Over the Hills and Far Away? Cost Surface Based Models of Prehistoric Settlement Hinterlands

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Abstract

The hinterland of prehistoric settlements played an important role in the agricultural livelihood and the economic exploitation of the environment in general. The size of these hinterland areas may have differed depending on the environment and on the needs of prehistoric people in different periods. According to this thesis we might assume that changes in size and layout reflect a change in settlement behavior and in the use of the natural environment for economic reasons. The algorithms for cost surface models, and the calculation of cost-based catchment areas and least cost paths based on these models have been presented in various papers in the CAA proceedings and elsewhere, cf. inter alia van Leusen 2002 or Herzog and Posluschny, in print; they are not the main topic of this paper. It is the aim of this paper to make use of cost-based catchment areas and to show how they can be used for simple interpretations of sites within their landscape.

***Keywords**: hinterland, site catchment, cost surface, GIS, "Fürstensitze", landscape archaeology*

1 INTRODUCTION

The project "Princely Sites" & Environs ("Fürstensitze" & Umland) investigates the so-called "Fürstensitze" of the Early Iron Age (about 500 BC) in southwestern Germany, eastern France and comparable sites in Bavaria and western Bohemia (fig. 26 [p. 314][1] These rich, fortified settlements, mainly situated on hilltops, are the result of a social and perhaps even cultural change or transformation of or within the proto-Celtic societies, a phenomenon which we still do not understand to its full extent. The aim is to investigate the dynamics of settlements and people from the Late Bronze Age so-called Urnfield Period to the Early Iron Age Hallstatt and the following Early Latène Period on the basis of the interconnection between man, culture, and environment.[2] One of the main questions when investigating these sites and their meaning is the mutual interdependency between the "Princely Sites", which could to a certain extent be compared to Christaller's "Central Places"[3] (and see Gringmuth-Dallmer[4]), and their surrounding area, their hinterland and neighboring settlements. The surrounding settlements are either dependent on the Central Place or the Central Place is dependent on its satellite settlements—or even both. Regular settlements and "Princely Sites" are both dependent on their hinterland regions as a basis for their economic needs. This might be compared with the model of core and periphery, or with Thuenen's isolated state (fig. 1). [5]

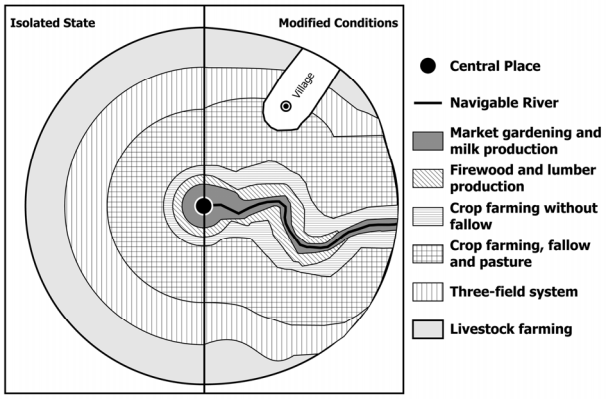

Figure 1. *The idea of Thuenen's isolated state (after Rodrigue, Comtois and Slack, fig. 7.8 [with modifications])*

[1]The underlying studies for this short paper are part of my research on Early Iron Age "Fürstensitze" ("Princely Sites") within the framework of the SPP 1171 program, funded by the German Research Foundation (www.fuersten-sitze.de/1121).

[2]Axel G. Posluschny, "From Landscape Archaeology to Social Archaeology. Finding patterns to explain the development of Early Celtic 'Princely Sites' in Middle Europe," in *Digital Discovery. Exploring New Frontiers in Human Heritage.* CAA Proceedings of the 34th Conference, Fargo, US, April 2006, ed. J. T. Clark and E. M. Hagemeister (Budapest: Archaeolingua 2007) 131–41.

[3]Walter Cristaller, *Die zentralen Orte in Süddeutschland. Eine ökonomisch-geographische Untersuchung über die Gesetzmässigkeit der Verbreitung und Entwicklung der Siedlungen mit städtischen Funktionen* (Jena: Gustav Fischer Verlag, 1933).

[4]Eike Gringmuth-Dallmer, "Methodische Überlegungen zur Erforschung zentraler Orte in ur- und frühgeschichtlicher Zeit," in *Centrum i zaplecze we wczesnosredniowiecznej Europie srodkowej.* Spotkania Bytomskie 3, ed. Sawomir Mozdzioch (Wroclaw: Wydawn Werk, 1999): 9–20.

[5]See also John Bintliff, "Going to Market in Antiquity," in *Zu Wasser und zu Land. Verkehrswege in der antiken Welt. Stuttgarter Kolloquien zur Historischen Geographie des Altertums 7, 1999*, ed. E. Olshausen and H. Sonnabend (Stuttgart: Franz Steiner Verlag, 2002) 209–50, at 244–47.

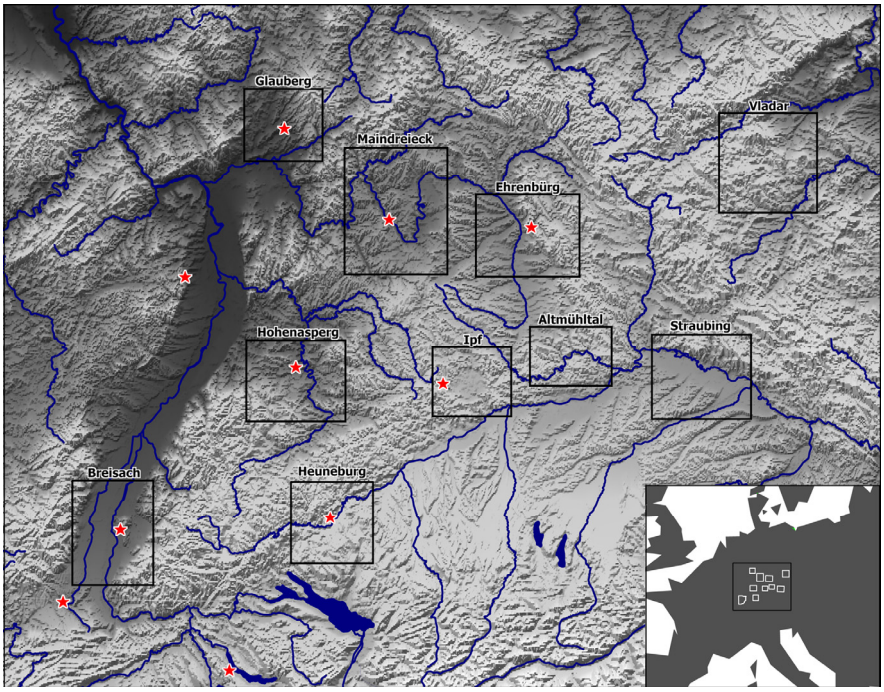

Figure 2. *Research areas within the project "Princely Sites" & Environs–DEM SRTM90.*

The definition of such a hinterland is of greater importance for questions of the economic abilities of the settlements, of subsistence vs. surplus production. The shape and the size of these areas might differ in a regional as well as in a chronological perspective, and there may also be differences between "Princely Sites" and regular settlements.

2 Cost Surface Analyses and Least Cost Paths

Most GIS software offers push-button algorithms to calculate cost distances and least-cost paths. The same is true for the calculation of a cost-dependent area, based on the maximum vicinity that can be reached within a maximum of time, with a maximum of abstract costs or with a maximum of calorie expenditure. Various algorithms are used by different software packages, which all produce results that differ to some extent and which are not always satisfactory.[1] Usually these algorithms are based on a cost or friction model that defines the costs of travel in a landscape.[2] One example that transfers slope into walking speed is the Gorenflo/Gale algorithm, based on Tobler's empirical data that has been collected from soldiers hiking different types of terrain.[3]

The result is a model of walking speed, calculated in kilometers per hour. For the use as a friction surface it then has to be recalculated into a cost model representing minutes per kilometer for each raster grid pixel. Figure 3 shows the resulting graph for the Gorenflo/Gale algorithm, where the minimum costs (maximum speed) correspond to a slight downhill slope (ca. -0.05), whereas steeper downhill slopes as well as uphill slopes result in lower speed (higher costs). The following calculations are all based on this cost model, using the IDRISI cost grow routine.[4] The algorithm presented by Llobera and Sluckin[5] is potentially a better

[1]Irmela Herzog and Axel G. Posluschny, "Tilt—Slope-dependent Least Cost Path Calculations Revisited," in *On the Road to Reconstructing the Past.* Proceedings of the 36th CAA Conference, Budapest, April 2–6, 2008 (Budapest: Archaeolingua, in press).

[2]David Wheatley and Mark Gillings, *Spatial Technology and Archaeology. The Archaeological Application of GIS* (London: Taylor & Francis, 2002) 151–163; James Conolly and Mark Lake. *Geographical Information Systems in Archaeology.* Cambridge Manuals in Archaeology (Cambridge: Cambridge University Press, 2006) 215–226.

[3]P. Martijn van Leusen, *Pattern to Process. Methodological Investigations into the Formation and Interpretation of Spatial Patterns in Archaeological Landscapes* (Ph.D. diss., Groningen University, 2002), http://irs.ub.rug.nl/ppn/239009177 (accessed November 7, 2006). van Leusen describes slope in the Gorenflo/Gale formula as slope of terrain in degrees while it should be mathematical slope, i.e. slope in percentage/100.

[4]J. Ronald Eastman, *IDRISI Kilimanjaro. Guide to GIS and Image Processing* (Worcester, MA 2003) 93; see also www.spatialanalysisonline.com/output/html/Accumulatedcostsurfacesandleastcostpaths.html (accessed April 14, 2009).

[5]Marcos Llobera and Tim J. Sluckin, "Zigzagging: Theoretical Insights on Climbing Strategies." *Journal of Theoretical Biology* 249 (2007): 206–17.

better fit for rough landscapes with steep slopes,[1] but as the idea of the settlement hinterland within a region of maximum height differences such as those in middle range mountain areas is strongly connected to arable landscapes, the hinterland calculation is restricted to non-alpine like regions, where the zigzagging potential of the algorithm mentioned by Llobera and Sluckin is not likely to be of much importance.

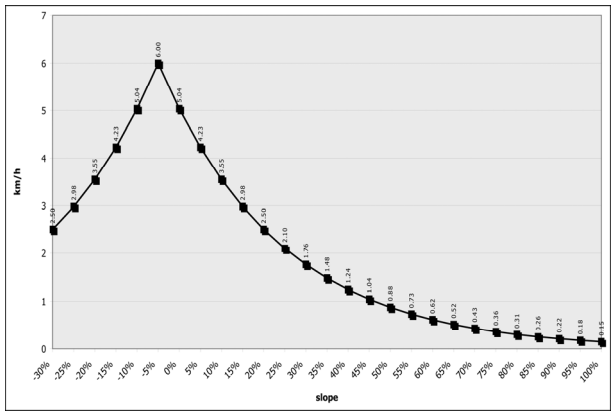

Figure 3. *Graph of the walking speed (km/h) based on slope, calculated with the Gorenflo/Gale algorithm.*

3 HINTERLAND DEFINITION

One main task when modeling a hinterland or the area of every day extensive use is to define the border of such an area. Prehistoric people certainly did not have strict rules for the limitation of their usable vicinity, but on the other hand it is sensible to assume that simply for economical reasons it was not very advisable to use land beyond a certain distance from a settlement. Chisholm,[2] and following him Bintliff,[3] argued—based on cost-benefit ratios—that the land used for agricultural needs, mainly for plowing, will not be further away than 1 or 2 km, which is approximately a 12–24 minute walk.[4] The hinterland used for cattle farming, exploiting forestal resources, and similar activities should be no further away than 5 km, or 1 hour of walking time.[5]

4 HINTERLAND LAYOUT AND SIZES

The research area of the "Fürstensitz" Marienberg in Northern Bavaria is presented in figure 4a. The polygons mark the calculated areas for a 60 minute walk for settlements of the Hallstatt period, when the importance of the Marienberg "Fürstensitz" reached its climax.

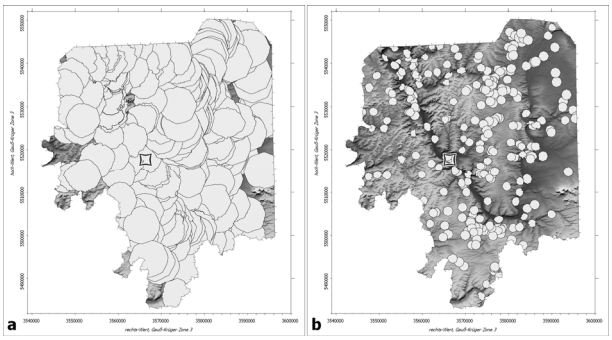

Figure 4 a. *Cost-based hinterland areas within 60 min. walking time in the area of the Marienberg "Fürstensitz" (Northern Bavaria).* **b.** *Cost-based hinterland areas within 15 min. walking time in the area of the Marienberg "Fürstensitz" (Northern Bavaria). DEM D-25 (25 m grid), © German Federal Office for Cartography and Geodesy 2004.*

The overlapping of most of the areas reveals that the areas exploited might belong not only to one, but to several settlements, even when we take into account that many of the settlements from one period—c. 300 years—were not coexistent. Social interaction as well as some kind of "political" agreements must have been the basis for contemporaneous settlements, using the same economic and cultural hinterland.

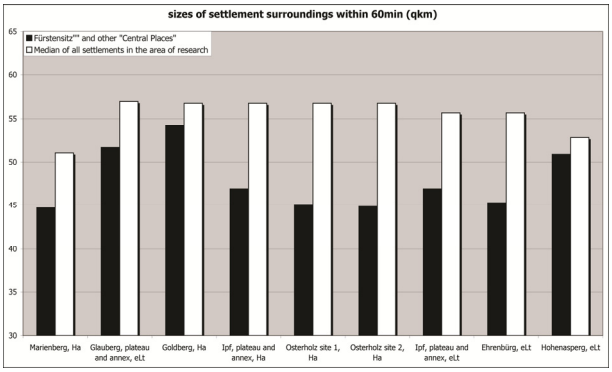

Figure 5. *Median values of the "hinterland" size (km2) of the regular settlements within each research area (white) compared to the size of the hinterland of the "central place" itself (black).*

Hinterland mapping is significantly different for the areas used for every day farming activities within a distance of 15 minutes walking, where it is obvious that there is a minimum of overlapping (fig. 4b); it is most likely that overlapping is to be expected mainly for those sites that were not contemporary.

[1]Herzog and Posluschny, p. 316n1.

[2]Michael Chisholm, *Rural Settlement and Land Use* (New Brunswick and London: AldineTransaction, 1962).

[3]John Bintliff, "Settlement and Territory," in *Companion Encyclopedia of Archaeology Vol. 1,* ed. Graeme Barker (London and New York: Routledge, 1999) 505–545; Bintliff, 2002, (p. 315n5).

[4] Bintliff, 2002 (p. 313n5) 245.

[5] Bintliff, 1999 (p. 315n4) 523–537.

Figure 5 shows the median values of the "hinterland" sizes of the regular settlements within each area of research (cf. fig. 1) compared to the size of the hinterland of the "Central Place" itself. The median values do not differ as much in the interregional perspective as do the sizes of the surroundings of the "Central Places". In general, the hinterland areas of the regular settlements are more or less comparable, while the "Princely Sites" and other important places obviously differed much more.

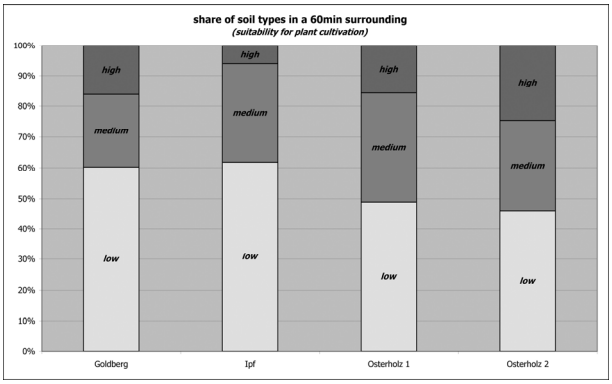

Figure 6. *Availability of soils within the 60 mins. hinterland area of the "Central Places" in the Nördlinger Ries (Ipf area).*

Within the area of the Nördlinger Ries, with its sites of the "Fürstensitz" Ipf and the two ditch enclosures of Osterholz, we can see the biggest spread between the regional mean value and the central place values. Only the fortified hillfort Goldberg in the same area is much more like the regular settlements here. The Ipf itself has the largest share of soil with low suitability for plant cultivation in its environs, as well as the smallest share of high quality soils.

In contrast, the availability of good or at least medium soils (fig. 6) is much greater around the ditch enclosures of Osterholz, which is balanced by their smaller surrounding areas. The Goldberg, with its larger hinterland, also had a relatively high percentage of good soils. Indicated in absolute measures (fig. 7), the high availability of suitable soils around the Goldberg is still apparent, as are the medium levels around the ditch enclosures and the very low availability around the "Fürstensitz" Ipf itself.

In Celtic times people made their living mainly by crop and cattle farming, so large hinterland areas where the median values are more or less the same as the value of the hinterland size of the "special settlement" itself are an indication of a mainly agricultural based way of life for the inhabitants of the "Central Place". We can assume that this was the case for the Goldberg (fig. 8), while the "Fürstensitz" on the Ipf itself (fig. 9), as well as the ditch enclosures of Osterholz on its foothills, seem to have played different roles in the settlement system.

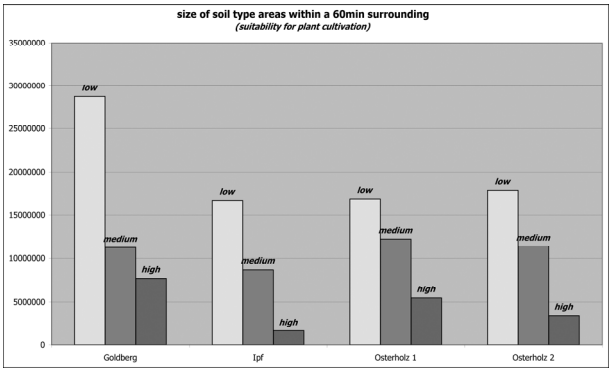

Figure 7. *Availability of soils within the 60 mins. hinterland area (absolute measures) of the "Central Places" in the Nördlinger Ries (Ipf area).*

Figure 8. *Aerial photo of the Goldberg in the Nördlinger Ries.*

Figure 9. *Aerial photo of the Ipf in the Nördlinger Ries.*

The Ipf is more or less a landmark in both a cultural/ritual and in an economical way as part of a traffic and trading system, whereas we have some, as yet weak, evidence that at least one of the Osterholz ditch enclosures ("Bugfeld") might have been a site with a ritual meaning.[1]

[1] Rüdiger Krause et al., "Der frühkeltische Fürstensitz auf dem Ipf bei Bopfingen im Nördlinger Ries (Ostalbkreis, Baden-Württemberg). Neue Forschungen zur Burg und deren Siedlungsumfeld," in *Frühe Zentralisierungs- und Urbanisierungsprozesse. Zur Genese und Entwicklung früh-keltischer Fürstensitze und ihres territorialen Umlandes.*

5 FEEDING "PRINCES" AND SUBJECTS

The region within 60 minutes walking around the Marienberg "Fürstensitz" is an area of 51 square kilometers or nearly 12,700 acres (fig. 10).

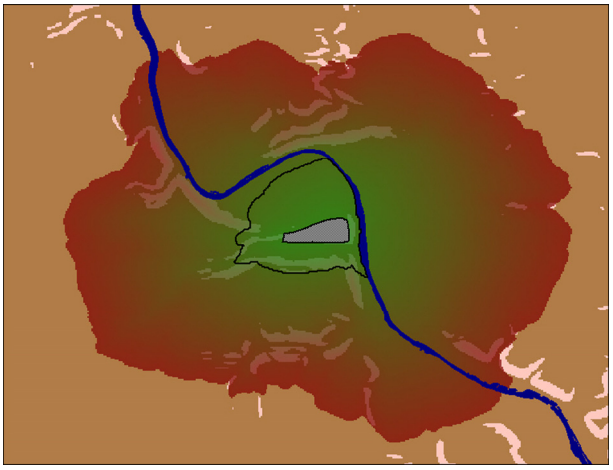

Figure 10. *The Marienberg site (grey) with its 60 mins. hinterland area. Brown: slope < 15°, pink: slope > 15°. DEM D-25 (25 m grid), © German Federal Office for Cartography and Geodesy 2004.*

This calculation is again slope based on walking speed, while the river Main, which is obviously a large obstacle within the landscape, was added as an area of slower movement. The area around the hillfort today is part of the city of Würzburg, so we do not have much information on the availability and the quality of arable land. When we want to ascertain whether the area around the Marienberg was suitable for crop farming, we have to use other means of assessment. The degree of slope gives us at least information on which areas could have been used for plowing, which was only possible on slopes of up to 15°.[1] Areas in brown are those with less than 15° slope, pink indicates slopes too steep for plowing.

On the other hand, it is not very likely that in general people walked 1 hour to and 1 hour back from their fields nearly every day in order to plow, weed, harvest or take care of their crops. So obviously a 15 minute walk (fig. 11), as mentioned above, demarcates an area of 433 hectares—much more suitable for every day agricultural activities. If we assume that prehistoric people did not cross the river Main to reach their fields, only 325 hectares remain accessible and of these only 85 % are not too steep to be ploughed, which is 275 hectares.

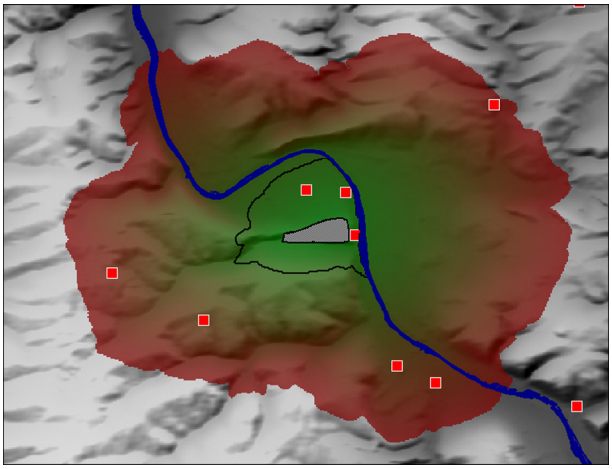

Figure 11. *The Marienberg site (grey) with its 15 mins. hinterland area within the 60 mins. area and the surrounding settlements (red squares).—DEM D-25 (25 m grid), © German Federal Office for Cartography and Geodesy 2004.*

According to our calculations, these 275 hectares are suitable for producing cereals for 678 to 1356 people (fig. 12).[2]

The hilltop settlement of the Marienberg is large enough to house up to 700 or even 1,000 people; although we might even assume a maximum of 400 people, based on the sparse density of the remains of housing on the hilltop. The crop that could be produced in the vicinity is sufficient to feed all these people, as long as we do not incorporate further land limitations based on soil quality.[3]

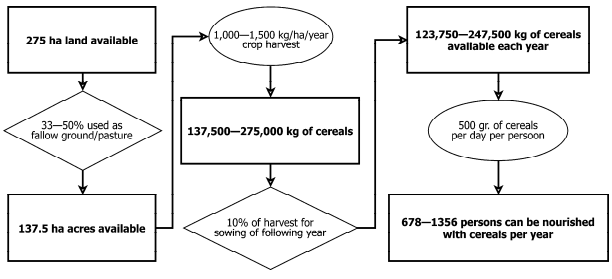

Figure 12. *Calculation of crop yield within the 15 mins. hinterland area around the Marienberg.*

Kolloquium des DFG-Schwerpunktprogramms 1171. Blaubeuren, Oct. 9–11, 2006. Forschungen und Berichte zur Vor- und Frühgeschichte in Baden-Württemberg 101, ed. Dirk Lutz Krausse (Stuttgart: Konrad Theiss Verlag, 2008) 249–79.

[1]Angela Kreuz and Klaus Friedrich, "Site-Catchment Analyse und Schätzung des eisenzeitlichen landwirtschaftlichen Potentials im Umfeld des Glauberges, ein Zwischenbericht," http://www.fuerstensitze.de/1180 (accessed April 22, 2008). A limitation of 7° for plowing is supposable only for modern agricultural activities with deeper and more effective plowing (use of a sod-turning plow), which results in a problematic amount of erosion (oral information from Elske Fischer, Manfred Rösch, Astrid Stobbe and others, March 5, 2009).

[2]See previous note.

[3]The choice of a 15 instead of a 24 min. catchment area already takes into account the low availability of soils which are suitable for crop farming.

The red squares in figure 11 indicate the existence of contemporary (but not necessarily coexistent) settlement sites. The one at the foot of the Marienberg is most likely some kind of trading place on the river Main closely connected to the hillfort on the Marienberg some 80 meters above it.[1]

All other settlements, especially those quite near the Marienberg, might then have been responsible for the feeding of the inhabitants of the "Princely Site" if we believe that the soil quality within 15 min. walk from the Marienberg was not suitable for crop farming. It is quite likely that there was a close relationship between the "Fürstensitz" and the surrounding settlements. It was possible without the support of the regular settlements to feed the people on the Marienberg with crops from their own fields, but the possible production of a surplus from crop farming, which could have provided a source for wealth and prosperity, was dependent on the surrounding settlements. The "Fürstensitz" itself was most likely in a position to benefit from its importance as a center of trade and contact, while the regular settlements around it gained from this wealth, from the presence of craftsmen in or around the hillfort, and from its protection. Simple calculations could show that it was not the agricultural aspect of the "Fürstensitz" itself that was responsible for its importance. In the case of the Marienberg, it is very likely that its important role was based on the site being a trading point with long distance connections, especially along the river Main.

6 Conclusion

This paper intended to show that the use of basic GIS tools is still one of the easiest ways to increase the benefit of computer based analyses, especially in landscape and settlement archaeology. In the examples shown above the results and the interpretation of data are not so much dependent on different algorithms, but very much based on the (correct) use of the method itself and the underlying prerequisites, such as the definition of the maximum agricultural hinterland area (e.g. 15 mins. walking time).

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[1]Michael Hoppe."Keltische Salzsieder in Würzburg?" *Das Archäologische Jahr in Bayern* (2001): 64–5.

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