Modeling a historical landscape using GIS ?

Exploring Roman stone quarrying and the cultural landscape in the Eifel (Germany)

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Abstract: This paper argues if we are sufficiently aware of the limitations GIS has in reconstructing a historical landscape and accompanying civilizations. By looking at the social-economic processes that took place in Roman stone quarrying in the Eifel during the transition from the Iron Age to the Roman period and the influence these processes had on the layout of the (cultural) landscape, limitations between landscape and cultural variables can be discovered. Through social-economic modelling it is possible to discover and illustrate the relationship between stone quarrying and the development of the surrounding cultural landscape. These models can then be used to derive a scale of landscape cultivation. These scales can then be combined with landscape variables and indicative maps of archaeological values to acquire a more detailed reconstruction of a historical landscape.

Keywords: Interdisciplinary research, dynamical landscapes, GIS, Quantitative vs. Qualitative relations

Introduction[1]

In recent years GIS has made an unmistakable impression in historical and archaeological research. It has proven itself very useful as a powerful tool to present complex spatial data to the layman or the general public. But is the flourishing of GIS for historical research a bliss or should we be cautious with the implementation of GIS on historical data? This paper argues if we are sufficiently aware of the limitations GIS has in reconstructing a historical landscape and accompanying civilizations. Can GIS grasp and explain all cultural dynamics that influence the layout of a historical landscape?

GIS is a broad term which incorporates a large number of techniques and programs. Therefore GIS is used in variety of ways. It is beyond the scope of this paper to discuss all these techniques here. In the Netherlands GIS is frequently being used as predictive modelling [2] and the formation of Indicative Maps of Archaeological Values (in Dutch: Indicatieve Kaarten van Archeologische Waarden - IKAW). [3] These maps predict the probability for archaeological finds through landscape variables and can therefore be used for the initial stages of development plans and the protection of cultural heritage. These maps do raise the question in what way these historical landscape analyses incorporate the closely connected cultural processes and dynamics in the landscape?

This paper will focus on the social-economic processes that took place regarding stone quarrying during the transition from the Iron Age to the Roman period in the Eifel region in Germany and try to

clarify what role they played in the formation of the early Roman cultural landscape. Additionally we will focus on the mutual limitations that exist between these social-economic processes and a historical landscape analysis using GIS and in what way historical modeling can contribute to prevent these limitations.[4]

To achieve this I will start with a short description of the research area as an introduction. I will try to give you a short impression of Roman stone quarrying in the Eifel, through the examples of the Roman exploitation of tuff and basalt.[5] To clearly view any mutual limitations between social-economic processes and an analysis using GIS I will distinguish both in a framework. I will start with a short description of the used GIS analyses in the physical-geographical framework. Following I will discuss the social-economic processes and created models in the social-economic analysis. If mutual limitations between the both exist, in what way is it possible to combine both sets of data? This question will be answered in the synthesis section. At the end of this paper some conclusions and recommendations will be given.[6]

Description of the research area

The Eifel region is located in the western part of Germany near the cities of Köln, Koblenz and Trier (fig. 1). The Eifel is situated to the west of the river Rhine and to the north of the river Mosel and stretches to the borders of both Luxembourg, Belgium and in a small part the Netherlands. In the Roman period this region was responsible for the production of stone for both Germania Inferior and Superior. A region and market, much larger than formerly known to the area, whereas quarrying in pre-Roman periods was limited to local use and production.[7] This intensification of stone production led to major changes in the cultivation of the local landscape. New towns were founded, some of them strongly committed to stone quarrying – the current towns of Mayen and Andernach for example.[8]

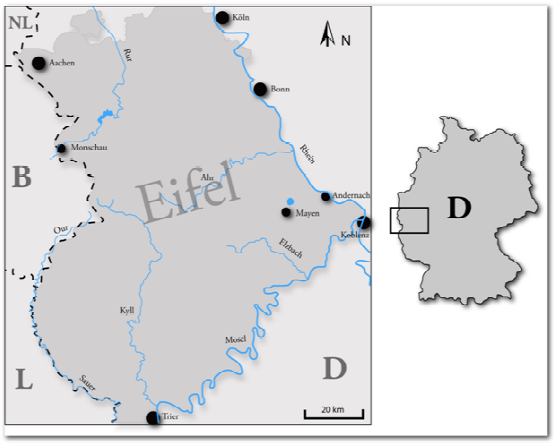

Fig. 1 – The Eifel region in Germany

Fig. 2 – Typical Roman basalt quarry around Mayen

Although stone quarrying in the Roman period proceeded at a scale previously unknown to the area, it is not limited to the Roman or later periods. In some stone quarries around Mayen production dates back as far as 7000 years ago, the Neolithic period.[9] In these stone quarries exploitation focused on the production of quernstones, which even in the Neolithic period already found their way to the north

of the Netherlands.[10] These early stone quarries were small in size and production proceeded through the use of fire (extreme heating) and water (fast cool down) which led to breaking the stone into small pieces. These techniques remained unchanged for centuries, until the introduction of iron tools in the quarries. At this point, stone production became more efficient and the area of stone quarries larger. [11]
In the Roman period the area of stone quarries grew even larger and production techniques changed further (fig. 2). The Romans introduced iron wedges into the stone quarries, which led to a even more efficient production and a growth in productive capacity. [12] Stone production got more organized. As seen by the formation of parcels and the stone residue that was used to create an entrance to the quarry. The Romans, if possible, expanded existing stone quarrying and if necessary constructed new quarries. In combination with better transport routes and a more efficient production the rapidly rising demand in stone could be met.
Some types of stone, for example tuff in the Eifel, were never exploited on a large scale before the Roman occupation.[13] But during the Roman period large quantities of tuff were used in the building of towns, legionary forts and funerary monuments. [14] The Roman demand for this stone led to new stone quarries, in this case, underground. As seen in the production of basalt, stone wedges were used here in similar manner, expressing the new uniformity in stone quarrying. The increasing organization of stone quarrying can clearly be seen by the logistics surrounding these underground stone quarries. [15]

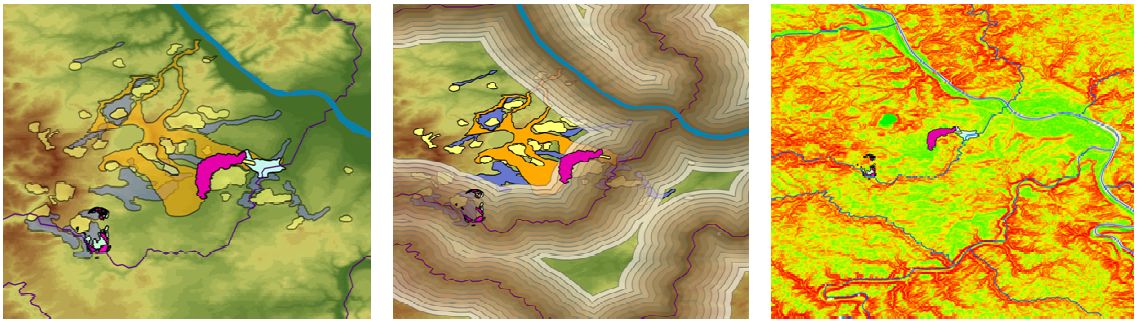

Fig. 3 – The three aspects in the GIS analysis. Left: geological aspects, middle: distance to the rivers and right: slope analysis. (These maps are derived from maps out of van Lanen 2008 and are used as indication; the used scale can therefore differ slightly.)

Physical-geographical Analysis

The stone quarries must have been dominant in the Roman landscape and the question remains if a landscape analysis like an Indicative Map of Archaeological Values for stone quarrying can also be created for this region.
And this leads to a problem: limited data. As said in the introduction, this paper is based on an explorative research. To obtain specific and extensive data on the research area proved to be difficult. In this case it was decided to limit the analysis to the data freely obtainable from the internet, which was not a desirable situation. To insure the quality of the GIS research, an accurate and extensive dataset is required. With the increasing availability of data on the internet and the growth of user-friendly programs GIS analyses can easily be made, one can question if a minimal threshold for data in a GIS analysis should not be introduced. Despite this limited data, or maybe because of it, I

restricted myself in my GIS analysis to 3 for stone quarrying important aspects (fig. 3): The first aspect were the ‘geological aspects’ - stone can only be exploited if the geological situation is suitable -. The second aspect was ‘the distance to the rivers’ - when demand for stone is upper-regional, rivers play a decisive part in the transport of stone – the furthest a (known) stone quarry was located from a river appeared to be 4 km. When we assume that 4 km reflects the most remote possible location, the potential production areas are limited as supposed to only the geological situation. The third, and last, aspect was ‘the slope analysis’. From which could be concluded that all of the major stone production areas were located in the more or less flat -green- areas which further adds to the restriction of potential production areas (compare fig. 3).

During these analyses it became clear that all these aspects have a mutual limitation on one another, and the probability of potential production areas throughout the landscape can differ strongly. Not every location in the landscape was evenly suitable for stone production related elements. It became clear that an Indicative Map of Archaeological Values, as described in the introduction section of this paper, is also possible for stone quarrying in the landscape.

Social-Economic Analysis

Can these indicative maps incorporate the cultural dynamics surrounding stone quarrying? As said in the introduction section of this paper I will focus on only one of the cultural elements: the social-economic processes. Only a small part in cultural dynamics but still very broad of its own. As we now know stone production transformed during the transition from the Iron Age to the Roman period. One can even state that there is a clear discontinuity between stone quarrying in the pre-Roman and Roman period.[16] As supposed to Iron Age stone quarrying, stone quarrying in the Roman period became an important and integral part in the formation of the early Roman cultural landscape, not only in the research area but also on a much larger upper-regional scale. To understand and view these changes I focused on theories and models originating from the evolutionary economy. [17]

The evolutionary economy is a relatively new economic school of thought that is inspired by terms and processes of evolutionary biology. It is best described as a theory of economic change and adaptation. The evolutionary approach tries to describe ‘how’ and ‘why’ the economic structure continuously changes under influence from economic cyclical developments, technological innovations and changing societal structures. Because of the great changes that took place during the transition from Iron Age to the Roman period, theories from the evolutionary economy can be helpful to understand the occurring social-economic changes. A few important, and for this analysis helpful, key points of the evolutionary economy are:

(a) Suboptimal results because of restricted rationality – This argues that individuals are only partly capable of understanding and retrieving all given information. This means that not everyone is equally equipped to understanding all processes surrounding them, landscape or other-wise. Furthermore not everyone is in an equal position to retrieve information. This would mean that each individual is unique in its capability to understand his or her

(b) environment. Thus meaning that landscape variables alone are inadequate to describe how far the historical individuals understand all processes surrounding them.

(c) Path dependency and irreversibility - The evolutionary economy states that it is best suited to research structural processes of change. It views mutual relationships as a path dependency. In short this means that ‘history matters’. Each development in town A has an influence on the relations it has with, for example, other towns. This influence can lead to developments itself and thus become irreversible processes. Although hypothetically the situation in town A can change to its original state, the situation in other towns will never be the same.

(d) Heterogeneity of agents – This heterogeneity is strongly joined to the restricted rationality mentioned in (a). Individuals are not equal. Not everyone is equally informed, has the access to same information, the capability to process this information or an uniform interpretation frame-work.

(e) Emphasis on processes of change – The evolutionary economic theory uses terms and ideas of the evolutionary biology. Evolution is gradual change, the evolutionary economy states that these processes like: mutations, natural selection and genetic inheritance in a slightly adapted form, can be translated to describe economic processes. Mutations become: Routines, natural selection: competition and genetic inheritance: innovation. [18]

Through these evolutionary economic theories and models it was possible to distinguish 3 different social-economic processes strongly joined with the development of Roman stone quarrying in the Eifel.

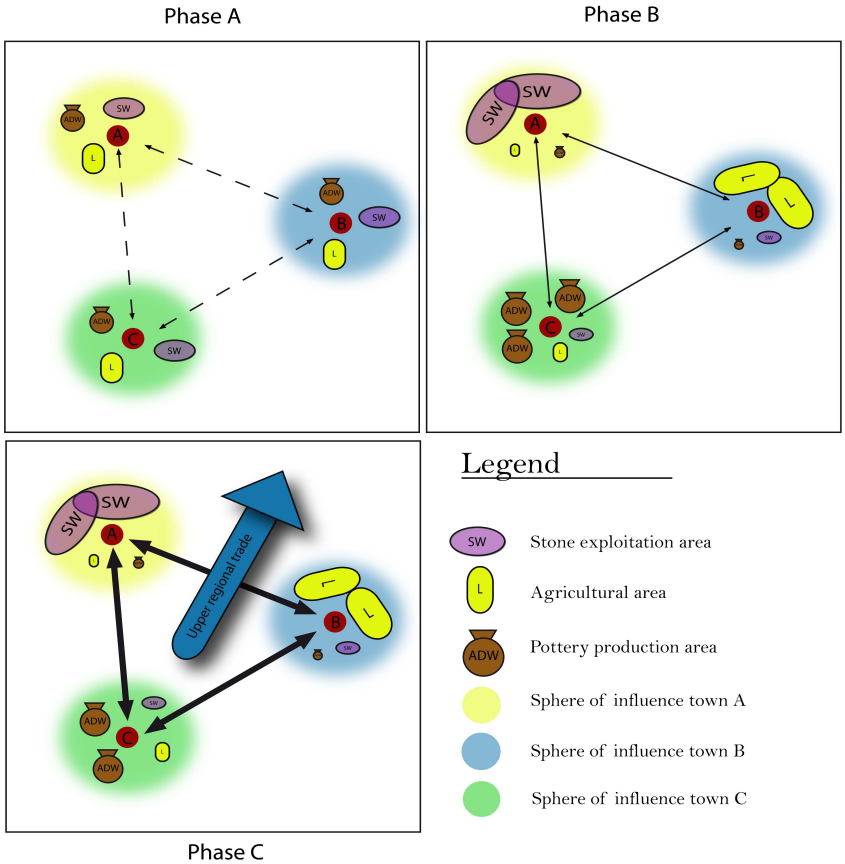

Fig. 4 – Settlement specialization

Settlement specialization

The first process distinguished here is the settlement specialization. In the Eifel but also in other northern Roman provinces[19] specialization of settlements is clearly visible in the archaeological record. Where in the pre-Roman period settlements mainly strived to be self-supporting and mutual relations were limited (phase A – fig. 4), this changes in the Roman period (phase B). Apparently settlements began to specialize in a certain industry. Why settlement A specializes in stone quarrying is undetermined and we will gather this under factor chance. For example it could be that in this settlement people arrived with a better knowledge of new products or production types (think about the use of wedges) through which production could become cheaper and more efficient. What the exact reason may be, settlement B en C turn to settlement A to cover their demand for stone. Because of the specialization of town A, town B and C had to find another specialization. Mutual relations intensify and production is becoming increasingly efficient. This process continuous until a surplus can be created and the upper-regional demand for stone can be met. If this specialization is voluntary or part of a political agenda is unclear.

Spatial-economic considerations for location choice of stone quarries

A second process that could be distinguished was the location-choice of stone quarries. As can be seen in figure 5 town A and its surrounding settlements are dependent on a nearby production area to cover their demand for stone (phase A). It soon became clear that distance to the river or town was not the decisive factor for the location choice of stone production areas. For in phase B another town

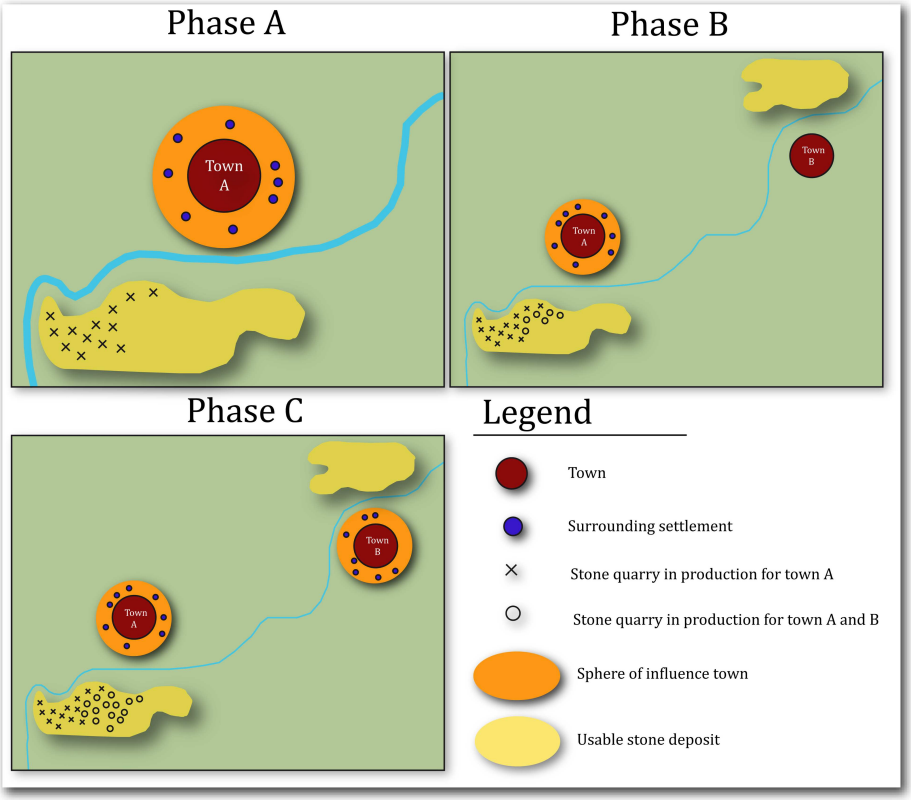

Fig. 5 – Spatial-economic considerations for location choice of stone quarries

(B) is founded and is dependent on town A to cover its demand for stone. As a response on this new demand town A constructs even more stone quarries. Even when the town-planning for town B is completed and it has (geological) knowledge of the surrounding area, stone still originates from the quarries in the south (phase C). The reason for this pattern is the fact that labor, knowledge and infrastructure concerning stone quarrying are all concentrated in town A. It would be easier and probably more profitable to continue importing stone from town A, then creating a new production area for town B itself, even though the landscape is similar.

Path dependency: the relationship between town and landscape.

Through these processes it becomes clear that there must have been a strong relationship between the development of Roman towns and stone quarrying, or even on a larger scale; the cultural landscape itself. It seemed that developments in stone quarrying and the cultural landscape acted path depended on each other. To clarify this relationship I decided to illustrate these processes in a path dependency model. It is beyond the scope of this paper to explain all details of this but just as an example, 2 out of 8 phases will be described.[20]

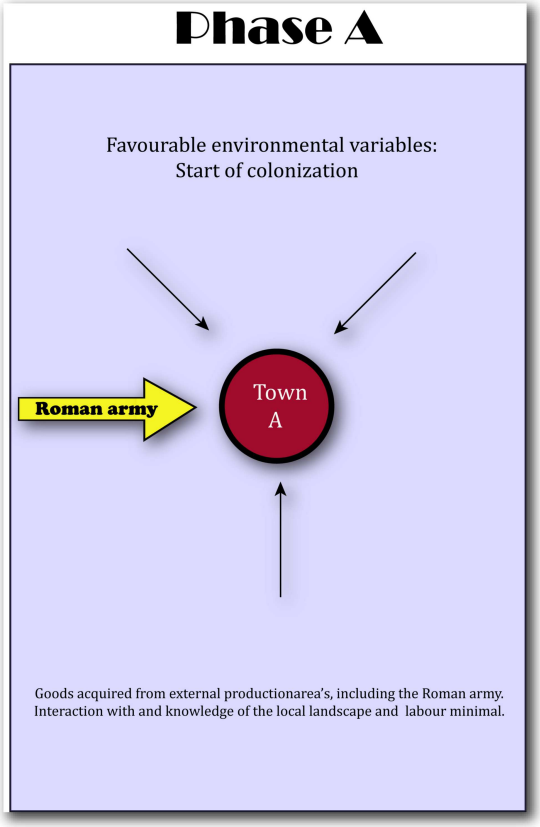

Fig. 6 – Phase A of the path dependency model

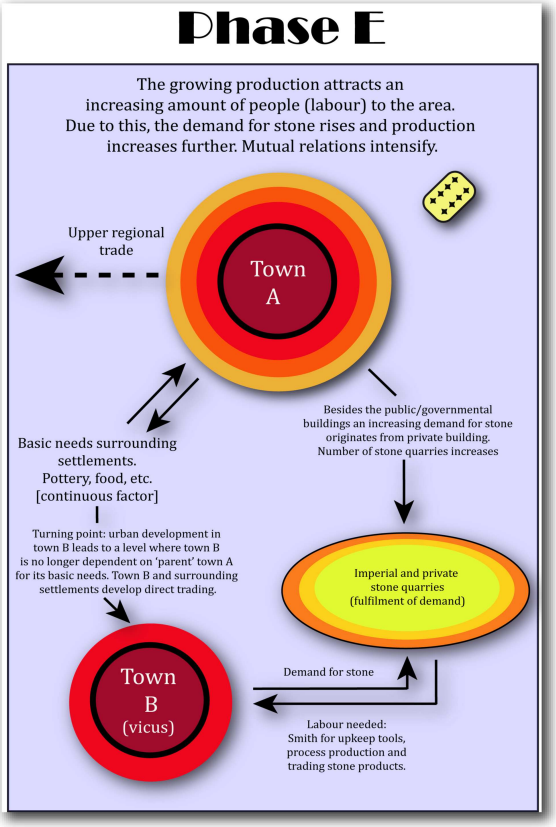

Fig. 7 – Phase E of the path dependency model

The first phase, phase A (fig. 6). This is the first phase of town-planning. Urbanization, on the Roman scale, is unknown in the northwestern part of Europe during the pre-Roman periods. In figure 6 you can see a new town is founded which is still a foreign element in the landscape. Town A has limited, to no knowledge of the surrounding area and lacks relationships with the surrounding local settlements.

For its supplies the town is dependent on external production areas and especially the Roman army which played a big part in the first layout of the cultural landscape and the town planning.
The other phases (phases B, C and D which are not shown here) illustrate that town A becomes increasingly familiar with the landscape, and commences direct trade relations with surrounding settlements and constructs its own stone production area. The increasing growth of town A leads to an equal growth in the demand for stone. Because of the ongoing specialization an upper-regional demand can be met. The increasing production in stone leads to the founding of town B, mainly a Roman vicus which focused on supporting the stone production in labor, knowledge and trade. This town is for a great deal dependent on town A to cover their demand for goods.
The second phase described in detail is phase E, the climax situation (fig. 7). Both towns A and B keep on growing and mutual relationships intensify. The growth leads to an increase in building activity and an equal demand for stone. The production of stone grows equally. At this point town B has sufficient knowledge of the landscape to commence direct trading relationships with the surrounding area and is no longer completely dependent on town A. You can also see the introduction of a wildcard (upper right corner) which represents unforeseen circumstances like natural disasters or diseases, that are of direct influence on the relations within the model.
The mutual relationships can also have a downside, as reflected in phases F, G and H (not included in this paper). The path depended relationships stimulate all areas in the model, a decline in one of these leads to an equal decline in the other. A migration in town A can lead to a decrease in building activity which then leads to a decrease in demand for stone. Eventually this can lead to the abandonment of town B and a limitation of the stone production to only local projects and a stone use in secondary context.
It is important to realize that following this model it can be concluded that relationships between towns and stone production in Roman times knew a similar path of development. When the development and growth of town A and B are at a climax situation, the cultivation of the landscape must be equally highly intensive. It can be assumed that through these social-economic relations it is possible to reconstruct the degree of cultivation on a social-economic basis. Van Lanen (2008, 92 – 94) distinguished 5 different scales of cultivation: absent, marginal, notable, intensive and highly intensive (table 1).
But although we now know how social-economic processes can be an indication for landscape cultivation, the question remains how we combine these processes with historical developments and make them suitable for a historical landscape analysis. To achieve this a combination relational flowcharts (i.e. decision trees) can prove very useful. Through these flowcharts it is possible to combine (known) historical development with different phase of path dependency. In this case the role of the Roman army, processes of product or production innovation and types material could all be combined with a degree of landscape cultivation on a social-economic basis. [21]

Pathdependency phase	Cultivation
Phase A	Absent
Phase B	Marginal
Phase C	Notable
Phase D	Intensive
Phase E	Highly intensive
Phase F	Notable
Phase G	Marginal
Phase H	Absent*

Absent	1
Marginal	2
Notable	3
Intensive	4
Highly intensive	5

Tab. 1 – Path dependency and landscape cultivation

Synthesis

The question remains however in what way landscape variables can grasp these kinds of social-economic processes? To combine the data from the physical-geographical and social-economic analyses we must focus on an integration table (table 2).

Social-economic value →

Physical-geographical value ↓

	1	2	3	4	5
1	1	1,5	2	2,5	3
2	1,5	2	2,5	3	3,5
3	2	2,5	3	3,5	4
4	2,5	3	3,5	4	4,5
5	3	3,5	4	4,5	5

Tab. 2 – Integration table. In green the described example.

As we have seen in the physical-geographical analysis it is possible to derive a probability zoning map through a GIS-analysis. We can also derive which zones are best suited for stone production elements (Indicative Map of Archaeological Values). When we distinguish 5 different scales in suitability for landscape cultivation it is possible to combine these with the ranking derived from the social-economic models – as seen in table 2. For example zone 3 is physical-geographically moderately suitable for stone quarrying but the path dependency relations are at phase E, highly intensive. This results that the demand for stone is at a scale in which even the less suitable areas become interesting for cultivation and landscape cultivation is actually at a classification of 4. The classification 5 illustrates the climax situation.

Outlook

Through this study it has become clear that there are certain social-economic processes of influence on the layout of the cultural landscape. It appears that a GIS-analysis based on solely landscape variables fails to include these processes. And because these social-economic processes are only a small element within the cultural dynamics one could question if the use of GIS alone in a historical landscape analysis is sufficient to explain and predict the location of archaeological remains.
Through the integration of both historical modelling, in this case the social-economic models, and GIS modelling it is possible to partly incorporate these social-economic processes in a probability zoning map. This would then result in a more accurate prediction of the location of archaeological remains. If these indicative maps are being used in the protection of cultural heritage, we must strive to incorporate cultural dynamics in our modelling to better protect our cultural remains.
An integration table as shown in table 2 also makes it possible to better understand and incorporate the spatio-temporal variables closely related to a dynamic landscape. The path depended relationships can only after a while develop to a highly intensive state and can therefore in Roman times never occur in the first phase of Roman occupation. Through this it is possible to create a Indicative Map of Archaeological Values for not only stone related elements in the landscape but also for each different period in the Roman occupation. This refinement of the Indicative Maps of Archaeological Values allows dynamic modelling and a better understanding of the spatio-temporal relationships between elements in the landscape.

Conclusions

The analysis above leads to the following conclusions. We have seen that, at least in the Roman period, social-economic processes affect the cultural and thus historical landscape and should be taken into account in historical landscape evaluation. It is clear that in this case social-economic processes have an influence on the layout of the landscape, outside the physical-geographical framework.
If this is true, it is inevitable to conclude that analyzing a historical landscape through only physical-geographical variables, fails to grasp – at least in part – cultural dynamics. We should try to find ways

to incorporate these processes in our GIS-analysis. If this is not directly possible through GIS itself, we should try combining them with theoretical historical modelling.
It would then be desirable to incorporate interdisciplinary ideas and theories in our historical modelling, especially derived from other human sciences. To my opinion there is no need for us to reinvent the wheel. Certain modelling from other human sciences can, despite the need for and dangers of translating these theories and techniques prove invaluable in the reconstruction of a historical landscape. And these historical models can help us to ask the right questions of our GIS-tools.
In this study it is mentioned that a good GIS-analysis is dependent on an accurate and extensive dataset. Without this dataset, testing will prove difficult and results questionable. With the rise of free data on the internet it could desirable to introduce a limited amount of data (threshold) before commencing a historical land evaluation. At least one should be aware of the limitations of his or her dataset and what questions can and cannot be ask of this dataset.

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[1] This paper is written for the proceedings of the 13th international congress "Cultural Heritage and New Technologies" in Vienna in November 2008.

[2] Predictive modelling, is a technique that, at a minimum, tries to predict “the location of archaeological sites or materials in a region, based either on a sample of that region or on fundamental notions concerning human behavior” Kohler/Parker 1986, 400.

[3] For more information compare: Verhagen 2007.

[4] It is not the goal of this paper to create a new kind of predictive modelling or present a GIS analysis of stone quarrying in the Roman Eifel. This paper merely aims at presenting the contributory value of historic modelling to historical spatial modelling. For a more detailed description of the theoretical background of this research compare: van Lanen 2008.

[5] This paper focuses on only a small number of stone quarries within the Eifel. These quarries will function as an example to Roman stone quarrying and used quarries. The author believes that the explorative nature of the original research and its main goal of searching for the advantages of a modeling approach in reconstructing a historical landscape justifies this approach. For a more elaborate description of the theoretical background of this paper compare the original research: van Lanen 2008.

[6] All the results presented in this paper are derived from a master thesis which bore the title: An exploration in the developments of stone quarrying in an early Roman cultural landscape. A modelling approach. As the title suggests this research was explorative in nature. It is therefore clear that future research should further test and, if necessary, improve these results. Despite the explorative nature some of the conclusions can still prove to be a very useful indication. For more information: van Lanen 2008.

[7] For more information about these early stone production activities: Von Berg/Wegner 1995, Harms/Mangartz 2002 en Hörter/Michels/Röder 1950/51.

[8] For a more elaborate description of the history and roles of these town within stone quarrying activities in the Eifel I refer to: Von Berg/Wegener 2005 and Bockius/Bosinski/Hörter/Hunold/Mangartz/Oesterwind/Schaaff/

Schäfer 2000.

[9] Compare for more information: Von Berg/Wegner 1995, Harms/Mangartz 2002 and Hörter/Michels/Röder 1950/51.

[10] For more information compare: Harsema 1979. For production types originating from the Eifel compare: Holtmeyer-Wild 2000 and specifically for Roman times: Oesterwind 2000, 33 - 57.

[11] In context of this research it is impossible to give an elaborate description of all the different stone quarries and products in the pre-Roman or Roman periods. For more information on these products and quarries compare: Harms/Mangartz 2002,

[12] For a more elaborate description of these techniques compare: Harms/Mangartz 2002.

[13] Compare for more information: Hunold/Ippach/Schaaff 2002, Lehner 1921 and Röder 1957/1958 and 1959.

[14] It is beyond the scope of this paper to describe the exact dispersion and function of stone from the Eifel. For a better understanding of and more information on the use of stone in the northwestern part of the Roman empire I refer to: Bedon 1983, Cüppers 1990, Fischer 2000, Horn 1989 and Pearson 2006.

[15] For more information and a summary of references about the logistics surrounding stone transport compare: Vermeulen 2003 and van Lanen 2008.

[16] This discontinuity is best shown by the changes in production techniques, the logistics and scale of stone production during the start of the Roman occupation.

[17] For more information on the evolutionary economic theory compare: Boschma/Frenken/Lambooy 2002.

[18] For more information about the theoretical background of these keypoints of the evolutionary economy I refer to: Boschma/Frenken/Lambooy 2002.

[19] In this case the Roman province Britannia, which was used as testing area for all models in the original research, compare: van Lanen 2008. For a more detailed description on the pre-Roman and Roman cultural landscape in Germania Inferior compare: Carroll 2001.

[20] All these phases are described in detail in van Lanen 2008, 85 – 92.

[21] For more information and details on these decision trees: van Lanen 2008, 94 – 102.