

Supermarket and discounter accessibility in rural Germany—identifying food deserts using a GIS accessibility model

Stefan Neumeier^{a,*}, Matthias Kokorsch^b

^a Thünen-Institut für Ländliche Räume, Bundesallee 64, 38116, Braunschweig, Germany

^b The University Centre of the Westfjords, Suðurgata 12, 400, Ísafjörður, Iceland



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ABSTRACT

A spatial concentration of basic services can be observed in many European regions. This concentration is a result of the interaction between socio-economic and demographic processes. Rural regions in Germany are particularly affected by concentration processes and the thinning-out of services. Even though this topic is covered and debated in media, among policy makers and regional scientists, few reliable data exist on the dimensions and consequences of these processes. Food retailing is one subject area wherein a spatial concentration can be observed and its consequences have a direct impact. Different aspects of the spatial concentration processes in food retailing are the core of this article, which aims to address the following questions: Can spatial food deserts (regions with limited access to affordable and nutritious food) be identified in rural Germany, and, if yes, which part of the population seems to be particularly affected by insufficient access to food? Food deserts are approached at the macro level utilising a distance-based concept building on a GIS accessibility model. Thus, the focus is on the analysis of the potential general spatial existence of food deserts, not on individual consumer perspectives, behaviours, capabilities, or consequences. The results of the analysis reveal that in Germany, transportation availability is a decisive factor determining if one lives in a food desert or not. Furthermore, living in a food desert is more of an individual experience that depends on individual living conditions and capabilities than a spatial distinct phenomenon. However, as the accessibility to food retail stores is comparatively worse in connected parts of Mecklenburg-West Pomerania, Brandenburg, Rhineland-Palatinate and the north of Saxony-Anhalt, less mobile people living in these areas are more likely to experience food desert.

1. Introduction

The current economic and demographic development in Germany (population decline in many rural regions, ageing population) emerges with fundamental social changes (Weishaupt, 2015; Järvinen et al., 2014). Examples are decreasing traditional ties, individualisation, cultural segregation and augmentation of cultural diversity, and economically motivated migration (Bundesregierung, 2011; Deutscher Kulturrat, 2010; Deutscher Städtetag, 2006 quoted according to Järvinen et al., 2014). These developments pose challenges to policy makers and regional planners. This particularly affects the policy fields of settlement and infrastructure, economics and labour markets, family, education and migration.

An aggravating factor is that no pattern can be identified regarding regional consequences of the socio-economic and demographic change; some (rural) regions are more affected than others (Järvinen et al.,

2014). Regions that profit from the changes and those that experience its disadvantages are scattered across the country. Such a patchwork complicates the development of solutions and policy instruments for responding to local socio-demographic changes. Since no one-size-fits-all solution can be found, concepts specifically adjusted to the particular regional problems are essential (Järvinen et al., 2014). The developments drafted above exert economic pressure on private and public providers of basic services. These might set a downward spiral in motion: The spatial concentration of basic services leads to a gradual abandonment of unprofitable locations (Higgs and White, 1997). Subsequently, this leads to a decrease in the attractiveness of the regions, which then might result in further or accelerated out-migration processes (Specht et al., 2013).

At the European level, these aspects are addressed within the ‘territorial cohesion’ policy where the main objective is an equal distribution of resources and services throughout the European regions (Clifton et al.,

* Corresponding author.

E-mail addresses: stefan.neumeier@thuenen.de (S. Neumeier), matthias@uw.is (M. Kokorsch).

2016; Neumeier, 2016; European Commission 2014). In Germany, the distinctive discourse on 'Daseinsvorsorge' (basic services) aims at the providing appropriate access to a sufficient offering of goods and services indispensable for life. This discourse is rooted in the general political objective to ensure 'Gleichwertige Lebensverhältnisse' (comparable living conditions) in all regions of Germany, legally stipulated in 1965 in § 2 of the Federal Regional Planning Act of Germany (Neumeier 2016; Bundesinstitut für Bau-, Stadt-und Raumforschung, 2015; Einig, 2008).

Although a debate that addresses the adverse effects of spatial concentration of basic services and its consequences is observed in the public and scientific discourses, surprisingly few reliable data exist on the dimension and consequences of these processes (Burgdorf et al., 2015; Küpper and Eberhardt 2012).

Due to a lack of necessary data, such discourses are mainly based on personal experiences, hearsay and portrayal in the media. However, detailed knowledge about the spatial distribution and accessibility of basic services is essential for politicians, planners, and scientists to identify and differentiate regions where political intervention might be appropriate. In Germany, one subject area where a spatial concentration can be observed and where its consequences have a direct effect on the people is food retailing (Neumeier, 2014; Küpper and Eberhardt, 2013a).

Two different strands of argumentation can be identified regarding the provision and access to food. First is the European discourse on 'territorial cohesion', as well as the specific German discourse on 'Daseinsvorsorge', which focuses on basic services per se – that is, all services indispensable for life (although different views exist among politicians and scientists on which services qualify as basic services; see for example Steinführer (2015)). Within this discourse, access to retail stores is one of the many basic services considered. Second is a specific discourse on food access that is embedded in an overall discourse on social inequality, mainly led in Anglo-Saxon countries. Here, the focus is on aspects of race and ethnicity as well as income disparities (Neumeier, 2015; Walker et al., 2010; Beaulac et al., 2009). Within this food desert discourse, the accessibility of (healthy) food and the consequences of an inadequate food accessibility are addressed.

Against this background, this article addresses three main research questions:

- First, we assess the effects of the ongoing consolidation and spatial concentration in food retailing in relation to the accessibility of food retailers in Germany.
- Second, we address the question whether or not the spatial concentration processes in food retailing led to the formation of regions in Germany that may qualify as food deserts.
- Third, we highlight the question of who is affected by insufficient access to food.

This study focuses on Germany as a whole (not at the meso-level of single communities/regions or the micro-level of the individual) against the background of the recent German discourse on basic services and the European discourse on territorial cohesion. The aim is to provide scientists as well as spatial planners with data about the general accessibility of discounter and supermarkets in Germany near the place of residence. Hence, we base the identification of food deserts on a distance metric (cf. Graßl et al., 2020).

Considerations on differences in the quality of the products as well as individual socio-economic aspects, individual shopping behaviour and preferences or consumer perspectives are not part of the analysis. Such considerations would provide valuable insights regarding individual consequences, coping strategies, etc. of living in a food desert; however, the macro level approach followed here allows to identify regions where access to food might be problematic for greater parts of the population. Regions can be identified where political intervention might be justifiable and necessary.

The theoretical foundation for our research is the linkage of two discourses: The German discourse on basic service accessibility outlined above and the concept of food deserts. Our definition of food deserts follows quantifiable and spatial approaches and is based on the universally applicable definition (Wright et al., 2016) of the United States Department of Agriculture (USDA) from 2015 (see Ver Ploeg et al., 2011; USDA, 2015; Khalil and Mendelson, 2017),¹ namely, if at least 33% of the people living in a community where travel times exceed 15 min (by the selected means of transport), the community is labelled a 'food desert'. Since we consider it overly simplistic to conclude upon reversion, that all other communities provide adequate access to food (Non-Food Deserts), we provide a novel analytical tool and introduce the notion of 'Potentially Perceived Food Desert'. This notion applies to regions in which travel times are below a certain threshold, yet more than 33% of the population experience travel times that are 1.5 times the average travel time of this region type.

Four sections follow the introduction. In the next section (2), we discuss different approaches to food deserts and present key data on German food retail sales. Section 3 provides an explanation of the accessibility model that the analysis is based on, followed by a presentation and discussion of the results (Section 4). The final section summarises the findings and provides conclusions and considerations for future research.

2. Literature review and key data on food retail sales in Germany

2.1. Food deserts

While the term 'food desert' first appeared in the 1990s in a British context, several aspects had been tackled much earlier. Discussions on inequalities, social aspects and disadvantages of rural consumers originated in the 1960s (US) and 1970s (UK) (Shaw, 2006; Wrigley, 2002). Common definitions of food deserts can be located in a triangle of spatial aspects, dietary issues and socio-economic factors and draw in both quantitative and qualitative studies with different academic foundations (see for example, McKey et al., 2020; Russel and Heidkamp, 2011; Beaulac et al., 2009; Shaw 2006).

In this regard, Shaw (2006, p. 241) discusses three main criteria that define food deserts: *ability*, or physical problems influencing the access of food; *assets*, defined as financial constraints; and *attitude*, defined as the state of mind. These criteria were expanded by the same author, adding distance to shops as moderating factors in France (Shaw, 2012a) and the UK (Shaw, 2012b). McEntee and Agyeman (2010, p. 165) define food deserts as '[...] areas of relative exclusion where people experience physical and economic barriers to accessing healthy food'. While providing a good foundation for the discussion of food deserts, it remains somewhat unclear, in quantitative terms, which factors comprise these barriers. For putting the food desert theory into practice, we consider the concise and universally applicable definition (Wright et al., 2016) of the USDA useful. Food deserts are defined as 'parts of the country void of fresh fruit, vegetables and other healthful whole foods, usually found in impoverished areas, largely due to a lack of grocery stores, farmers' markets and healthy food providers' (Khalil and Mendelson, 2017; USDA, 2015; Ver Ploeg et al., 2011). To qualify as a community with low food access, 'at least 500 people and/or 33 percent of the census tract's population must reside more than one mile from a supermarket or large grocery store (for rural census tracts, the distance is more than ten miles)' (Khalil and Mendelson, 2017; USDA, 2015; Ver Ploeg et al., 2011). Even though this definition is very US-specific and

¹ Unfortunately, because of a revision of the USDA website, the original USDA document about defining food deserts is no longer available online.

² For more details on this definition, please see section 2.1 as well as the last paragraph of section 3.

applies to a generally fragmented and manifold shopping infrastructure (Augustin, 2014), we still consider it applicable for the German context and macro level analyses – given some adjustments. Regional realities and perceptions need to be considered: People living in different regions might have different expectations on what represents an adequate or an inadequate access to a food store (see for example, Jürgens, 2015). Particularly in rural areas, people tend to either adjust to or accept longer distances and travel times as well as a lack of choice between stores (Küpfer and Eberhardt, 2013a).

2.2. Development of food retail sales and kinds of shops

With regard to food retailers, the diversity of shops and their locations, Germany has gone through tremendous structural changes in the past decades. These changes comprise concentration processes (spatial, but also in terms of an oligopolistic market structure), the reduction of personal services, standardised shops and the replacement of independent stores through chains and franchising (Kokorsch and Küpper, 2019). Simultaneously, discounters gradually adopted the function of a local supplier by diversification especially in fresh products (Kokorsch and Küpper, 2019; Wotruba, 2016; Kuhlicke and Petschow, 2005: 39). Another trend is the agglomeration and cooperation of food retailers in retail parks, which are usually located outside the city centres and settlement areas (Wieland, 2014). In addition, the number of small independent stores (corner shops/neighbourhood stores) is in a steady decline (Kokorsch and Küpper, 2019; Lein, 2012; Vallée and Lenz, 2007; KPMG, 2005, Kuhlicke et al., 2005). Some authors have predicted the gradual disappearance of stores smaller than 400 m² (sales area) in the long run (KPMG, 2016; Reutterer and Teller, 2009).

Collectively, the number of shops has been in a continuous decline since 1990³ particularly in rural areas (Jürgens, 2015, 2017; Küpper and Eberhardt, 2013b). Localities with a catchment area⁴ below 5000 inhabitants, are not considered as profitable for most food retailers (Küpfer and Eberhardt, 2013b). With regard to corner stores, Jürgens (2017, 2016) remarks that because of the higher prices for food products, compared to supermarkets or discounters, as well as the limited assortment, these kinds of shops are mainly visited for covering ‘Gelegenheitsbedarf’ (occasional shopping purposes) or ‘Vergeßlichkeitsbedarf’ (products forgotten to buy elsewhere)^{5,6}. For farmers, direct marketing the situation is similar. The current development and its possible continuation lead to the assumption that the nationwide local supply is at risk and the distances consumers have to cover for shopping purposes are going to increase (Kokorsch and Küpper, 2019; Heinritz et al., 2003). Corner stores excluded, food retail stores in Germany can be differentiated into the following four categories: Supermarket, large supermarket, hypermarket and discounter. An overview about the main distinguishing factors between these four types of supermarkets is given in Table 1.

As regards the development of food retailers, numbers dropped from 85,000 shops in 1990 to 37,551 shops in 2018 (–47,449 shops, or a 56%

³ 1990 is the reference point for our analysis, given the German reunification that year.

⁴ Here, the sociological/human geographical meaning of the term is meant; that is, the area/region where the customers of the single shops come from.

⁵ ‘Gelegenheitsbedarf’ and ‘Vergeßlichkeitsbedarf’ are common technical terms in German retail research. As we are not aware whether there exist equivalent English terms comprising the whole meanings we provided a simplified translation in order to give an idea what is meant.

⁶ That is, the relevance of small corner stores for meeting the demand for ‘Produkte des täglichen Bedarfs’ (products of daily need) decreased dramatically within the last decades in Germany. Thus, one can argue, that even if available, such shops play only a subordinate role for daily grocery shopping. Even though such shops might indeed be the only viable shopping opportunity for the less mobile population, the restrictions in product range and pricing were crucial for our decision to not consider these stores for our assessment.

decrease) (<http://www.food-monitor.de> October 01, 2013; Handelsverband Deutschland e.V., 2013; Handelsverband Deutschland, 2019a; TLG Immobilien AG, 2017). With detailed numbers from 2008 to 2018 at hand, it is striking that the decline is comprised almost entirely of corner stores with up to 400 m² sales floor (2008: 13,900; 2018: 8600). By contrast, the number of discounters has increased at a low level (0.5% or 84 shops until 2017 before dropping by 1% between 2017 and 2018). Among supermarkets (12% increase or 1310 shops) and large supermarkets (24% increase or 224 shops), a steady increase in number of shops can be identified between 2007 and 2018. The development of hypermarkets is comparatively mixed, with a slight tendency to decrease since 2012 (Table 2).

The available statistics only provide aggregated data on the development of stores in Germany, without any further differentiation between regions or localities. Therefore, it is impossible to assess to what extent rural regions are affected by the decrease in shop locations.

However, the authors received two data sets in 2013 (from wer-zu-wem.de) and 2017 (from gb-consite), which allow for such a regional differentiation. (For details on the datasets please see Section 3, Methodology – The accessibility model). The regional differentiation in this analysis follows the Thünen-Typology of Rural Areas (see Table 3).⁷ With this typology at hand, the following development can be traced: The strongest total decline in shop locations between 2013 and 2017 can be detected in non-rural regions with a net decrease of 242 shops (2%) between 2013 and 2017. Among the four different types of rural regions, a division based on the socio-economic situation can be identified. In ‘rather rural’ and ‘very rural’ regions with a good socio-economic situation, an increase of shops can be discovered (174 in total or 2%). Their socio-economic counterparts are confronted with a decline of 336 shops (around 3%). Hence, closures of supermarkets and discounters between 2013 and 2017 occurred in regions that have been particularly affected by the processes of demographic change. This observation coincides with the assumption of Kuhlicke and Petschow (2005) that local food retailers are usually located in regions with a high purchasing power and population density and simultaneously tend to neglect sparsely populated rural regions.

2.3. Key data on food shopping and mobility in Germany

In 2017, Germans visited a grocery every other day on average spending € 19.40 on average per visit in a grocery store (Scholz, 2019).⁸ The frequency of grocery shopping and the amount spent per trip have been decreasing during the past few years (Scholz, 2019).

In addition, an analysis of the German Federal Ministry of Transport and Digital Infrastructure (Bundesministerium für Verkehr, Bau und Stadtentwicklung) on means of transport choice for shopping purposes in Germany revealed that the choice of the means of transport is

⁷ We decided for the Thünen-Typology of Rural Areas as we consider it more appropriate for classifying rural areas in Germany than the frequently used alternative ‘Siedlungsstrukturelle Kreistypen’ (classification of counties by settlement structure) of the Federal Institute for Research on Building Urban Affairs and Spatial Development as of 2011. The reason is that the ‘Siedlungsstrukturelle Kreistypen’ classify the regions based on the share of population and population density only (http://www.bbsr.bund.de/cln_032/nn_1067638/BBSR/DE/Raumbeobachtung/Raumabgrenzungen/Kreistypen4/kreistypen.html). In addition, this classification intends to differentiate urban from rural regions, rather than differentiating different kind of rural regions. By contrast, the intention of the Thünen-Typology of Rural Areas is to explicitly differentiate different kinds of rural areas based on their structural performance. This is achieved by incorporating several structural as well as socio-economic indicators. For a more detailed introduction of the Thünen-Typology of Rural Areas, please see Annex I.

⁸ There can be observed a trend towards a decline in the frequency of food shopping combined with a decrease in the amount spent per shop visit in the last years (Scholz, 2019).

Table 1

Difference between supermarket, hypermarket, large supermarket and discounter.

	sales floor in m²	average sales floor in m²	average nr. of articles	average customers per day	average annual sales in €	assortment
Supermarket	400 to 2500	1370	10,500	1531	62,50,000	full service grocery store Nonfood I articles and small amount of Nonfood II articles
Hypermarket	≥5000	7449	50,000	3991	3,29,30,000	full service grocery store Nonfood I articles and Nonfood II articles
Large supermarket	1500 to 5000	3254	25,000	2773	1,44,80,000	full service grocery store Nonfood I articles and Nonfood II articles
Discounter	400 to 1200	761	800 to 1.700	n.s.	n.s.	narrow and flat assortment of articles with high shares of private labels. Only limited amount of fresh products

Non-food I articles: perfumery and drugstore products, cleaning agents, pet food.**Non-food II articles:** consumer durables and consumer products of medium- and long-term need, such as textiles, shoes, gardening supplies, consumer electronics, whiteware, media and books.Source: Illustration by the authors, based on EHI, 2013; Bundesverband des Deutschen Lebensmitteleinzelhandels, 2013; Küpper and Eberhardt (2013a); Borutta et al. (2012); <http://Wirtschaftslexikon24.com>, 2013; Springer Gabler Verlag (2010).**Table 2**

Changes in food retail stores by business type.

Year	Discounter	Supermarkets	Large supermarkets		Hypermarkets	Corner stores	Food retail stores total
	number of shops						
2007	15,600	9590	903		877	14,900	41,870
2008	15,970	9660	931		887	13,900	41,348
2009	16,020	9700	955		885	12,800	40,360
2010	16,240	9980	985		890	11,193	39,288
2011	16,462	10,148	1002		893	10,650	39,155
2012	16,393	10,505	1010		894	10,064	38,866
2013	16,222	10,655	1054		888	9781	38,600
2014	16,195	10,785	1070		875	9600	38,525
2015	16,211	10,870	1098		864	8900	37,943
2016	16,054	10,900	1127		851	8750	37,682

Source: EHI Retail Institute, quoted by TLG Immobilien AG, 2017, p. 7; Handelsverband Deutschland (2019a), p. 26

Table 3

Changes in discounter and supermarket store locations by type of region between September 2013 and November 2017.

Thünen-Typology of Rural Regions	September 2013			November 2017			Development in markets between 2013 and 2017					
	Discounter	Supermarkets	total	Discounter	Supermarkets	total	Discounter		Supermarkets		total	
							nr	%	nr	%	nr	%
total	16,072	15,273	31,345	15,716	15,225	30,941	-356	-2	-48	0	-404	-1
very rural/less good socio-economic situation	3089	3179	6268	2993	3116	6109	-96	-3	-63	-2	-159	-3
very rural/good socio-economic situation	1757	1978	3735	1740	2069	3809	-17	-1	91	5	74	2
rather rural/good socio-economic situation	2194	2619	4813	2272	2641	4913	78	4	22	1	100	2
rather rural/less good socio-economic situation	2996	2188	5184	2853	2154	5007	-143	-5	-34	-2	-177	-3
not rural	6036	5309	11,345	5858	5245	11,103	-178	-3	-64	-1	-242	-2
rural total	10,036	9964	20,000	9858	9980	19,838	-178	-2	16	0	-162	-1

Source: Own calculation; Location of markets: wer-zu-wem.de (for 2013) and gb-consite (for 2017); Rural Typology: Küpper (2016); see also Appendix I)

dependent on the travel distances. According to this analysis, grocery shopping is characterised by comparatively short distances and a high share of non-motorised traffic (Bundesministerium für Verkehr, Bau und Stadtentwicklung, 2011).

The more recent study ‘Mobilität in Deutschland’ (Mobility in Germany) of the Bundesministerium für Verkehr und digitale Infrastruktur (2018) concretises this finding and provides relevant results for our subject matter. This study ascertained that consumers spend 17.3 min on average (median 10 min) daily for shopping-related routes. Regarding passenger-kilometres for shopping purposes, numbers are decreasing from 279 million km per day in 2002 to 214 million km in 2017 (Bundesministerium für Verkehr und digitale Infrastruktur, 2018). Regarding the means of transportation commonly used for grocery shopping, the vast majority of the respondents chose the car (72%, multiple answers

possible), followed by 47% who walk, 29% who use a bicycle, and 10% who use public transport. These numbers change considerably between types of regions.⁹ In urban regions, the numbers for cars are between 48% and 79%, while in rural regions numbers range from 72% to 85% in the most rural setting. Walking is the common form for grocery shopping for 44%–72% in urban regions and for 28%–48% in rural regions. Particularly noteworthy are the differences regarding public transport. Numbers vary between 4% and 24% in urban regions and 2%–8% in rural settings. In another study, conducted for the Federal Ministry of

⁹ The Ministry of Transport and Digital Infrastructure uses a different typology and differentiates between seven regions of which four are urban and three are rural. For clarity, we decided not to list all of them.

Food and Agriculture in 2017, participants were asked about shopping behaviour and preferences. For 49% of the respondents the commonly frequented grocery store was within walking distance¹⁰, for 46% that store was at a distance of up to 15 min by car, while 5% of the respondents needed a travel time of more than 30 min by car (Bundesministerium für Ernährung und Landwirtschaft, 2017). These numbers vary significantly when the size of town is taken into account. For respondents living in places with less than 5000 inhabitants, 25% had their commonly frequented store within walking distance, while 66% needed up to 15 min by car and 8% over 30 min. Regarding the store choice, Lein (2012)¹¹ ascertained that 55.3% of the consumers in Germany prefer supermarkets for food shopping, followed by 33.6% who prefer discounters; 11% of the consumers prefer other forms of retail formats, such as consumer markets (4.9%), specialised markets (2.8%), organic food stores (1.5%) or farmers markets (1.3%). However differences in the choice of transport means exists between urban and rural areas. In other words, with increasing rurality the share of the non-motorised traffic for shopping purposes as well as the shopping frequency decreases while the share of the motorised traffic increases (Bundesministerium für Verkehr, Bau und Stadtentwicklung, 2011).

Against the background of these findings, it is concluded that foot, bicycle, and car are feasible means of transportation for grocery shopping in Germany. However, the practicability for using a distinct means of transport is strongly dependent on different distinct regional (e. g. distances, terrain) as well as individual (e. g. age, fitness, preferences) characteristics.

3. Methodology – the accessibility model

In the past decade, an increasing number of publications have focused on food deserts and GIS modelling. Some provide important insights into the applicability of accessibility models (Helbich et al., 2017; Mulrooney et al., 2017; Križan et al., 2015; Russell and Heidkamp, 2011). Regarding rural areas in Germany, there is one recent publication on food deserts (Jürgens, 2018). However, the scope is slightly different, as this study adopts a demand-oriented perspective and focuses on the meso-level of selected communities within the federal state of Schleswig-Holstein. By contrast, our study considers the situation of the general supply from a macro level (nationwide) perspective. Our research builds upon a GIS accessibility analysis of supermarkets and discounters in Germany for the years 2013 (September) and 2017 (November).¹² The locational data of the supermarkets and discounters is based on the address data sets of the commercial address-resellers ‘wer-zu-wem.de’ (2013) and gb-consite (2017). Although addresses in the 2013 data set were already geocoded, the 2017 dataset was geocoded by the authors using the address geocoder of the Federal Office for Cartography and Geodesy, prior to the analysis. The 2013 data set contains locational information on 15,273 supermarket locations and 16,072 discounter locations (for details see Author A, 2014). The 2017 data set contains locational information on 15,225 supermarket locations and 15,716 discounter locations.¹³ However, due to inconsistencies in either data sets to geocode or the reference address data

base, singular allocation errors are inevitable. Those errors cannot be corrected manually with a reasonable cost-value ratio. Nonetheless, focusing on the macro level of Germany as a whole, the authors believe that such inconsistencies can be disregarded.

We decided to focus on travel times in traffic networks and use geographic accessibility to acquire accessibility indicators (see for example Hemetsberger and Ortner (2008), Dahlgren (2008), Schulz and Bröcker (2007), Schwarze (2005), Bleisch (2005), Bleisch et al. (2003) or Schürmann et al. (1997)).

Therefore, we measure accessibility within traffic networks with a ‘raster-based accessibility modelling approach’ (Rauch and Rauh, 2016; Neumeier, 2012). It allows us to obtain results below the level of the administrative unit of the communities and to generate scalable results. This is achieved by overlaying the area of interest (Germany) with a small-scale vector-raster (grid). Thereafter, the distance, respectively travel time – within the street network – from the centroid of every single grid-cell to the nearest location of a supermarket or discounter, is calculated. The resulting distance, respectively travel time, is then assigned to the grid-cell under consideration. Since within grid-cells distances are not considered, the size of the grid-cells influences the precision of the model. Simultaneously, the smaller the grid-cells, the higher the computation costs for one modelling cycle. Taking all this into consideration, together with the fact that we also intended to estimate the share of the population affected by certain accessibilities, we decided for the so called EWZ250¹⁴ developed by the Bundesinstitut für Bau-, Stadt und Raumforschung, as analysis grid (for details see Burgdorf, 2010). This grid resolution is 250 m × 250 m and contains population data for every grid-cell, obtained by disaggregating the population data from the latest German census of 2011.¹⁵ This grid is small enough to allow for the calculation of accessibility by foot. With 5,713,823 grid-cells, the data are quite detailed but do not cause overly expensive computation costs.¹⁶ As it was impossible to perform a ‘many-to-many point’ analysis for entire Germany with the available hardware, we decided to base the accessibility calculation on a two-step process.

First, at least the ten nearest service locations are determined by Euclidean distances via a knn-nearest neighbour algorithm for every centroid of the analysis grid.

Second, the street distance, respectively travel time, to all the identified source-target service location pairs, is computed. Finally, the shortest computed distance, respectively travel time, is selected for every source. We decided to consider the ten nearest possible locations, since experience suggests that this can minimise possible allocation errors. For example, if one considered the three nearest possible locations, it would be quite likely that close to rivers, or other barriers, the nearest locations by Euclidean distances are on the other side of the barrier. According to street distances, however, this is not always the closest destination. The accessibility calculation itself is performed with the utilisation of the Open Source Routing Machine (OSRM) (Luxen and Vetter 2011) in the traffic network of the OpenStreet Map (OpenStreetMap contributors (2017). Planet dump December 15, 2017, downloaded from <https://download.geofabrik.de>). The calculated

¹⁰ Unfortunately, no definition of walking distance was provided.

¹¹ Based on data from CIMA GmbH, a private company specialising in consulting and marketing services.

¹² Both data sets were acquired from address resellers, as in Germany no official data set about shop locations exists. That is, these data sets were actually produced to assist in marketing purposes. The acquisition of data sets for several years was therefore not possible, considering the extremely high costs of the address data sets. As such it was not possible to incorporate considerations about shop location changes over time (except the years 2013 and 2017) in the analysis.

¹³ Those retail stores that share an address (e.g., agglomerations in retail parks) are treated as one location for analysis purposes.

¹⁴ EWZ 250: This is the name of the raster data set, not an abbreviation.

¹⁵ This grid does not contain any additional structural data, in addition to the disaggregated population data. In general, in Germany, there does not exist any kind of gridded statistical data except the so-called census grid. However, the census grid only contains gridded population numbers as well as basic household and building data. That is, the information contained does only allow to differentiate households by persons and marriage status, not by socioeconomic status, etc. The lowest level statistical data is available for Germany in general are the communities. However, many socioeconomic indicators are only available at the district level.

¹⁶ One modelling cycle takes 57, 138, 230 distance calculations into consideration and runs for eight to 10 h.

travel time by car is based on the speed profile ‘car’ of the OSRM for Germany. Travel times by foot are calculated based on computed travel distances, taking into consideration that the walking speed varies between 1.3 m/s to 1.45 m/s, due to demographic and socio-economic characteristics, such as sex, age, living environment, etc. (Granacher et al., 2012; Morgenroth, 2008; Götz-Neumann, 2006; Perry and Davids, 1992). We decided on 1.3 m/s for converting distances to walking times, thus using an integrative approach that also considers slow-walking people. By bicycle, the average speed is somewhere between 10 km/h and 20 km/h¹⁷ depending, for example, on fitness, traffic situation, terrain, etc. For the study, a cycling-speed of 15 km/h is assumed.

An assessment framework for a qualification of accessibility is the next prerequisite. Scientists might define adequate accessibility differently than politicians that are somewhat bound to the normative goal of providing ‘gleichwertige Lebensbedingungen’ (comparable living conditions) in all areas of Germany. However, the influence of politicians is quite limited, since location decisions for shops are commonly made by private entrepreneurs. According to the Department for Spatial Development and Geoinformation (Amt für Raumentwicklung und Geoinformation) of the Canton St. Gallen (CH), a travel time of 15 min can be taken as a threshold to differentiate between adequate and inadequate accessibility (AREG, 2008).¹⁸ This travel time is also in accordance with the latest findings on mobility in Germany presented above (see Section 2) and fits the commonly used distances in other sources (see for example Križan et al., 2015).

With a threshold of 15 min being set, we will now explain why small corner shops, bakeries and butchers, etc., as well as mobile shops and petrol stations are not part of this analysis. One reason is the lack of available data. Another reason is, that those formats do not qualify as adequate supplier, regarding aspects such as opening hours, pricing and assortment. The latter applies in particular to petrol stations and their shops. While some authors have argued that these shops could substitute missing food retailers in rural areas (Varsamidis and Zimmermann, 2009; Zentes, 2006; Hese, 1999), more recent research has shown that this does not apply to 98% of rural regions in Germany for two reasons (Neumeier, 2015). First, in Germany, petrol stations are, in most cases, not better accessible than a supermarket or discounter. Second, the assortment is limited and tailored to convenience-shoppers with higher prices compared to common food stores (Neumeier, 2015). For small and independent corner stores, Jürgens (2017, 2015) noted that such shops usually provide a limited assortment with comparatively high prices. Hence, Jürgens (2017, 2015) concluded that those shops are mainly visited to cover ‘Gelegenheitsbedarf’ (occasional shopping needs) or to cover ‘Vergeßlichkeitsbedarf’ (shopping products forgotten elsewhere).¹⁹ We highlight the importance of mobility and, considering the fact that the share of households without a car is low in rural Germany²⁰ (Bundesministerium für Verkehr und digitale Infrastruktur, 2018; Neumeier, 2012), one can argue that in rural areas the decision against a car is likely to be tied to financial restrictions. Assuming that the majority of households without a car are also not financially affluent, higher priced corner shops are not a viable alternative. Thus, one can

¹⁷ <https://zu-schnell-gefahren.de/fahrrad-geschwindigkeit/> (13.04.2018); <http://www.radfahren-macht-spass.de/startseite/wissenswertes/> (13.04.2018).

¹⁸ Other approaches and analysis tend to set a threshold at 800 or 1000 m for an acceptable distance (‘by foot’), but without unfolding the criteria(s) these thresholds are based on. Thus, they seem to be more a political agreement or agreement in food retail planning than scientifically verified values.

¹⁹ ‘Gelegenheitsbedarf’ and ‘Vergeßlichkeitsbedarf’ are common technical terms in German retail research. As we are not aware whether there exist an equivalent English terms comprising the whole meanings, we provided a simplified translation in order to give an idea what is meant.

²⁰ About 90% of the households outside urban areas have access to a car, according to the latest survey of the Federal Ministry of Transport and Digital Infrastructure (see Bundesministerium für Verkehr und digitale Infrastruktur, 2018).

argue, that even if such corner shops are the closest available option for grocery shopping near the place of residence, such shops play only a subordinate role for daily grocery shopping for the majority of the population and especially for the poorer rural population corner shops are not a feasible alternative for the bulk purchase of food products because of the comparable high product prices^{21 22}.

With this qualification, we provide a definition for food deserts and introduce the terminology ‘Potential Perceived Food Deserts’ into the discourse. Since the smallest statistical unit in Germany is not census tracts but communities, the identification here is based on the administrative level of the communities. Earlier, we set a limit of 15 min for the differentiation between adequate and inadequate accessibility. This threshold is also used here for the identification of food deserts. To a certain extent, the definition from the USDA (see 2.1) can be applied: if at least 33% of the people living in a community where travel times exceed 15 min (by the selected means of transport), the community is labelled a ‘Food Desert’. However, we consider it overly simplistic to conclude upon reversion, that all other communities provide adequate access to food (‘Non-Food Desert’).²³ Therefore, we provide an extension to the dichotomy food desert/no food desert, by introducing the notion ‘potentially perceived food desert’. This notion applies to regions in which travel times are below 15 min, yet more than 33% of the population experience travel times that are 1.5 times the average travel time of this region type. The merging of the original definition of the USDA and our Germany-specific extension is illustrated in Fig. 1.

4. Findings

4.1. Accessibility of supermarkets and discounters in Germany

Our calculations reveal interesting results regarding the accessibility of supermarkets and discounters in Germany (see Table 4). Nationwide (populated cells of the analysis grid), 2.5 supermarkets or discounters can be reached within 5 min by car. The share is higher (4.8 markets) in urban areas than in rural areas (2.5 markets). When other means of transportation are considered, these figures decrease considerably.

In addition to the accessibility of supermarkets and discounters within a certain travel time, the median travel time needed to reach the nearest shop provides additional information (Table 5). According to our calculations, the median travel time to the nearest supermarket or discounter is 6 min by car, 16 min by bicycle and 50 min by foot.

One of the findings in previous studies (see Section 2) can be confirmed: There is not much difference in median travel times to the nearest supermarket or discounter between rural and non-rural areas, nor among the four types of rural areas.

As one might expect, the median travel times and distances are lowest in the three city-states (Berlin, Bremen, Hamburg). For the 13 remaining federal states, the following results were ascertained within the rural areas: Within a travel time of 15 min, supermarkets and discounters can

²¹ Which poses the question whether this shopping behaviour might potentially support the emergence of ‘food deserts’ (Dannenberg et al., 2017).

²² We do not want to neglect the role that these corner stores (‘Dorfläden’) exhibit regarding social aspects, for example, as meeting points. This aspect has been extensively covered by several authors in Germany (Eberhardt et al., 2014; Küpper and Eberhardt, 2013). This analysis here, however, had to differentiate strictly between shopping purposes and social aspects.

²³ We would like to point at the research of Jürgens (2018) who argues somewhat in the same vein by introducing the notion of mental and real food deserts. For our analysis, this terminology is not applicable, since the assessment of ‘mental’ food deserts requires survey data from affected groups. However, for a case-study based assessment of food deserts, we consider the approach of Jürgens as useful extension to the discourse.

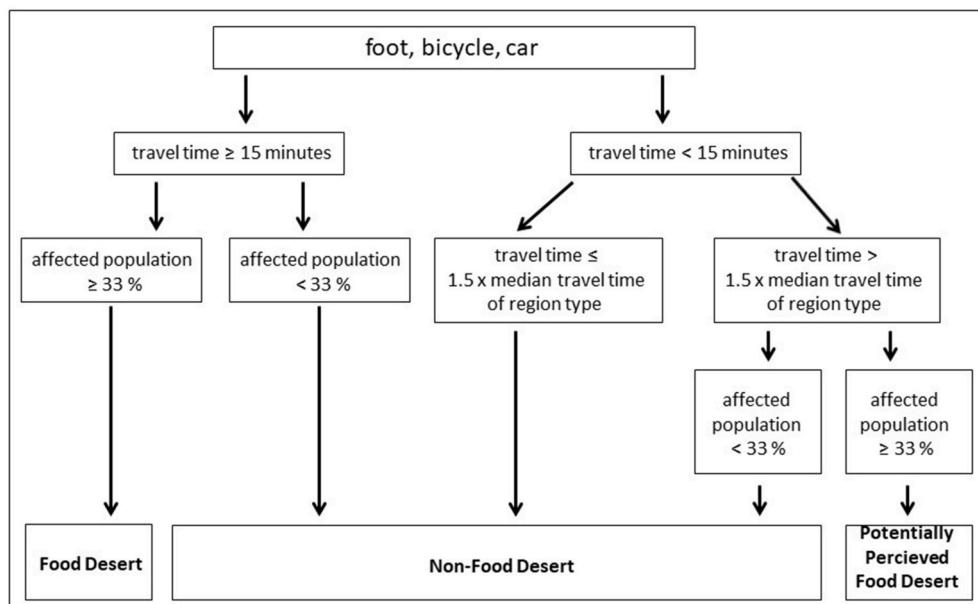


Fig. 1. Suggested approach to define 'food deserts' in rural Germany. Source: Author's own design.

Table 4

Average number of accessible supermarkets and discounters in settlement areas by Thünen-Types of rural areas in 2017.

Thünen-Typology of Rural Regions	travel time in minutes								
	≤5			≤10			≤15		
	by car	by bicycle	by foot	by car	by bicycle	by foot	by car	by bicycle	by foot
average number of accessible supermarkets or discounters									
total	2.5	0.7	0.1	6.5	2.0	0.3	9.0	3.2	0.6
very rural/less good socio-economic situation	2.0	0.5	0.1	5.9	1.5	0.2	8.7	2.5	0.5
very rural/good socio-economic situation	1.6	0.5	0.1	5.1	1.2	0.2	8.2	2.0	0.4
rather rural/good socio-economic situation	1.9	0.5	0.1	5.8	1.4	0.2	8.9	2.4	0.4
rather rural/less good socio-economic situation	2.4	0.6	0.1	7.0	1.8	0.3	9.4	3.1	0.6
not rural	2.1	0.6	0.1	6.1	1.7	0.2	8.8	2.8	0.5
rural total	4.8	1.5	0.1	9.1	4.4	0.6	10.1	6.5	1.3

Annotation: The table shows the average number of accessible supermarkets and discounters in settlement areas. (That is, all cells of the analysis raster with population values greater than zero).

Source: Authors' own analysis.

only be reached when using a car or a bicycle.²⁴ The longest median travel times and distances can be found in Brandenburg, Mecklenburg-West Pomerania and Saxony-Anhalt. The lowest median travel times can be found in Saarland, North Rhine-Westphalia and Hesse.

With a few exceptions in Brandenburg, Mecklenburg-West Pomerania and Saxony-Anhalt, the median accessibility by bicycle is below a travel time of 20 min in all rural areas. This cannot be said about accessibility by foot: except rather rural areas with less good socio-economic situation in Saarland, not a single rural setting comes up with a number below 30 min, with ranges from 28 min (Saarland, rather rural/less good socio-economic situation) to 90 min (Brandenburg, very rural, less good socio-economic situation). The vast majority of rural areas exceed 40 min travel times for the means of transportation foot. One possible explanation for these numbers is that the aggregates for federal states are quite big administrative units compared to the analysis grid, a phenomenon known as the modifiable areal unit problem. The explanatory power of data acquired at small scale, decreases when aggregated for greater reporting units, because important intraregional

differences are not reflected by the aggregated values (Madelin et al., 2009). This can be seen when comparing the median values for the federal states with the small-scale accessibility maps based on the 250 m × 250 m analysis grid depicted in Fig. 2.

As illustrated in Fig. 2, supermarkets and discounters at a walking distance can generally be found in agglomerations and within the core settlement areas of rural areas. The picture changes with the means of transportation. Regarding bicycles, it can be distinguished between adequate accessibility in and around agglomerations and a moderate accessibility in most parts of the rural areas within the western federal states²⁵ as well as Saxony and parts of Thüringen in the east. This is contrasted by inadequate accessibility in the rural areas of the remaining eastern federal states²⁶ (Brandenburg, Saxony-Anhalt, Mecklenburg-West Pomerania).

By car, there are only a few areas where travel times exceed 15 min. Areas where this threshold is exceeded are located mainly in

²⁴ Please note that these results consider median travel times and the conclusion that no supermarket or discounter can be reached within 15 min by other means of transport anywhere in rural Germany would be a false one.

²⁵ These are Schleswig-Holstein, Lower Saxony, North Rhine-Westphalia, Bremen, Hamburg, Rhineland-Palatinate, Saarland, Baden-Württemberg, Hesse, Bavaria.

²⁶ These are Mecklenburg-West Pomerania, Brandenburg, Saxony-Anhalt, Saxony, Thüringen.

Table 5

Median accessibility of the nearest supermarket or discounter by federal states, Thünen-Types of rural areas and means of transport in 2017.

Thünen Typ	Germany total		Schleswig Holstein		Hamburg		Lower Saxony		Bremen		North Rhine-Westphalia		Hesse		Rhineland-Palatinate					
	median accessibility of the next supermarket or discounter in minutes by ... (car: speed profile of openStreetMap; bike: 15 km/h; foot 4.7 km/h)	car	bike	foot	car	bike	foot	car	bike	foot	car	bike	foot	car	bike	foot				
total	6 16	50	6	16	52	3	6	18	6	16	50	3	7	21	4	11	36	5 13 41 6 17 54		
very rural/less good socio-economic situation	6 19	60	6	17	54	0	0	0	6	17	55	0	0	0	5	17	54	5 16 51 6 19 61		
very rural/good socio-economic situation	6 15	48	0	0	0	0	0	6	15	47	0	0	0	5	13	42	5 13 42			
rather rural/good socio-economic situation	5 13	41	6	15	49	0	0	0	5	14	45	0	0	0	5	12	39	4 12 37 4 12 39		
rather rural/less good socio-economic situation	6 16	53	6	17	55	0	0	0	5	14	45	0	0	0	5	12	39	5 14 45		
not rural	4 8	25	4	10	31	3	6	18	4	9	29	3	7	21	4	8	27	3 8 24 3 7 23		
rural total	6 16	52	6	17	54	0	0	0	6	16	51	0	0	0	5	13	42	5 14 44 6 17 56		
median distance to the next supermarket or discounter in km																				
total	3.9				4.1			1.4			3.9			1.6			2.8		3.2	4.2
very rural/less good socio-economic situation	4.7				4.2			0.0			4.3			0.0			4.2		3.2	4.8
very rural/good socio-economic situation	3.7				0.0			0.0			3.6			0.0			3.3		3.2	4.4
rather rural/good socio-economic situation	3.2				3.9			0.0			3.5			0.0			3.0		3.2	3.1
rather rural/less good socio-economic situation	4.1				4.3			0.0			3.5			0.0			3.1		3.2	3.5
not rural	2.0				2.4			1.4			2.3			1.6			2.1			1.8
rural total	4.1				4.2			0.0			4.0			0.0			3.3		3.4	4.4

Brandenburg, Mecklenburg-West Pomerania and the northern part of Saxony-Anhalt.

But what can these results reveal about the population affected? Considering the accessibility merely by different means of transport is one way to approach food deserts. An important extension is a calculation of the population that is possibly affected. Taking both into consideration, means of transportation and population affected, allows for a comprehensive assessment of supermarket and discounter accessibility.

Table 6 provides an overview of the relative share that lives within a specific type of rural region and the accessibility of the nearest supermarket or discounter within a set time frame. Altogether 88% of the population in Germany can reach the nearest supermarket or discounter within a travel time of up to 5 min by car. With a threshold of 15 min, this number increases to 99%. When the bicycle is the chosen means of transportation, some 68% can reach a supermarket or discounter within 5 min, and 90% have a shop available within 15 min bicycling. Numbers drop to 18% (5 min) and 66% (15 min) when the shop is to be accessed by foot.

Taking the different types of rural regions into account, 99.6% of the population can reach the nearest supermarket and discounter within 15 min in rural regions by car. This counts for all four types of rural regions. Regarding the two other means of transportation, the picture is skewed. For accessibility by bicycle, numbers differ between 77% (very rural regions with good socio-economic situation) and 91% (rather rural regions with good socio-economic situation). For foot, the range is from 49% (very rural regions with less good socio-economic situation) to 86% (rather rural regions with less good socio-economic situation).

The share of the population that can reach a supermarket or discounter within 15 min travel time decreases to 96% in very rural regions with less good socio-economic situation within Brandenburg. Considering the means of transportation bicycle and foot, the situation is worst for people living in very rural regions with less good socio-economic situation in Brandenburg, where the share of the population that can reach the nearest supermarket or discounter within 15 min by bicycle equals 63% and by foot equals 44%. Only slightly better results can be ascertained for bicycle (69%) and foot (36%) among the population of very rural regions with less good socio-economic situation in Rhineland-Palatinate.

All in all, the following conclusions can be drawn regarding our first research question: First, for rural regions in Germany it seems to be more a question of rurality than of the socio-economic status of a certain region that decides grocery store accessibility in general. Yet, the picture varies between the federal states. Second, mobility has a significant impact on the accessibility of shopping localities. Not surprisingly, the

population with access to a car should not face travel time or distance problems. With some limitations, the same can be said about those with the ability to use a bicycle. Interestingly enough, in both types of rural regions with good socio-economic situation the share of population that can reach the next market by bicycle is slightly below that of the rural regions with less good socio-economic situation. Third, regarding foot it is a population share of over 35% (including non-rural regions) that needs to travel more than 15 min before reaching the nearest supermarket or discounter. For 17% the travel time even exceeds 30 min.

Fourth, the share of people affected by specific accessibilities between the different federal states and types of rural regions differ from one another. While the range is almost negligible among car users (96%–100% of the population in all rural areas and federal states can reach the nearest supermarket or discounter within a travel time of 15 min), the gap widens among bicycle and foot. For rural areas of the federal states in the east, the situation is less adequate than for their counterparts in the west. However, some exceptions excluded (see Table 6), the deviation in the share of population for which a supermarket or discounter is accessible by bicycle and foot within a specific time-window is small between the different federal states and types of rural areas.

4.2. Are there food deserts in rural Germany, and if yes, for whom?

Having discussed the accessibility of supermarkets and discounters in general, this section focuses on food deserts, and whether they occur in Germany.

Applying the criteria defined above, the results for each means of transportation are illustrated in the figure below (Fig. 3). By foot, there are only a few regions where supermarkets and discounters can be reached within the accepted travel time of 15 min. Considering the accessibility by bicycle, a considerable improvement in the accessibility of supermarkets and discounters can be identified in great parts of the rural areas. However, especially in great, connected parts within the federal states of Schleswig-Holstein, Mecklenburg-West Pomerania, Brandenburg, Rhineland-Palatinate and the North of Saxony-Anhalt, improvements in the accessibility by using a bicycle are not distinct. The picture looks different for the accessibility of supermarkets and discounters by car. There are only a few regions in Mecklenburg-West Pomerania, Brandenburg, North-West Bavaria, Rhineland-Palatinate and Saxony-Anhalt where the threshold of 15 min is exceeded. Bringing in the extension of ‘potentially perceived food deserts’, such areas can be found in connected parts of Mecklenburg-West Pomerania,

Baden-Württemberg			Bavaria			Saarland			Berlin			Brandenburg			Mecklenburg-West Pomerania			Saxony			Saxony-Anhalt			Thuringia					
median accessibility of the next supermarket or discounter in minutes by ... (car: speed profile of openStreetMap; bike: 15 km/h; foot 4.7 km/h)																													
car	bike	foot	car	bike	foot	car	bike	foot	car	bike	foot	car	bike	foot	car	bike	foot	car	bike	foot	car	bike	foot						
5	13	42	6	15	48	4	11	35	2	4	12	8	24	77	8	23	75	5	15	47	7	19	61	6	17	53			
6	17	54	6	17	53	5	14	45	0	0	0	9	28	90	8	24	77				7	21	67	6	17	55			
6	15	49	6	16	50	0	0	0	0	0	0	0	0	0	0	0	0				0	0	0						
5	12	40	5	14	43	5	11	36	0	0	0	0	0	0	0	0	0				0	0	0						
0	0	0				4	9	28	0	0	0	8	23	73	7	19	61				0	0	0						
3	8	25	3	8	25	4	8	26	2	4	12	5	10	33	4	7	22				3	6	19	3	6	19	4	9	30
5	14	45	6	15	49	5	12	37	0	0	0	8	24	77	8	23	75				6	15	48	7	19	61	6	17	54
median distance to the next supermarket or discounter in km																													
3.2			3.7			2.7			0.9			6.0			5.8			3.7			4.7			4.2					
4.2			4.2			3.5			0.0			7.0			6.0						5.2			4.3					
3.8			3.9			0.0			0.0			0.0			0.0						0.0								
3.1			3.4			2.8			0.0			0.0			0.0						0.0								
0.0						2.2			0.0			5.7			4.8			3.8			3.9			3.9					
2.0						1.9			2.0			0.9			2.6			1.7			1.5			1.5			2.4		
3.5						3.8			2.9			0.0			6.0			5.8			3.7			4.8			4.2		

Source: Authors' own analysis.

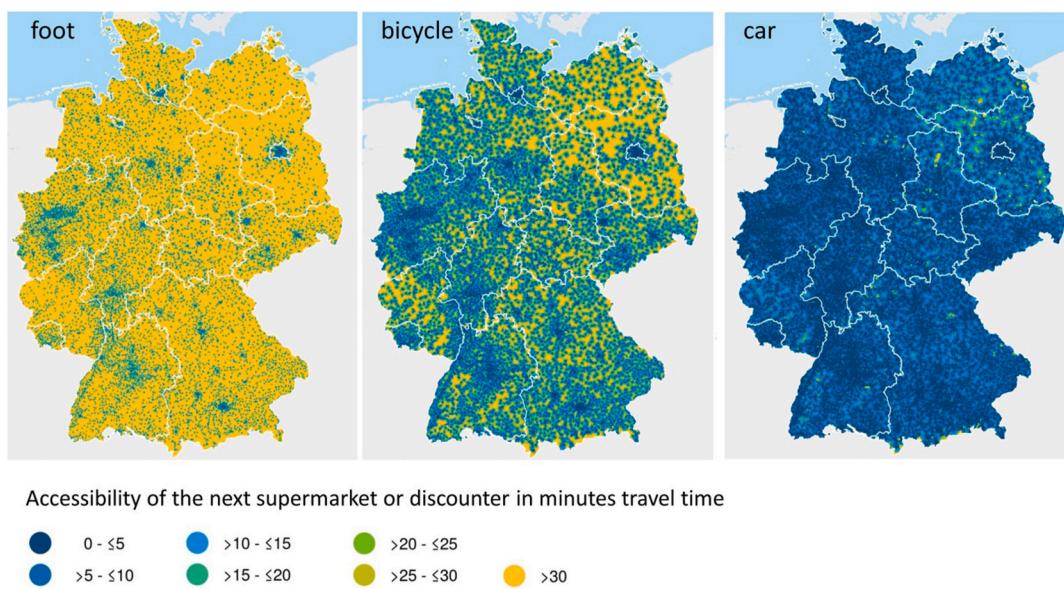


Fig. 2. Accessibility of the nearest supermarket or discounter by means of transport. Source: Authors' calculation.

Brandenburg and Rhineland-Palatinate. In a more dispersed pattern, such regions can also be found within all other federal states except North Rhine-Westphalia and the three city-states.

The results here confirm that the means of transport influences the accessibility of supermarkets and discounters directly. Focusing on foot as the means of transport, about 82% of the rural communities

²⁷ We were not able to run a routing for the means of transport 'public transport' for two reasons. First, all information regarding time-tables and routes is the property of the different local public transport providers. Until January 2020, the majority of public transport providers refused to release this data. Although this changed with the Delegated Regulation 2017/1926 of the European Union, the available data on public transport still has significant gaps. Second, the task of modelling public transport accessibility is quite complex and computationally intensive. We are currently in the conceptional and testing stage and thus cannot deliver robust results.

potentially qualify as food deserts. Of the approximately 46 million people that live in rural regions, 63% live in these communities. Regarding the means of transportation bicycle, about 44% of the rural communities potentially qualify as food deserts, being home to some 15% of the rural population. Finally, with the means of transport car, it is 45 communities (0.4%) that match the criteria of a food desert. These communities are inhabited by 0.04% of the rural population of Germany. Notwithstanding, 12% of the rural communities can be identified as 'potentially perceived food deserts'; 2.5% of the rural population have their domicile within those areas.

5. Summary and conclusion: accessibility of supermarkets and discounters in rural Germany

Based on a raster-based GIS-accessibility analysis, we scrutinised the accessibility of supermarkets and discounters in Germany. With the aim

Table 6

Accessibility of supermarkets and discounter by means of transport, Thünen-Types of Rural Regions, federal states and population 2017.

Thünen Type	Region	travel time in minutes																			
		0 - ≤5	>5 - ≤10	>10 - ≤15	>15 - ≤20	>20 - ≤25	>25 - ≤30	>30	car	bike	foot	car	bike	foot	car	bike	foot	car	bike		
		means of transport																			
		car	bike	foot	car	bike	foot	car	car	bike	foot	car	bike	foot	car	bike	foot	car	bike		
		population in %																			
total	Germany	88	68	18	11	16	29	1	6	19	0	4	9	0	3	5	0	2	3	0	1
very rural/less good socio-economic situation		75	51	13	21	16	21	4	10	15	0	9	8	0	6	5	0	4	4	0	5
very rural/good socio-economic situation		81	54	12	18	19	23	2	10	17	0	8	10	0	5	6	0	3	4	0	2
rather rural/good socio-economic situation		88	63	14	11	19	26	1	8	20	0	5	11	0	3	6	0	1	4	0	1
rather rural/less good socio-economic situation		82	58	14	16	17	25	2	9	17	0	7	9	0	4	5	0	2	4	0	2
not rural		97	83	23	3	13	36	0	2	21	0	1	9	0	0	4	0	0	2	0	0
total	Schleswig-Holstein	85	63	15	14	18	26	1	6	20	0	6	11	0	3	5	0	2	3	0	2
very rural/less good socio-economic situation		81	56	13	17	19	22	2	8	18	0	8	10	0	5	6	0	3	4	0	2
very rural/good socio-economic situation		83	60	13	15	20	24	1	7	20	0	6	12	0	4	6	0	2	4	0	2
rather rural/good socio-economic situation		80	56	14	18	18	23	2	8	17	0	7	11	0	5	6	0	3	4	0	3
not rural		96	80	22	4	15	33	0	3	23	0	1	11	0	1	4	0	0	2	0	0
total	Hamburg	98	87	26	2	10	39	0	1	20	0	0	8	0	0	3	0	0	2	0	0
very rural/less good socio-economic situation		98	87	26	2	10	39	0	1	20	0	0	8	0	0	3	0	0	2	0	0
very rural/good socio-economic situation		86	63	15	13	17	27	1	8	19	0	5	10	0	3	5	0	2	3	0	1
rather rural/good socio-economic situation		81	55	12	17	19	23	2	9	18	0	7	10	0	5	6	0	3	4	0	3
rather rural/less good socio-economic situation		85	59	14	14	20	25	1	9	18	0	6	10	0	3	7	0	2	4	0	1
not rural		83	56	13	17	19	23	1	10	18	0	7	10	0	4	6	0	2	4	0	1
total	Bremen	97	82	23	3	12	36	0	3	21	0	1	8	0	1	4	0	0	2	0	0
very rural/less good socio-economic situation		98	85	23	1	13	38	0	1	22	0	0	10	0	0	4	0	0	2	0	0
very rural/good socio-economic situation		98	85	23	1	13	38	0	1	22	0	0	10	0	0	4	0	0	2	0	0
rather rural/good socio-economic situation		94	74	17	6	17	31	0	5	23	0	2	11	0	1	5	0	0	3	0	0
rather rural/less good socio-economic situation		77	50	12	20	16	22	2	11	14	0	10	9	0	6	5	0	3	3	0	4
not rural		89	65	15	10	20	27	1	8	21	0	4	12	0	2	6	0	1	4	0	1
total	North Rhine-Westphalia	93	73	16	7	17	30	0	5	24	0	3	12	0	2	5	0	0	3	0	0
very rural/less good socio-economic situation		87	58	12	13	21	24	0	12	20	0	6	11	0	3	6	0	1	5	0	0
very rural/good socio-economic situation		96	78	19	4	17	33	0	3	23	0	1	11	0	1	5	0	0	3	0	0
rather rural/less good socio-economic situation		91	68	16	9	16	30	0	7	20	0	5	10	0	2	5	0	1	3	0	1
not rural		78	49	11	21	17	20	1	12	15	0	10	9	0	6	5	0	4	4	0	3
total	Hessen	86	55	12	14	21	23	0	10	18	0	8	11	0	4	6	0	2	4	0	1
very rural/less good socio-economic situation		89	63	13	10	19	28	1	9	19	0	6	10	0	2	6	0	1	4	0	1
very rural/good socio-economic situation		98	84	21	2	13	37	0	2	23	0	1	10	0	0	4	0	0	2	0	0
rather rural/less good socio-economic situation		80	53	13	18	18	22	2	10	16	0	8	10	0	5	6	0	3	4	0	3
not rural		67	38	10	29	17	15	4	14	12	0	12	8	0	8	5	0	5	4	0	6
total	Rhineland-Palatinate	88	57	11	12	22	22	0	10	21	0	6	12	0	3	7	0	2	4	0	0
very rural/less good socio-economic situation		83	56	12	15	20	24	2	11	17	0	7	10	0	3	6	0	2	5	0	2
very rural/good socio-economic situation		97	78	21	3	18	33	0	3	22	0	1	12	0	0	5	0	0	3	0	0
rather rural/less good socio-economic situation		90	67	16	10	18	28	1	7	20	0	4	10	0	2	6	0	1	3	0	1
not rural		77	47	12	21	15	19	1	12	15	0	11	8	0	8	6	0	5	2	0	2
total	Baden-Württemberg	79	51	11	20	19	21	2	11	16	0	9	10	0	6	6	0	3	4	0	2
very rural/less good socio-economic situation		89	62	14	10	21	26	1	9	19	0	5	11	0	2	6	0	1	4	0	1
very rural/good socio-economic situation		97	80	20	3	15	34	0	4	23	0	1	10	0	0	5	0	0	2	0	0
rather rural/less good socio-economic situation		97	80	20	3	15	34	0	4	23	0	1	10	0	0	5	0	0	2	0	0
not rural																					

to provide policy makers and scientists with the necessary data about the status quo of local supplies, we embedded our research in approaches to the food desert discourse. Our goal was to highlight the question whether food deserts – in a spatial sense – exist in Germany and to estimate the affected population. The results of the accessibility analysis are unambiguous: Although a close-meshed net of supermarkets and discounters can be found in Germany, there are some gaps. Interestingly, for rural regions, it seems to be more a question of rurality than of the socio-economic status of a region, that decides about grocery store

accessibility in general. In particular, outside the core settlements of rural areas, the accessibility by foot is problematic. Accessibility by bicycle is slightly better, given that travel times up to 30 min are accepted. Nevertheless, in the peripheral regions outside the core settlement areas and its surroundings, accessibility by bicycle is not always given. Within the vast majority of rural areas, retail food stores can be reached within a travel time of 15 min by car. Thus, it can be concluded that it is especially the less mobile people – mostly young adults and elderly people – living in rural regions for whom food retail stores are inadequate

Source: Authors' own analysis.

accessible. Although in rural areas the share of public transport use for grocery shopping is quite low (2%–8%), a consideration of public transport accessibility of food retail stores would be a valuable

completion to our analysis especially with regard to the observable trend towards an ageing rural population. Unfortunately, the necessary data as well as technical prerequisites for conducting public transport

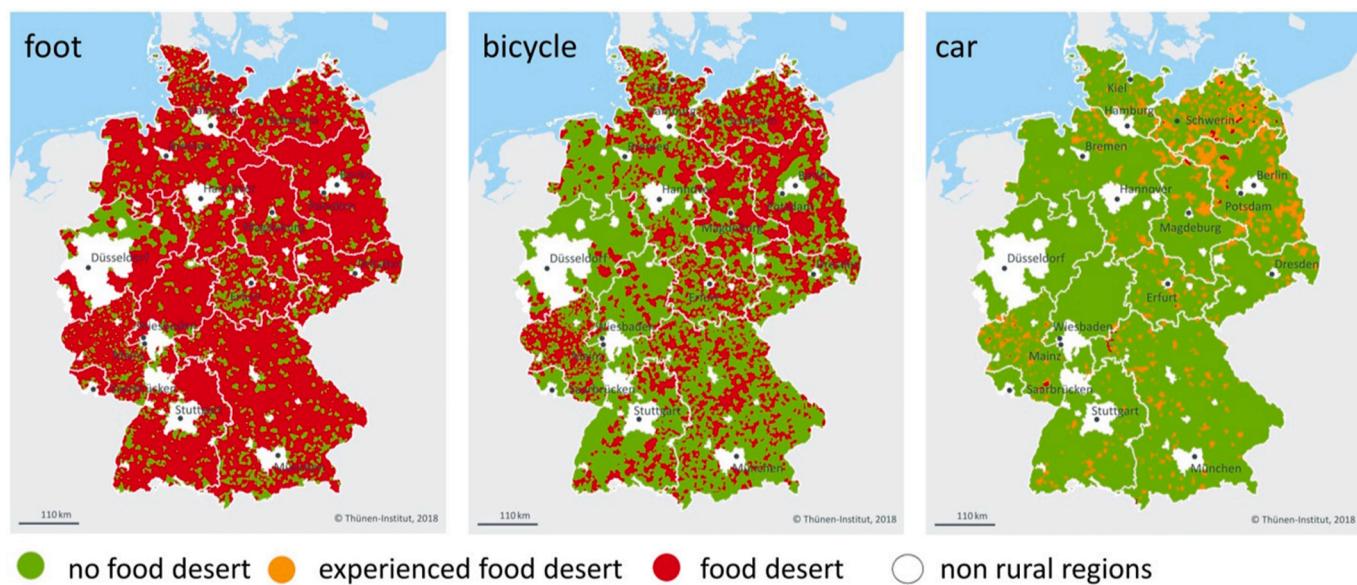


Fig. 3. Identified ‘food deserts’ in rural Germany by means of transport²⁷ at the administrative level of the communities. Source: Authors’ calculation; Rural Typology: Küpper (2016).

accessibility analyses for Germany as a whole were not available.²⁸

Although online shopping has increased steadily, at present, it cannot compensate a missing food retailer near the place of residence (Kokorsch and Küpper, 2019). Fast Moving Consumer Goods (FMCG), which include food and beverages, have a share of around 8.4% of the total online trade (Handelsverband Deutschland, 2019b). However, food products are hardly purchased online (1.2% in 2018) (Handelsverband Deutschland, 2019b). Home delivery services of supermarkets are only available in the bigger cities in Germany and even there with a limited capacity.

Considering the above conclusions, we address the question of the spatial existence of food deserts in Germany.

Our analysis revealed that the answer to this question is linked to the means of transportation and mobility in general. Our findings on the existence of food deserts in Germany are in line with those of White et al. (2004) or Coveney and O’Dwyer (2009). White et al. (2004) conclude that food deserts exist only for a minority of people who do not or cannot shop outside their immediate locality and for whom the locality suffers from poor retail provisions of foods (Cummins et al., 2008, p. 403 cited after White et al., 2004). According to Coveney and O’Dwyer (2009) the available means of transport is one of the decisive factors determining if one lives in a food desert or not. We can confirm these findings for the German context. More concrete, from a macro level point of view, there is strong evidence that living in the same rural neighbourhood the question about adequate accessibility depends on the individual mobility and varies between those who can use a car and those who cannot. Hence, living in a food desert is likely to be more of an individual experience, depending on individual living conditions and capabilities than a spatially distinct phenomenon. In this sense, focusing on the means of transport foot, our analysis revealed that 82% of rural communities match the criteria of a food desert. A number that drops drastically, when the means of transportation is a bicycle (44%) or car (0.4%).

Apart from this, we introduced a third category to the food desert discourse, namely ‘potentially perceived food deserts’. With the

introduction and operationalisation of this category, we discussed the thoughts expressed in some studies that food deserts are less likely a distinct spatial phenomenon universally affecting all people living in a certain region, but more an individual experience (see for example Jürgens, 2018; Jürgens, 2015; Küpper and Eberhardt, 2013b; Hillstrom, 2012). We thus developed a methodology to identify such areas at the macro level with the help of a data driven analysis. Applied to Germany, we can show that the almost negligible number of 0.4% of potential car users live in food deserts, contrasted by some 12% of rural communities that qualify as ‘potentially perceived food deserts’; that is, communities where a considerable share of the population experiences longer travel times than on community average. Such ‘potentially perceived food deserts’ are inhabited by approximately 2.5% (or approximately 1.2 Million people) of the rural population. As travel times to food retail stores are comparatively longer in connected parts of Mecklenburg-West Pomerania, Brandenburg, Rhineland-Palatinate and the North of Saxony-Anhalt, less mobile people living in these areas are more likely to live in a ‘Potentially Perceived Food Desert’. Except North Rhine-Westphalia, such regions exist in all federal states, but to a lesser extent and with a more dispersed pattern.

An overall conclusion of this analysis, and thus the main contribution to the still young discourse on food deserts in Germany, is that food deserts are just to a certain extent a distinct spatial phenomenon, that can be identified on the basis of GIS-analysis and numbers. In this context it has to be noted that our research design was limited by the unavailability of location data of small independent corner shops/local grocery shops specialised in food products. Such shops complement the German food retail landscape, which is however dominated by retail chain stores. Although these kinds of shops do only play a subordinate role for daily (bulk) grocery shopping for the majority of the population we would like to encourage their inclusion in future research once the necessary data is available. This would provide an even more precise and realistic insight in the German rural food retail landscape. Once such information is available, our approach to define food deserts could be expanded with an additional category focusing on individual food shopping capabilities. That is, regions where ample local grocery stores do exist, but where parts of the people are not in the economic situation to consider these available local stores as daily grocery shopping locations.

In this sense, a macro-level analysis like ours can only be a first step in identifying, addressing and understanding food deserts in Germany.

²⁸ With the Delegated Regulation 2017/1926 of the European Union we are confident that we can supplement our findings presented in this paper with additional considerations on public transport accessibility of food retail stores in the near future.

The maps and figures need to be enriched with individual everyday realities that are linked to the distinctive question of mobility, expectations and capabilities. To fully understand the emergence of food deserts, such observations should also be enriched by and linked to considerations on the effect of local food buying habits and choices as, for example, recommended by Wright et al. (2016) or Shaw (2006). In depth analyses tailored to individual regions with a comparably inadequate access to food retail stores as well as households living in these regions are necessary. The results of our analysis identify such regions in Germany where political intervention with regard to food access might be sensible in light of the discourse on 'Daseinsvorsorge' (basic services) and 'Gleichwertige Lebensverhältnisse' (comparable living conditions).

Last but not least we would like to strongly encourage to also analyse the transferability of our German specific approach presented in this

paper to future food desert studies in comparable international settings.

Availability of data

Research data are not shared

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Declaration of competing interest

The authors declare that they have no conflict of interest.

Appendix A. Thünen-Typology of Rural Areas

The Thünen-Typology of Rural Areas considers rural regions as regions with a low settlement density and population in the surroundings of the regions, low-density areas and a relatively high share in agricultural and forestry areas that are located in a peripheral position to the economic and population centres. The classification is based on the administrative level of the 'Kreisregionen' (county regions: analytical regions where smaller counties and urban communes are merged in order to build homogeneous statistical units comparable to each other throughout Germany). The classification is based on an index calculated by a factor analysis of the following indicators: settlement density (2013), share of agricultural and forestry areas (2013), share of one and two family houses at all houses (2013), regional population potential (2011, 2016 average), accessibility of population and economic centres (2014, 2015, 2016 average). The rural areas are then differentiated according to their socio-economic performance in regions with good and less good socio-economic performance (for details on determining the socio-economic performance, see Küpper 2016). The Thünen-Typology of Rural Areas results in the rural classification depicted in Figure A1.



Source: Küpper 2016

Fig. A.1. Thünen-Typology of Rural Areas. Source: Küpper (2016)

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