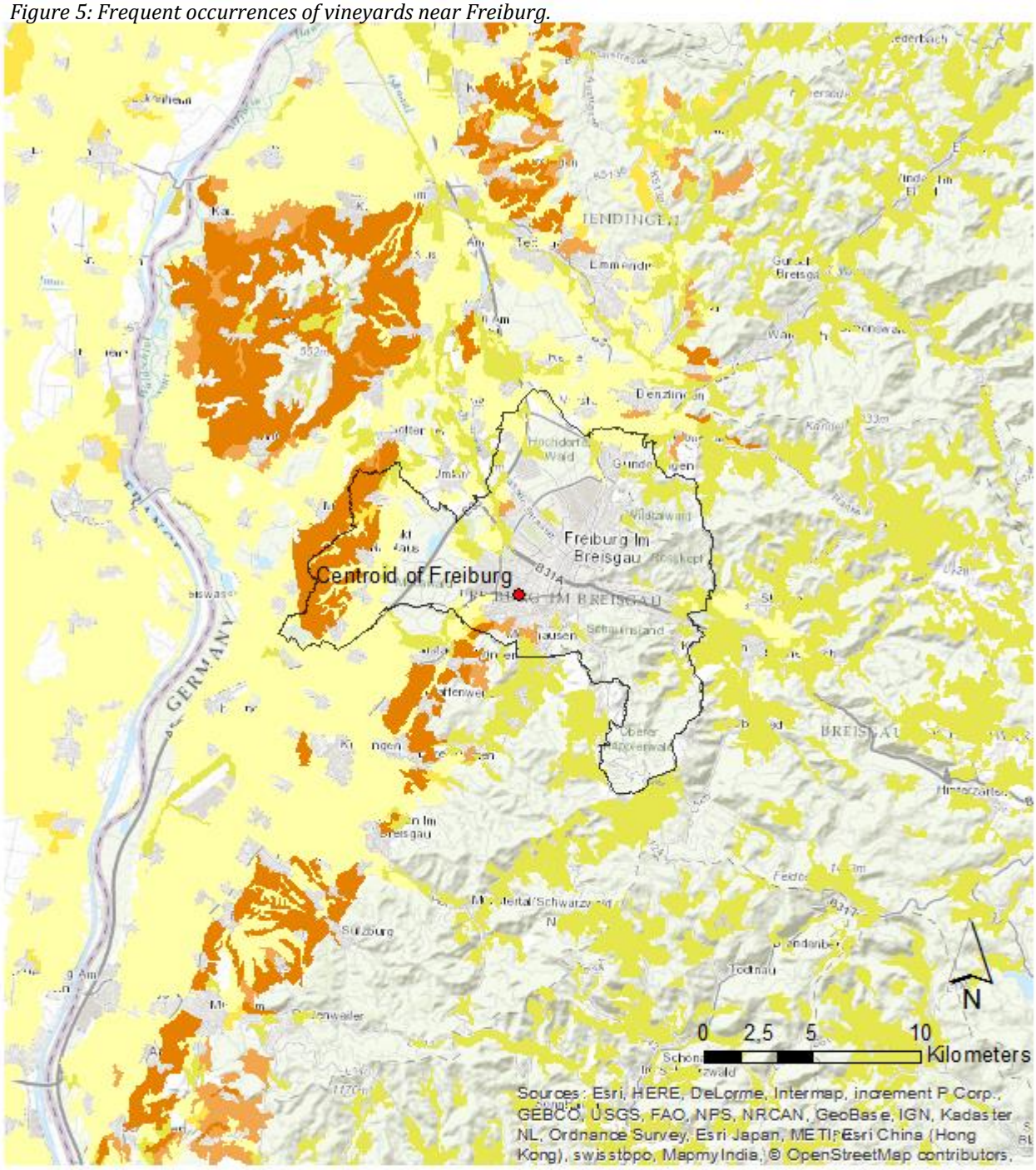
Appendix:

Figure 5: Frequent occurrences of vineyards near Freiburg.



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