University of Bern

Geographical Institute

Spring semester 2018

Supervising professors: Jorge Ramirez, Pascal Horton & Andreas Zischg

Environment analysis of prehistoric lake settlements in Switzerland

Author: Corina Gottardi

Tel. 078 779 92 73, mail: corina.gottardi@students.unibe.ch

Student number: 13-111-737

Date: 31.08.2018

Table of contents

1. Introduction 3
2. Methods and available data 3
3. Analyses 4
   3.1. Visibility analysis 4
   3.2. Soil suitability analysis 6
   3.3. Land-lake ratio analysis 10
   3.4. Landform classification based on the topographic position index (TPI) 14
   3.5. Nearest river analysis 17
4. Conclusion 19
5. Bibliography 20

1. Introduction

In Germany, Austria, France, Slovenia, Italy and Switzerland a typical settlement type in the Neolithic and Bronze Age are lake settlements. Today, due to changing lake levels over the last thousands of years, many of them are either submerged in the lake or at least in a permanently wet soil. These circumstances lead to an exceptional preservation of the artifacts and the remainings of the houses themselves. This makes lake settlements extremely important for archeological researches, since next to bone, stone and ceramic artifacts also wooden artifacts and textiles can still be found. This was also acknowledged by the UNESCO World Heritage program. Of the several 100 known lake settlements 111 were given the world heritage status, 56 of them are situated in Switzerland (Palafittes 2015). In this project paper the focus was not on the findings of the settlements, which most of the research concentrates on, but on the surrounding environment. The aim of the project paper was to find out if there are common landscape patterns beside the lakes, to see if the closeness to water was the only factor for the settlement location or not. For this purpose analyses were conducted to research the visibility of the settlements, the soil suitability and the landforms of the surrounding environment as well as the ratio of land and water and the distance to the nearest river.

2. Methods and available data

For all analyses a Python script was made which is supported by ArcGIS. To carry out functions from ArcGIS the arcpy library was used. The library matplotlip was used to display graphics and simpledbf to convert dBase files to data frames. Finally, the library os was used to join certain paths.

For the analyses an Excel file of the settlements with coordinates was used which was provided by Barbara Fath from the Swiss Coordination Group UNESCO Palafittes. From this Excel file a point shapefile was created. The digital elevation model and the river and lake data are from Swisstopo. The soil suitability map can be found on the federal administration website under the section of the federal office for agriculture FOAG where the map itself and further geodata are provided (Bundesamt für Landwirtschaft BLW 2016).

3. Analyses

For this project five different scripts and analyses were made since each could be used individually. The separated scripts simplify the use if another researcher is only interested in some of the analyses later on.

3.1 Visibility analysis

The visibility Analysis was conducted (fig. 1) to see if it was of importance, that the settlements were visible from far away and/or if it was important to see as far as possible from the settlement. This could be of importance because of prestige or also from a standpoint of defense. The "visibility" function already exists in ArcGIS; however, with Python a loop was created that allowed to automatically conduct this analysis for each settlement separately. Normally, this would have to be done manually for each individual settlement. The reason is, that if you conduct the "visibility" function for all settlements at once you cannot see which visible area belongs to which settlement in the resulting raster and attribute table. Furthermore, Python was also used to save the information of the visible area in square meters for each settlement in a combined dBase file which in turn allowed to do a small statistical analysis.

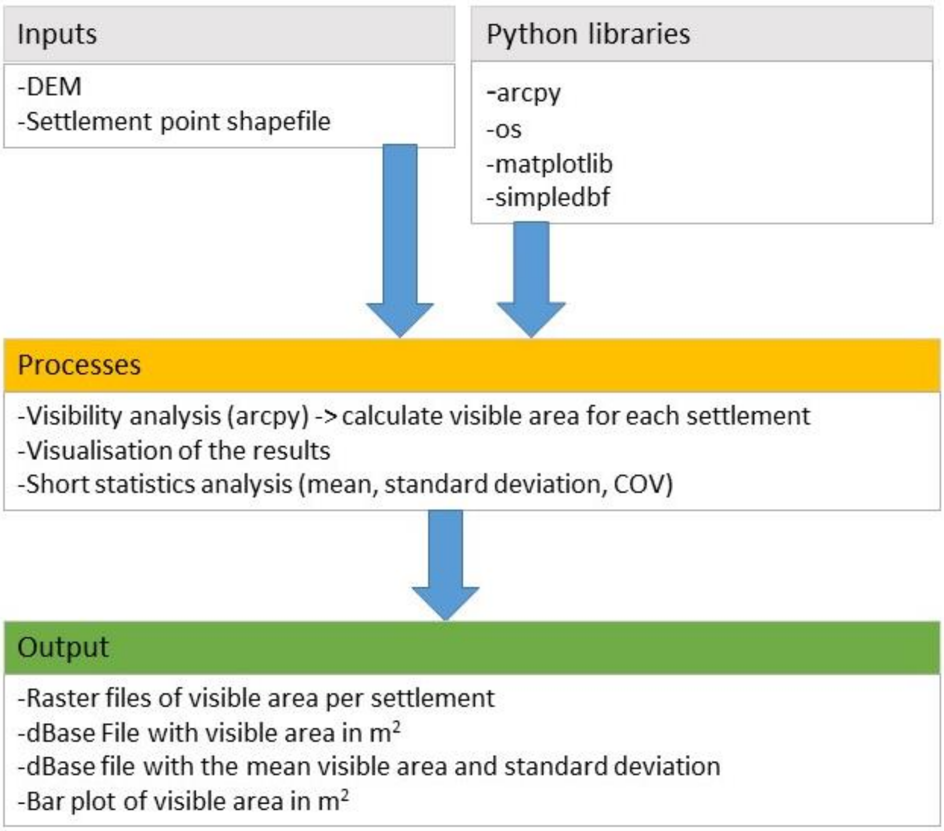

Fig. 1: Work flow of the visibility analysis

The results showed that the visible area can vary greatly from village to village (fig. 2). There is a spike around 100'000'000m^2 to 230'000'000 m^2; however, there are still more than 20 settlements more or less evenly spread between 300'000'000 m^2 and 760'000'000 m^2 of visible area. This high variety also shows if you compare the mean of 283'487'857 m^2 to the standard deviation of 200'245'602 m^2 which leads to a coefficient of variance of 70.6 percent. If the visible area was important for the location of the settlement you would rather expect a more distinct cluster of villages around a certain amount of visible area. The high standard deviation and coefficient of variance underline that it is not likely that a high visibility was important for the location of the settlement.

Further tests could be done with the "visibility" function with different settings. For example, there is the possibility to elevate the point of observation, in this case a point in the village, to imitate a watchtower. In this study this setting was not used because a lot of the land was covered in forests in Neolithic and Bronze Age times. For this analysis the simplified assumption was made that the height of the trees and the height of a possible watchtower would balance each other out and no adjustments needed to be made. Another possibility for further research would be to limit the distance of the "visibility" function to a radius of for example 20 km which is roughly a day's journey on foot. If there was a rather high amount of visible area compared to non-visible area at this distance it could show that it was possibly important to see people approaching. In this study no limit was set because a tendency to build a settlement in a highly visible place can have different reasons than just to see who approaches. A reason could also be that it was important to be seen by others to show importance. Another possibility could be that a settlement location where you can see certain landmarks or mountains (because of cultish or religious reasons) was desirable.

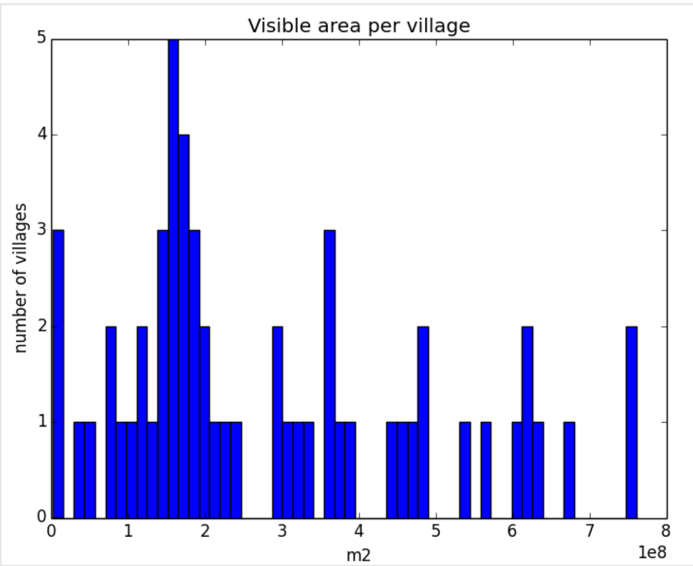

Fig. 2: square meters of visible area per village.

3.2 Soil suitability analysis

Agriculture was an important part of human life since the Neolithic. This soil suitability analysis was conducted to see if settlements were build specifically on or near certain soils which were especially suitable for agriculture. In the attribute table of the soil suitability map of the FOAG are several categories. For this analysis only the soil suitability category was looked at. The soil suitability map has one disadvantage which is that villages or cities are a category of their one (combined with rocks and glaciers). Wherever there is a modern settlement the actual soil type beneath the settlement is not stated. In consequence every soil that is beneath a modern settlement was excluded from this analysis. To my knowledge there is no map available where the soil types/suitabilities beneath settlements are specified for Switzerland.

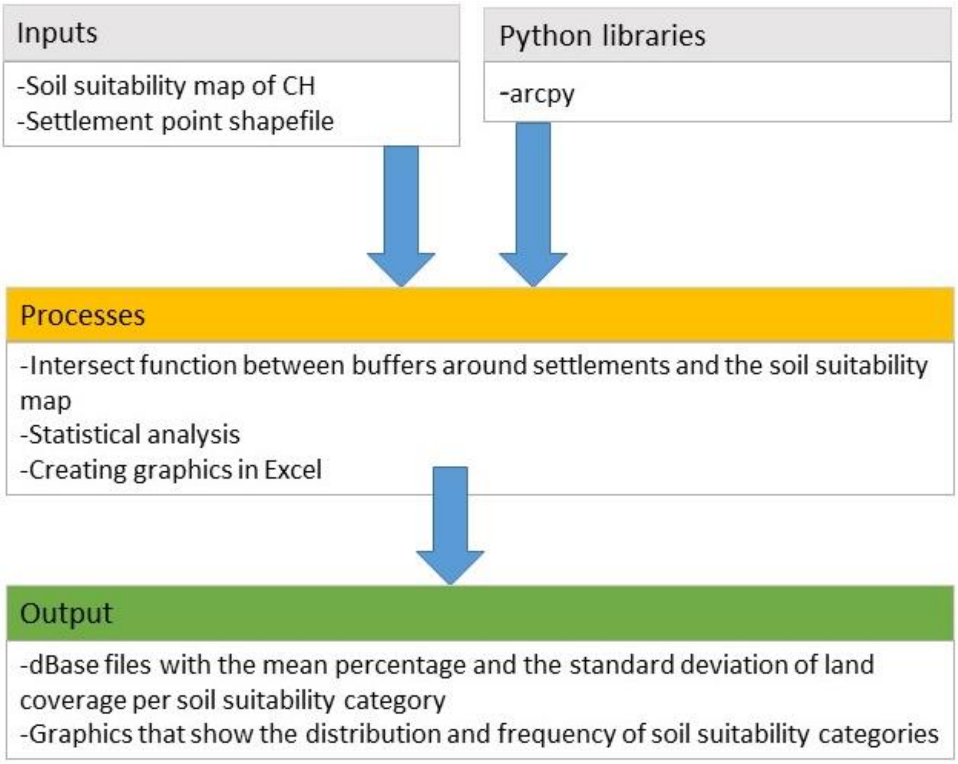

Fig. 3: Work flow of the soil suitability analysis

For the analysis buffers with radii of 100 m, 500 m, 1000 m and 5000 m were set around the settlements. These buffers were then intersected with the soil suitability map. Finally, with a statistical arcpy function the mean percentage of each soil suitability per settlement/buffer was determined. However, the mean percentage is not over all settlements/buffers. If a soil suitability category only appears in five settlements the percentage shows the mean percentage for those five settlements and not for all 56. Below in figures 4 to 7 the results are shown in a bar plot which was created in Excel.

As stated in the manual that accompanied the downloaded geodata from FOAG (Bundesamt für Landwirtschaft BLW: 2016) a "+" next to an agricultural category means suitable, "++" very suitable, "+/-" moderately suitable and "-" not suitable. The category names in the manual are in German. To avoid inaccurate translations for some of the more specific soil suitabilities the German names were kept for the bar plots. The most important translations are: Ackerbau = crop farming, Getreideanbau = cultivation of grain, Futterbau = animal feed production and Viehweide= pasture. For this analysis the categories of crop farming and cultivation of grain are expected to have a higher coverage and frequency than the others.

With the 100 m buffer (fig. 4) there is no clear pattern. The most common category and at the same time the category with the second most land coverage in percent is the category of animal feed production. The second and third most common categories are suitable or even very suitable for crops or grain. However, the third most common category has a relatively low percentage of land coverage compared to the other categories. Furthermore, another category (number 7) that would be suitable for crop production only appears in a few settlements. Because of this, there does not seem to be a clear pattern that good crop or grain land was clearly preferred.

A 100 m radius buffer is also relatively small and it is possible that the agriculture was done a little bit further away from the village. Also, 21 settlements are not included at all because they fall completely in locations where modern settlements are and therefore no information to the soil type is available. With the other buffer distances this is less of a problem because at least a part of the buffer area falls on todays "non-settlement" ground. Lastly, it should be noted that the standard deviation is very high over all.

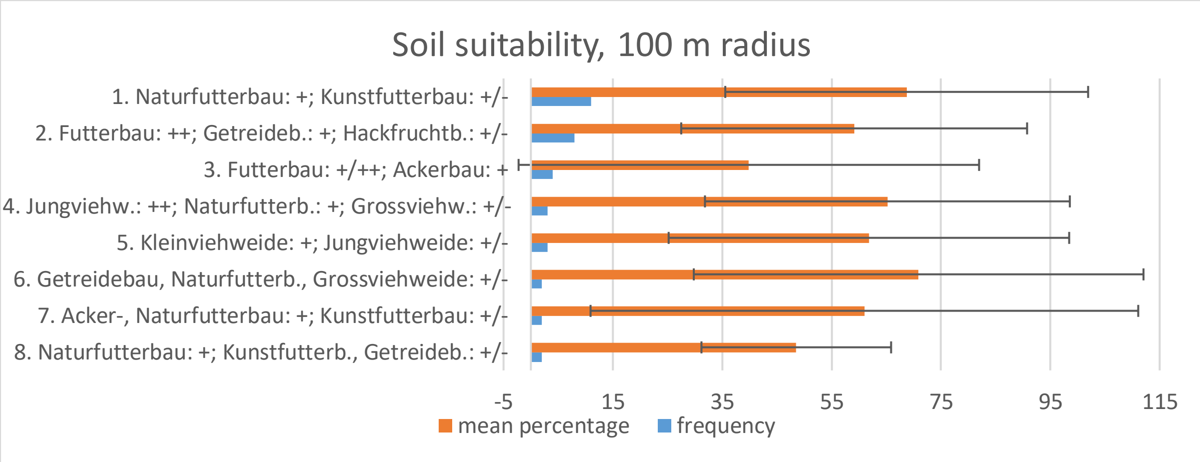

Fig. 4: Mean percentage of land coverage and the number of villages the soil categories appeared in for the 100 m radius buffer. The standard deviation is shown in black.

When the 500 m radius buffer (fig. 5) was used, all categories that contain suitable soil for crop or grain are distributed between the second to seventh most common soil suitability categories. In other words, they are in the upper half of the total 14 categories. This could be a sign for a small tendency that locations with suitable soil for crops or grain were preferred. However, the most common category is most suitable for animal feed production and the category with the most land coverage in percent (number 9) is most suitable for pasture. It has also to be noted that the standard deviation for a lot of the suitability classes is very high again.

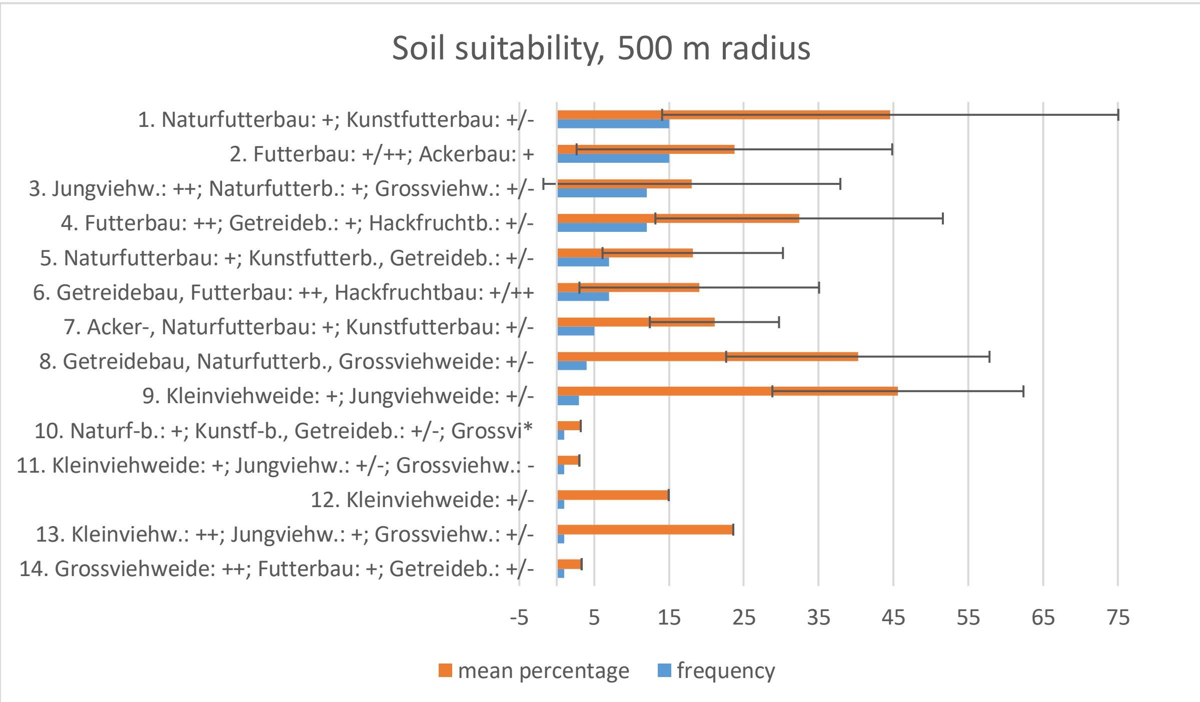

Fig. 5: Mean percentage of land coverage and the number of villages the soil categories appeared in for the 500 m radius buffer. The standard deviation is shown in black.

With the 1000 m radius buffer (fig. 6) the three most common categories are all suitable or even very suitable for either crop or grain land, although with a relatively low percentage of land coverage per settlement. The highest land coverage belongs to a category (number 8) that is only moderately suitably for crops, animal feed production and pasture. Again, as with the 500 m, this could show a small tendency that locations were chosen with suitable land for crops and grain. Although, there is a very high standard deviation again for all the categories that appear in more than one village.

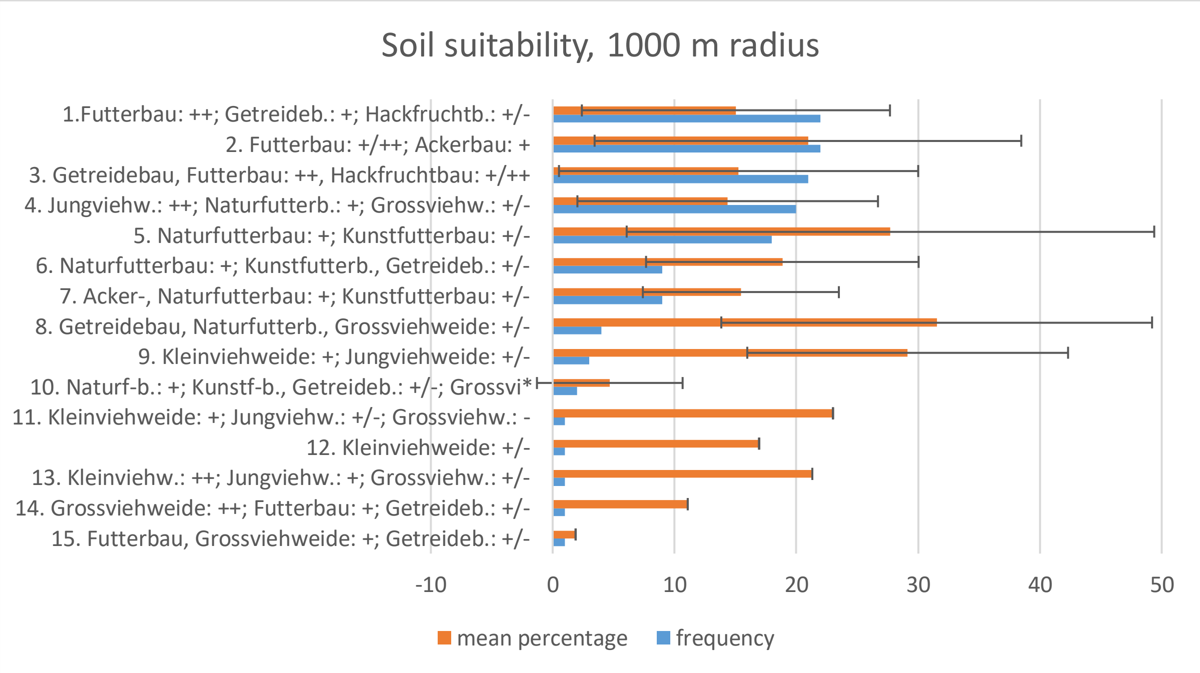

Fig. 6: Mean percentage of land coverage and the number of villages the soil categories appeared in for the 1000 m radius buffer. The standard deviation is shown in black.

Within the first six most common categories are four that are either suitable or very suitable for crop or grain with the 5000 m radius buffer (fig. 7). Most of them even have a high percentage of land coverage per village which shows a possible tendency that specifically locations with land suitable for crops and grain was chosen. As with the first three there is a very high standard deviation for most categories.

Although the 500 m, 1000 m and 5000 m radii buffers show possible tendencies that land suitable for crops and grains was preferred more steps would be needed to confirm it. Firstly, the overall distribution of these soil suitability categories over all of Switzerland or, even better, just around the lakes of Switzerland should be looked at. It is possible that the categories with suitable land for crop and grain are very common everywhere in Switzerland or at least around the lakes and that the figures only show more or less the normal distribution of the categories. Although, even with this additional information it would probably be difficult to get a reliable answer to the research question because of the high standard deviations. What further could be done is to look into other indicators for a good soil in the attribute table of the soil suitability map such as the soil skeleton. It is possible that the standard deviation would not be as high for other categories in the soil suitability map as for the suitability itself. Due to time constrains and to keep the length of this paper a little bit restricted this could not be done in this paper.

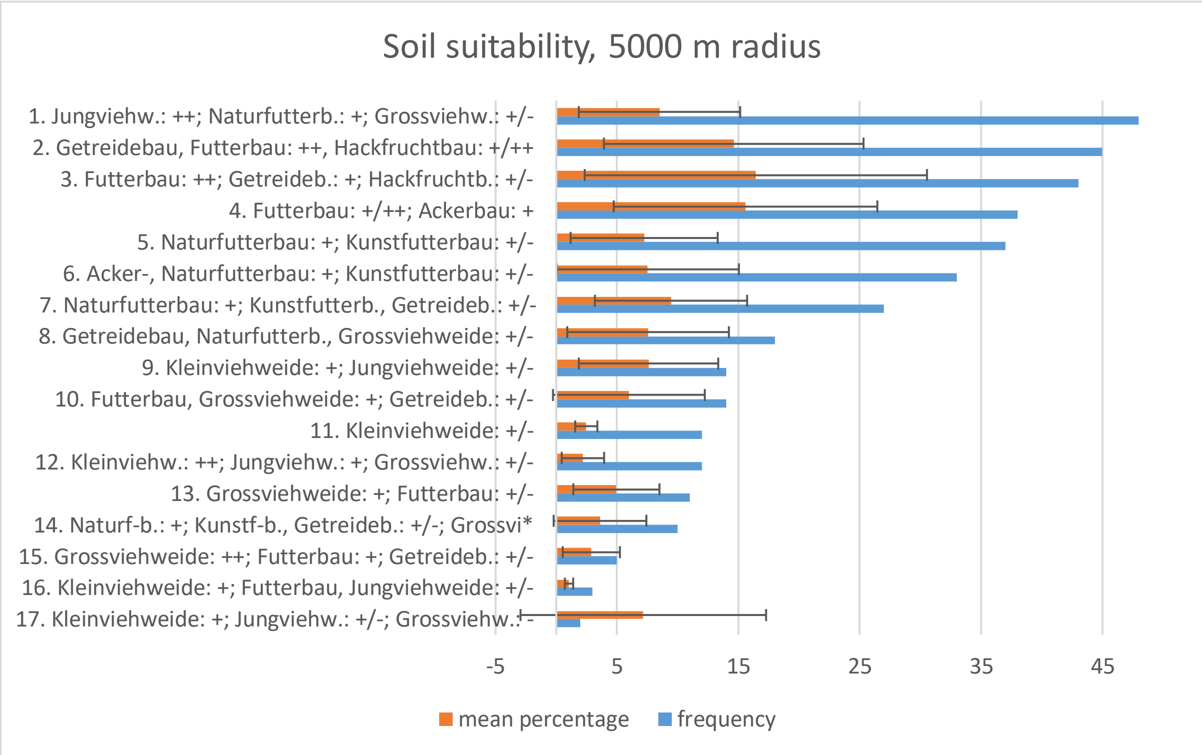

Fig. 7: Mean percentage of land coverage and the number of villages the soil categories appeared in for the 5000 m radius buffer. The standard deviation is shown in black.

3.3 Land-lake ratio analysis

This analysis was conducted to see if the ratio between lake and land for most of the settlements is similar in specific distances. For this the hydrography data from the swissTLM3D from Swisstopo was used. As with the soil suitability analysis buffers with radii of 100 m, 500 m, 1000 m and 5000 m were put around the settlements and intersected with the lake polygon shapefile. The 100 m and 500 m were set for the immediate surrounding and the 1000 m and 5000 m buffers were set to see if for example settlements at smaller lakes had other lakes nearby that would balance out the difference in the land-water ratio compared to settlements situated at larger lakes.

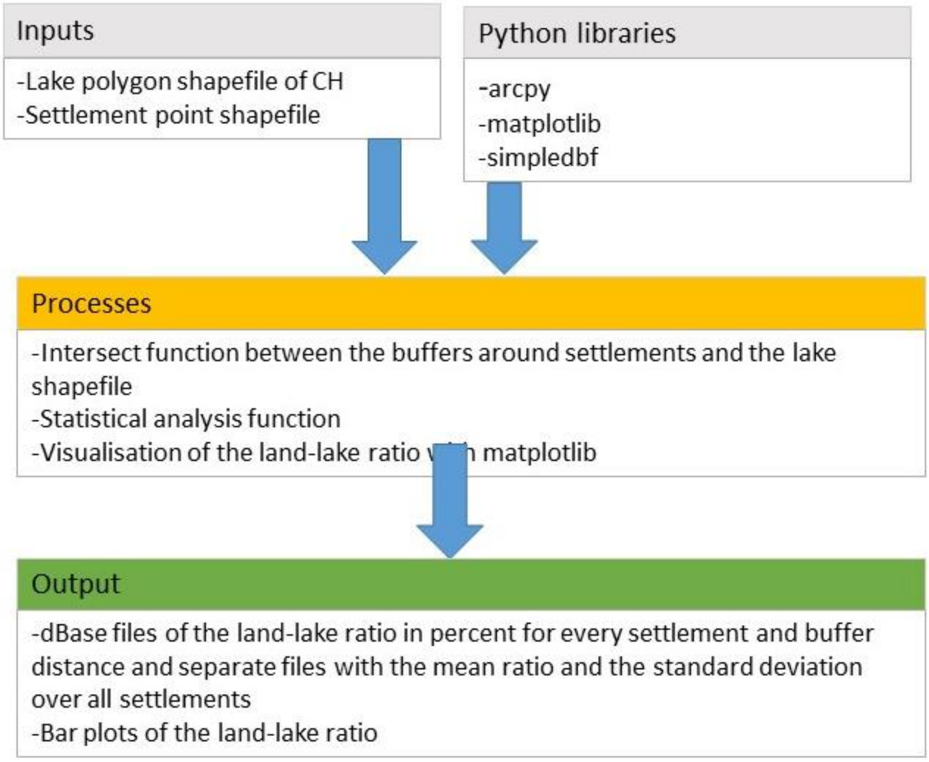

Fig. 8: Flow chart of the land-lake-ratio analysis

When the 100 m radius was used the result was an almost evenly distributed range of lake coverage in percent between 100 and 0 % (fig. 9). The spike at 100 % can be explained with changing lake levels. These six settlements were most likely built at a time where the lake levels were lower. Therefore, the spike should not be considered as a sign that the settlements were built in locations with as much water as possible around or even not at land at all. The mean lake surface is 57 %; however, the standard deviation is 32 % which leads to a coefficient of variation of 57 %. These numbers fit the image of the almost evenly distributed settlements in figure 9.

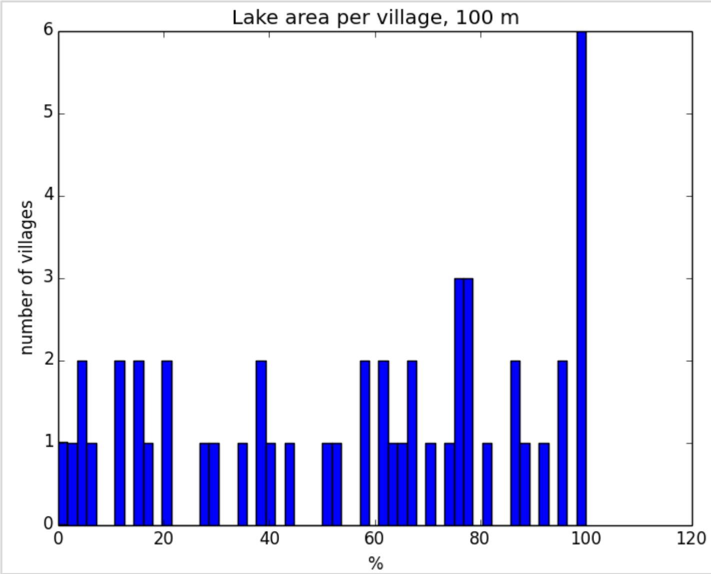

Fig. 9: percent of lake surface for a buffer with a 100 m radius.

With the 500 m radius buffer the lake surface percentages are a bit less evenly distributed (fig. 10). There is a small spike around 40 % to 60 % lake surface. The mean is 47 % of lake surface and the standard deviation is 22 %. This leads to a coefficient of variance of 51 %. Furthermore, the spike/cluster consists of roughly 20 settlements the other 36 are rather evenly distributed over the whole range. In conclusion, despite the visible spike in figure 10 the standard deviation and the coefficient of variance are rather high which speaks against a clear trend that a certain ratio between land and lake surface was desirable.

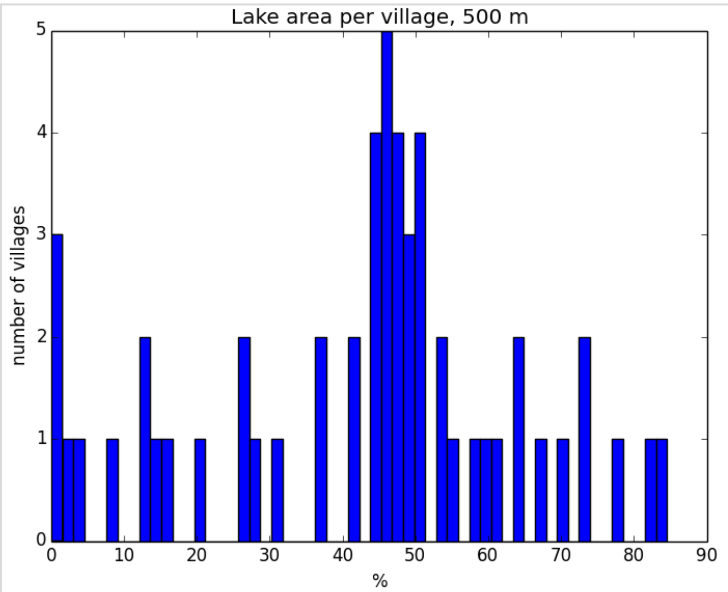

Fig. 10: percent of lake surface for a buffer with a 500 m radius.

As with the 500 m buffer a small spike around 40 % to 60 % is visible for the 1000 m radius buffer. Yet, again the cluster only consists of ca. 23 settlements, the others are rather evenly distributed over the whole range (fig. 11). Furthermore, the standard deviation of 21 % and a coefficient of variance of 55 % are very high. The mean itself is 39 % of lake surface.

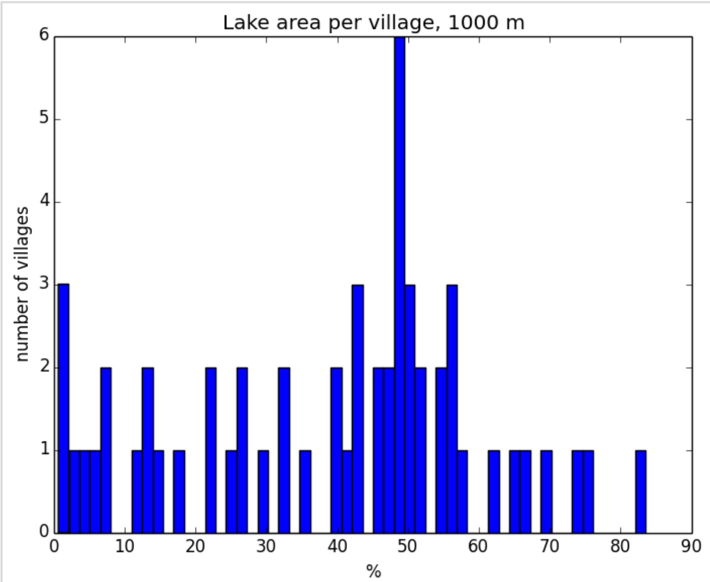

Fig. 11: percent of lake surface for a buffer with a 1000 m radius.

For the 5000 m radius buffer the lake coverage in percent is a little bit more evenly distributed again. In opposition to the 100 m radius a lot of settlements have a very low percentage of lake surface compared to land surface. Although it was to be expected that there would be less and less lake surface the further you go away from the settlements. This is also shown in the rather low mean of 26 % of lake surface. The standard deviation is 17 % which leads to a coefficient of variance of 64 %.

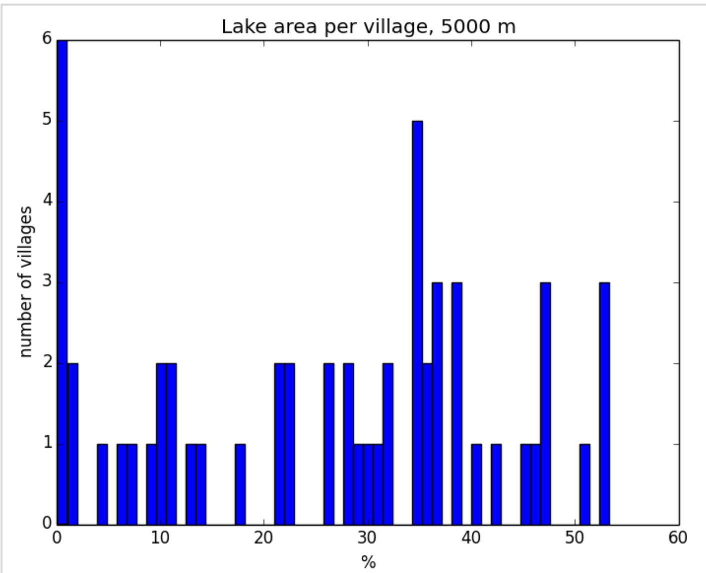

Fig. 12: percent of lake surface for a buffer with a 1000 m radius.

No matter what buffer distance was used, it does not seem that there was a distinct preferred ratio between land and lake surfaces for the location of the settlement. However, it is to say that the lake levels of today are not the same as in the Neolithic or Bronze Age. If the data was available for the lake levels of these time periods the analysis could be rerun to see if the results are more or less the same.

3.4 Landform classification based on the topographic position index TPI

This analysis was conducted to see if next to the lake other specific landscapes were important for the location of the settlements. To classify the surrounding landscapes the topographic position index (TPI) was used. The TPI "compares the elevation of each cell in a DEM to the mean elevation of a specified neighbourhood around that cell" (Weiss 2001). Weiss (2001) also suggested six different classification for the landscapes as seen in fig. 13. These classes were also used in a study that analysed landforms around archaeological sites in Crete (Argyriou: 2017).

Class	Description	Breakpoints
1	ridge	> + 1 STDEV
2	upper slope	> 0.5 STDV =< 1 STDV
3	middle slope	> -0.5 STDV, < 0.5 STDV, slope > 5 deg
4	flats slope	>= -0.5 STDV, =< 0.5 STDV , slope <= 5 deg
5	lower slopes	>= -1.0 STDEV, < 0.5 STDV
6	valleys	< -1.0 STDV

Fig. 13: the six classes used for the landscape classification (Weiss 2001)

The TPI was determined with the "focal statistics" function of arcpy and Map Algebra. Map Algebra was also used for the classification. However, it is to be noted that the classification does not work in Pycharm only in the Python console in ArcGIS or with other IDEs. In the corresponding script it is described in detail which lines do not work in Pycharm.

The classified raster was then converted into a polygon shapefile which was later used for "intersect" function. Before this the lakes had to be extracted from the shapefile with the "erase" function since they were classified as landforms as well and would influence the results. The following steps were then the same steps as the steps of the soil suitability and land-lake ratio analyses, where buffers of radii of 500 m, 1000m and 5000 m were set around the settlements. Because the classified shapefile had a cell size of 200x200 m the 100 m radius buffer was left out. Why such a coarse resolution was chosen is explained in detail in the corresponding script.

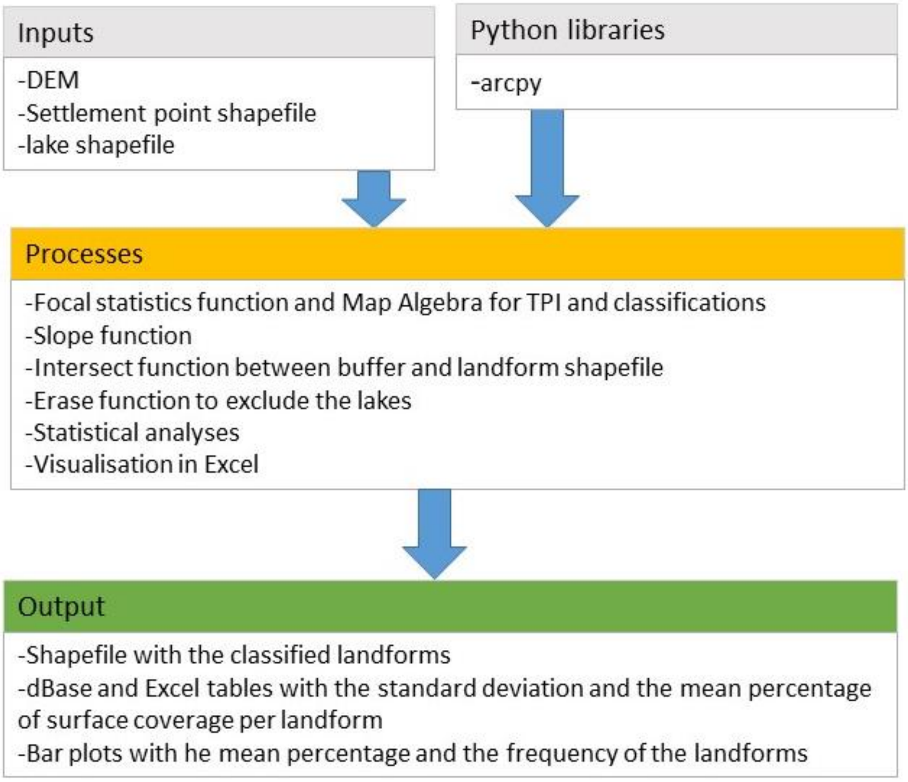

Fig. 14: Flow chart of the TPI analysis

When the 500 m radius was used the most common landform were gentle slopes. At the same time this is also the landform with the highest surface coverage. In the mean over 25 % of the landforms around the village in a 500 m radius are gentle slopes (fig. 15). This landform is followed by lower slopes and steep slopes which also appear often and cover a large part of the surface. Valley bottoms, ridges and upper slopes only make up a small part of the landscape and valley bottoms are by far the least common. However, the standard deviation for all the landforms is very high.

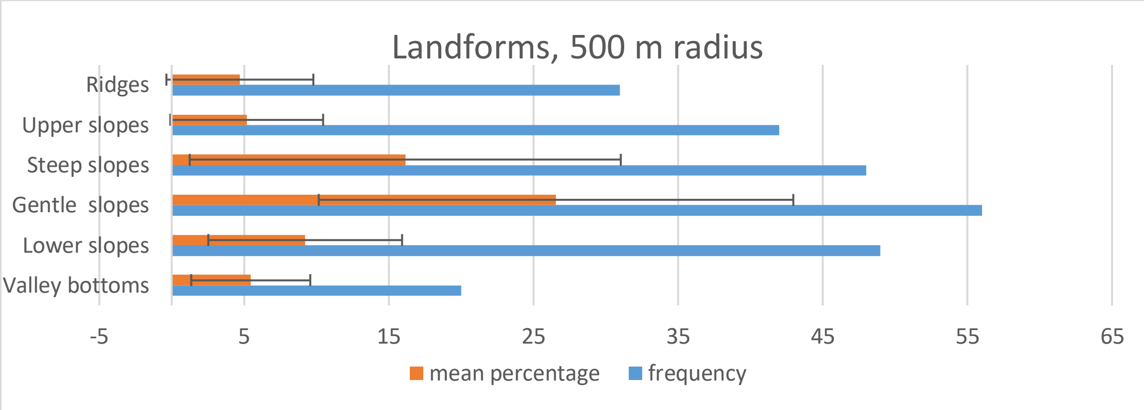

Fig. 15: Landform classes (500 m radius): Mean percentage surface coverage (orange) and the number of settlements they appeared in (blue).

With the 1000 m radius buffer there is a very similar result. The gentle slopes are still the most common as well as the landform with the most surface coverage followed be steep slopes (fig. 16). Lower slopes are still the second most common; however, in comparison with the steep slopes their surface coverage has gotten lower. Valley bottoms are a bit more common although still with a very low surface coverage in percent. As with the 500 m radius the standard deviation is very high overall.

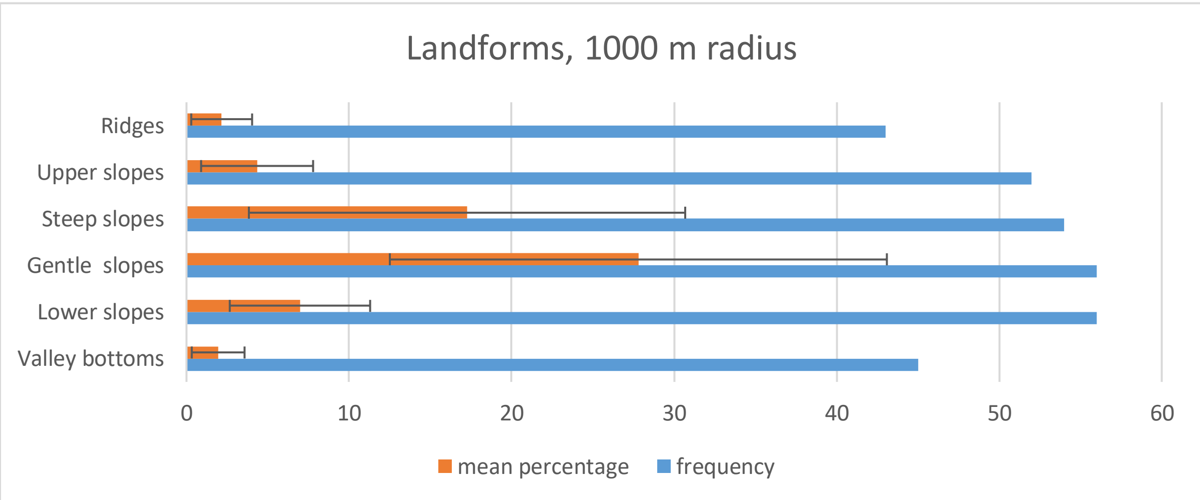

Fig. 16: Landform classes (1000 m radius): Mean percentage surface coverage (orange) and the number of settlements they appeared in (blue).

When the 5000 m radius buffer was used every landform appeared in every settlement (fig. 17). The landform with the most surface coverage is still gentle slopes; however, now very closely followed by steep slopes. The other four landforms only take a small part of the overall surface coverage. Even if the high standard deviation is considered gentle slopes remain the landform with the most or at least second most surface coverage.

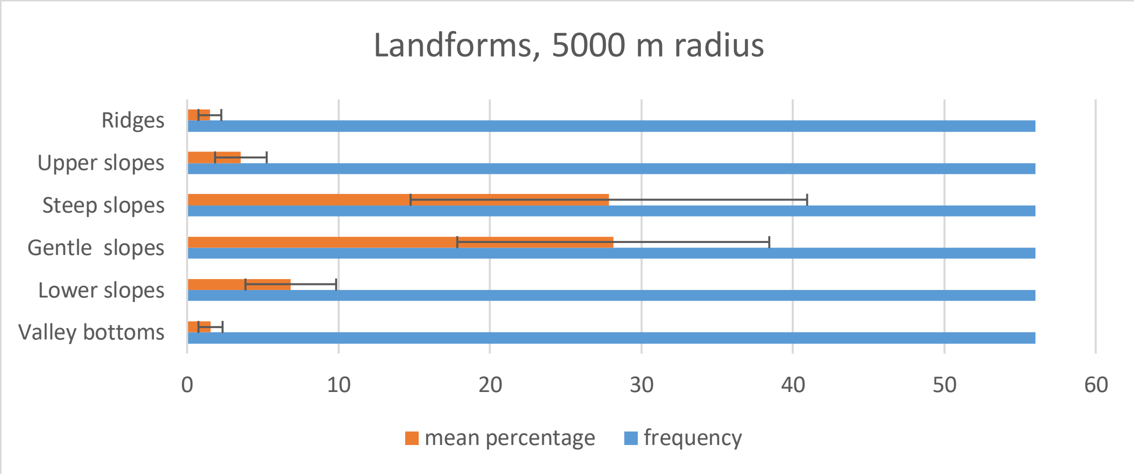

Fig. 17: Landform classes (1000 m radius): Mean percentage surface coverage (orange) and the number of settlements they appeared in (blue).

As with the soil suitability before a tendency to settle near steep and gentle slopes could be suggested further research is needed. Again, the overall surface coverage of the different landforms around all the lakes of Switzerland should be analysed and compared with these results. If they are roughly the same, these results just represent the normal distribution of the landforms. If not, then there is the possibility that certain landforms were preferred by the Neolithic and Bronze Age settlers.

3.5 Nearest river analysis

This analysis was conducted to see if it was important to have a river nearby as an additional water source next to a lake. A reason for this could be, especially with smaller lakes, that the water right next to the settlement could get polluted over time. If that happened a nearby river could have served as a clean water source. For this the "near" function from arcpy was used. The results were then visualized in Python. The mean, the standard deviation and the coefficient of variance were also determined through the Python script.

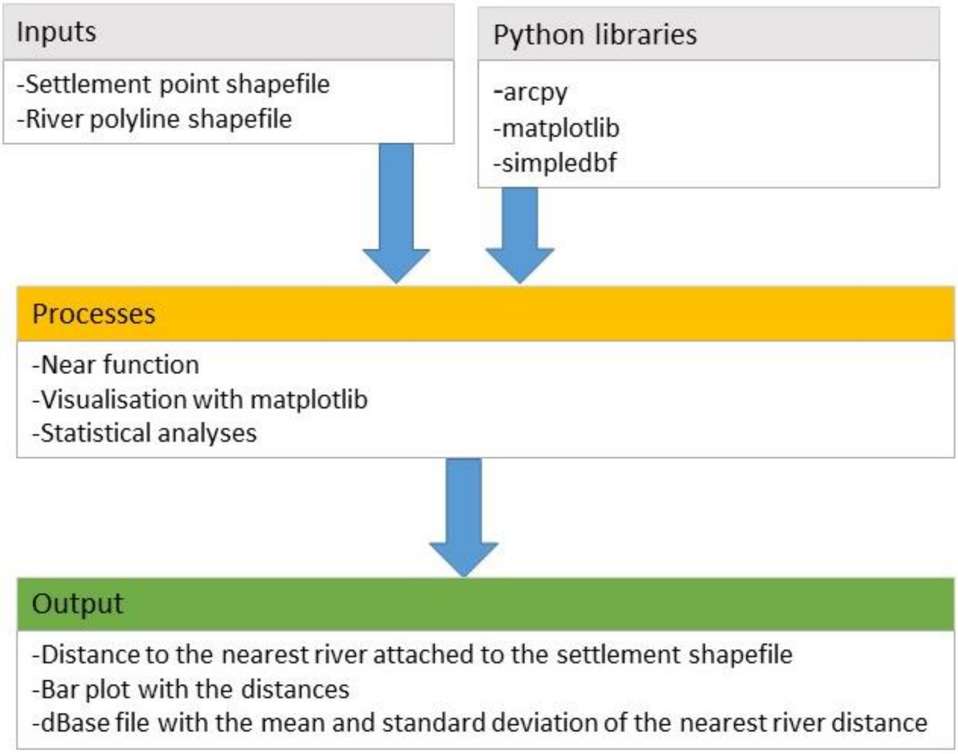

Fig. 18: Flow Chart of the nearest river analysis.

As shown in figure 19 for 37 settlements the nearest river is less than 400 m away. Only for eight settlements the nearest river is more than 600 m away. The mean distance to the nearest river over all settlements is 352 m. Although the standard deviation of 313 and the coefficient of variance of 89% are very high there seems to be a tendency that the settlements are located near rivers since 66% of them are closer than 400 m to a river. The standard deviation is also surly influenced by the outlier settlement where the nearest river is almost 1800 m away.

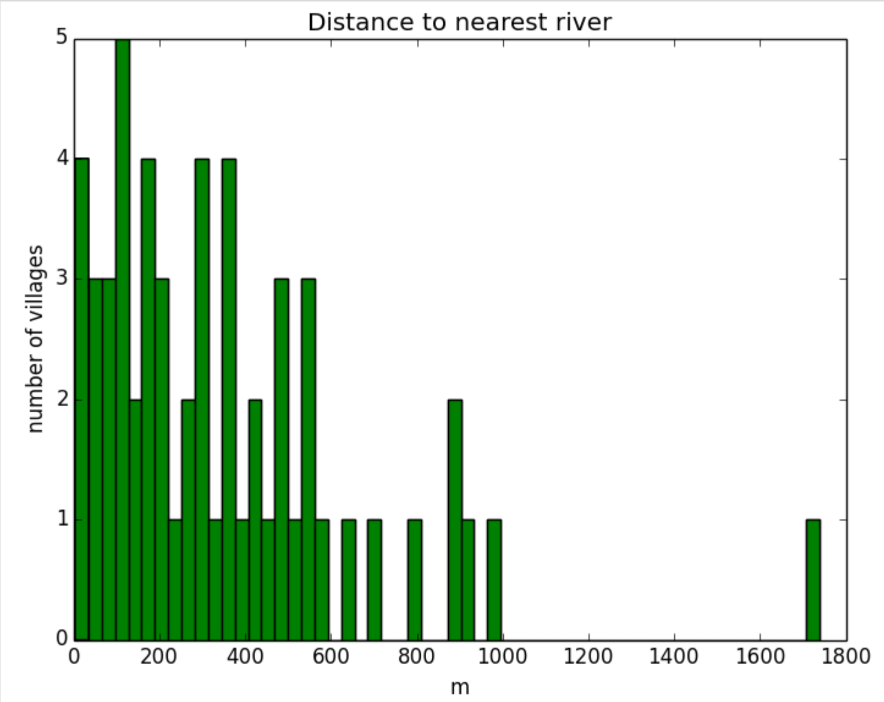

Fig. 19: Distance to the nearest river

However, the stream courses from today are often not the same stream courses as in Neolithic or Bronze Age times. They naturally changed their form and direction over the years and in modern times they were also artificially changed. To be able to certainly speak of a tendency that Neolithic and Bronze Age settlers chose to live near rivers, data from the stream courses of those time periods would be needed.

4. Conclusion

For all five analyses there was always a high standard deviation and if it was determined also a high coefficient of variance. However, most of the analyses at least showed some small possible tendencies that certain surroundings were preferred: The results of the soil suitability analysis showed that the soils which are good for crops or grain are often very common and the results of the landform analysis showed that gentle and steep slopes are always very common and have a high land coverage in percent through all buffer distances. For the river analysis 66 % of the villages are closer than 400 to a river. The land-lake ratio also shows some small spikes with the 500 m and 1000 m buffer although a little bit less distinct than other analyses. With the visibility analysis the cluster of settlements around the same amount of visible area is at the lower end, which is, as described, the opposite of what was expected. As already mentioned all of these analyses would need further research to confirm or deny that certain surroundings were preferred. The average distribution of landforms and soil suitability categories around the lakes of Switzerland should be compared with the results the landform and soil suitability analyses. This would show if the results of these two analyses only show the normal average distribution. The nearest river analysis and the land-lake ratio analysis should be done with hydrography data that shows the state of Neoltihic and Bronze Age times. With the visibility analysis, as stated, it could be interesting to restrict the distance of the analyses for e.g. to 20 km to see if it was important to see most of the close surrounding land around the settlement. Even if all this additional research is done, there is still the problem of the very high standard deviation, which rather speaks against tendencies that certain locations with a specific surrounding were preferred. For this paper only the 56 UNESCO World Heritage settlements were used because I only had the coordinates for them readily available. However, the Palafittes (2015) database has registered 466 lake settlements for Switzerland. It is possible that if all these settlements were used that the results would get more distinct: Either the standard deviation gets smaller, which would support the hypothesis that certain environments were preferred, or the standard deviation stays high, which would speak against the hypothesis.

In conclusion, without further research no certain statements can be made about location requirements for lake settlements.

5. Bibliography

Argyriou, A.V., Teeuw, R.M. & Sarris, A. (2017). GIS-based landform classification of Bronze Age archaeological sites on Crete Island [online]. Available at: "http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0170727" [Last accessed 27.07.2018].

Bundesamt für Landwirtschaft BWL (2016). Geografisches Informationssystem GIS. Download Geodaten [online]. Available at: "https://www.blw.admin.ch/blw/de/home/politik/datenmanagement/geografisches-informationssystem-gis/download-geodaten.html" [Last accessed 24.07.2018].

Palafittes (2015). UNESCO World Heritage. Prehistoric Lake Dwellings Around the Alps [online]. Available at: "http://sites.palafittes.at/" [Last accessed 30.06.2018].

Weiss, A.D. (2001). Topographic Position and Landforms Analysis. Poster presentation, ESRI User Conference, San Diego, CA.