Constructing Epistemic Landscapes: Methods of GIS-Based Mapping

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Hans-Dieter Evers, Sven Genschick, Benjamin Schraven

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Abstract

The construction of knowledge maps, demonstrated in this paper, is designed to show the epistemic landscape of cities, countries or regions. Knowledge assets, knowledge producing and disseminating organisations are referenced to spatial objects and integrated into GIS. They are further represented in thematic maps and in 3-D perspective graphs. Special attention is given to mapping and measuring knowledge clusters. Statistical procedures to measure the degree of knowledge clustering are discussed and ways are indicated to compare and determine the emergence of knowledge clusters. We conclude that the construction of knowledge maps showing the complexity of epistemic landscapes will enhance the chances of government agencies, companies and civic organisations to understand and use knowledge for development. This paper is in the first place meant as guideline for the related analysis.

Key Words

Knowledge and development, knowledge maps, epistemic landscapes, knowledge clusters, Geographic Information System (GIS)

1. Introduction: Epistemic Landscapes and Knowledge Maps

The World Development Report of 1999 has drawn attention to the fact that knowledge is not evenly distributed within countries, regions or urban areas. This has been described as the existence of a "knowledge gap" or, in relation to the ICT backbone of a knowledge system, as the "digital divide". It is then proposed to close these gaps by appropriate development policies. So far most studies have tried to show the narrowing or widening of knowledge gaps by using indicators, as provided by the KAM (knowledge assessment methodology) data base of the World Bank Institute, like number of researchers per million population, investment in R&D (research and development) as percentage of GDP and other indicators. In most cases these data have measured knowledge gaps between countries or regions, without paying closer attention to the geographical distribution of knowledge assets as well as the existence of knowledge gaps within countries, provinces or cities. We intend to close this particular "knowledge gap" by providing a methodology to show and measure the geographical distribution of knowledge related assets, people or organizations, which we have referred to as "epistemic landscapes". This paper is thus designed to discuss the methodology of creating knowledge maps and analyzing epistemic landscapes. Data and maps from ongoing research in the Mekong Delta in Vietnam[1] are used to illustrate various methodological issues and to show examples of maps and graphs. As discussed elsewhere (Evers 2008), knowledge landscapes are formed by knowledge clusters, knowledge hubs and the distribution of knowledge assets. Following the work of Porter on the competitive advantage of nations (Porter 2003; Porter 1990) there has been an upsurge of research and data collection on industrial clusters (Sölvell 2009). These studies usually assume that modern industrial clusters are centres of innovation and therefore desirable. Our concept of knowledge landscapes is less value laden and intends to show the spatial distribution of knowledge. Which type of knowledge landscape optimizes intellectual or industrial output remains a question to be decided by further empirical research.

We define epistemic landscapes in a geographical sense, i.e. we refer to the spatial distribution of knowledge assets within a predefined region (Evers 2008). The concept is not yet standard social science terminology. We are using the term "epistemic" in line with "epistemic culture", the culture of knowledge production, as coined by Karin Knorr-Cetina (Knorr-Cetina 1999). The term "epistemic" has been used in different contexts. One line of argument refers back to Bacon and 18th-century 'encyclopaedism' and defines an epistemic landscape as depicting a synthesis of knowledge (Wernick 2006). In Weisberg and Muldoon's study a single epistemic landscape corresponds to the research topic that engages a group of scientists. Agent based modelling with NetLogo software is used to model the changing epistemic landscape according to research strategies of participating scientists (Weisberg and Muldoon 2007). Conceptually distance rather than Euclidean distance is shown in graphs, similar to those used to illustrate social networks. In our study we follow a different path and focus on the development strategies of governments, strategic groups, firms, research institutes and their success in shaping the epistemic landscape of a region. The allocation of human and financial resources creates knowledge assets which are geographically distributed and can be measured, mapped and made to depict the contours of an epistemic landscape.

Epistemic landscapes develop over long periods of time. They are seldom shaped by individual actors, but more often by the collective action of strategic groups (Evers and Benedikter 2009; Evers and Gerke 2009). Firms connected by a common interest to capitalize on the competitive advantage of clustering have an impact on epistemic landscapes through their location decisions. More over government strategies to develop knowledge-based societies and economies have often been decisive in shaping epistemic landscapes. Relevant development policies have been assessed in detail elsewhere for Malaysia and Indonesia (Evers 2003), Singapore and Germany (Hornidge 2007). In fact, developing regions of high-

[1] This refers to ongoing research on knowledge management and knowledge governance in the water sector of the Mekong Delta (WISDOM project http://www.zef.de/1052.0.html), carried out jointly by the Center for Development Research (ZEF), University of Bonn, the Southern Institute of Social Sciences, HCMC and The Mekong Development Research Institute of Can Tho University. Useful comments by Steffen Gebhardt, DLR, are gratefully acknowledged.

tech industries, clusters or knowledge hubs are, by now, standard practice in many regional planning departments around the world.

In order to visualize and analyze epistemic landscape we have developed knowledge maps[2]. A knowledge map is the cartographic representation of captured information and relationships which enables the efficient communication and learning of knowledge by observers with differing backgrounds at multiple levels of detail (Meusburger 2000). The individual items of knowledge included in such a map can be text, stories, graphics, models or numbers. Maps can also serve as links to more detailed knowledge sources ranging from text-based groupware documents to database schemas as well as pointers to implicit knowledge (such as experts).

The creation of knowledge maps is by now a standard tool of knowledge management in organizations. "In their simplest forms, knowledge maps serve as guides to the type of knowledge held both inside and outside the organization. They serve as locators of that knowledge, and locators of people holding particular knowledge. They give a visual overview of the knowledge available to the organization" (Foles 1998:14).

The term „mapping" is, perhaps unfortunately, often used in the sense of „listing", i.e. creating a list of items, like organisations, persons or assets. "Yellow pages" listing names of persons or firms and their knowledge assets are (often used) to make knowledge easily accessible in large organizations and bureaucracies. In this paper "mapping" is, however, used in a cartographic sense. A list of knowledge producing organizations, i.e. research institutes and universities in Ho Chi Minh City and the Mekong Delta[3], lists next to name and function also the address or the geographical coordinates. Furthermore the geographical distance to other organisations is captured.

Figure 1: Example of Knowledge Mapping / Listing

Research Organizations in the Mekong Delta

No.	English Translation of organization	Latitude	Longitude	Function
1	Cuu Long Delta Rice Research Institute	10.104799	105.620077	wr
2	Southern Fruit Research Institute	10.406300	106.122190	wr
3	Biotechnology Research and Development Institute	10.028193	105.770270	wr
4	Mekong Delta Development Research Institute	10.030410	105.766008	wr
5	Hoa An Bio-Diversity - Application - Research Centre	9.869289	105.774001	wr
6	Tri Tue Viet Humane Resource Dev. & Training Centre	10.034732	105.779015	n
7	Computer, Science & Technology Centre	10.251991	105.971513	n
8	Research Centre for Rural Development	10.037803	105.786273	wr
9	Research Centre for Social Sciences and Humanity	10.037803	105.786273	n
10	Centre for Science Application and Technology Transfer	9.935052	106.342977	n
11	Research Centre for Agriculture and Rural Development	10.354048	106.371293	wr

Note: wr=water related research; n= no water related research

These lists can easily be used to build thematic maps. These maps show the distribution of data in geographical space. We shall, however, concentrate on one particular type of maps, showing the "clustering" of organisations. Maps of this kind are used in geographical or sociological research or created for use in information systems like the WISDOM information system, and for regional planning. Cluster research goes back to industrial location theory and assumes that proximity reduces transaction cost and spurns innovation. Data banks, like the European Cluster Observatory (http://www.clusterobservatory.eu) or the Vietnamese Provincial Competitive Index

[2] All maps in this paper have been designed and produced by the authors on the basis of data generated within the WISDOM Project.

[3] This list was compiled by Tatjana Bauer in 2008-09 in the course of her doctoral thesis research within the WISDOM project.

(http://www.pcivietnam.org), are designed to identify industrial clusters within nations. Our approach looks at knowledge clusters within cities, provinces and regions and uses the exact geographical location of organisations as a basis for analysis. Please note that this paper is designed as guideline for the analysis of knowledge clusters.

2. Examples of Thematic Maps and Landscapes

2.1 Distribution of Knowledge Producing Organisations

A map example is the "distribution of organisations" in Ho Chi Minh City (Evers and Bauer 2009). In this case we have chosen to work with data[4] that have been geo-referenced via GPS and Google Earth.

After importing data to the GIS (geographical information system), they can be used to create symbols in a simple map. A visual examination of the map shows the unequal geographical distribution of organizations, but only with the assistance of statistical calculations the spatial patterns can be further analyzed and compared.

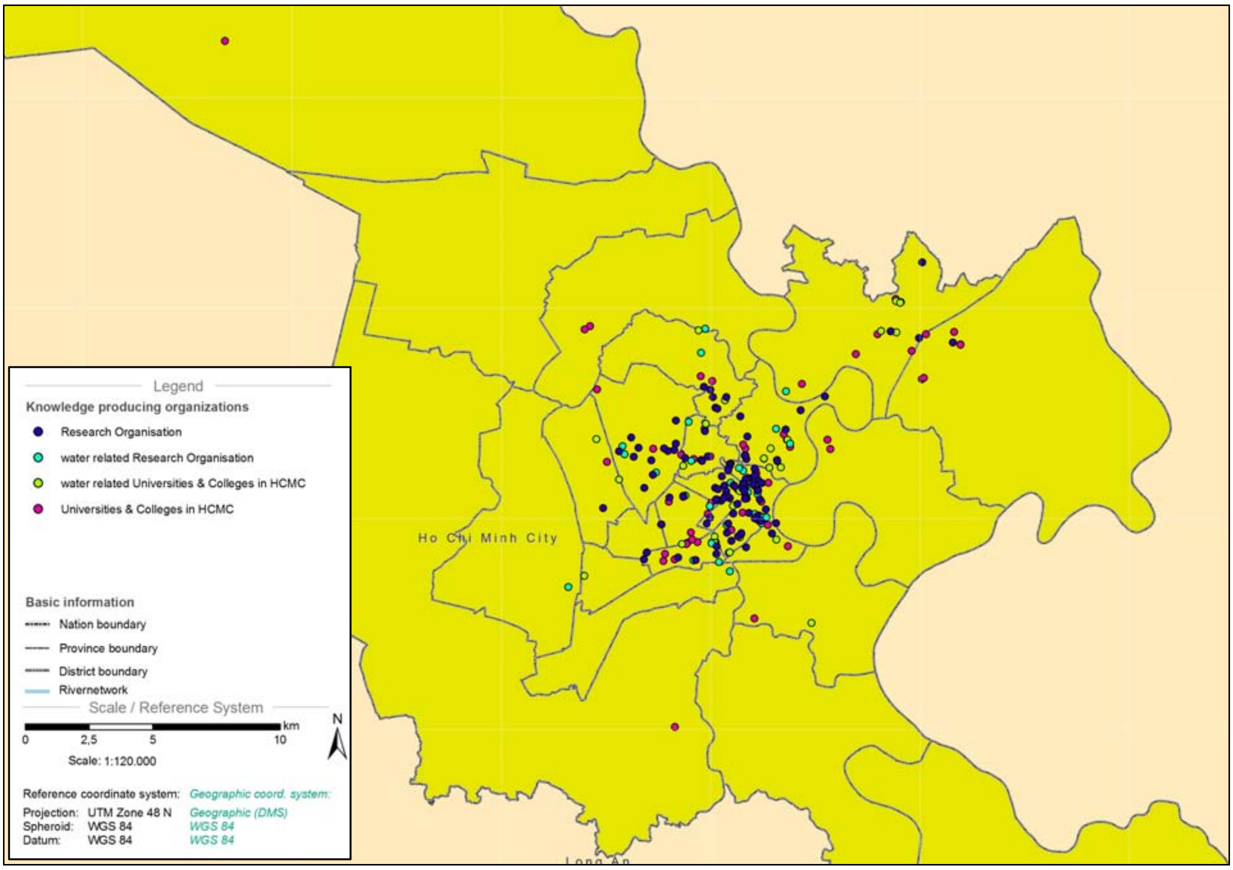


Figure 2: Knowledge producing organisations within the district boundaries of Ho Chi Minh City.

By adding additional variables the existence of knowledge clusters can be analysed. As an example we distinguish between water-related and non-water-related research institutions. By this we indicate, which institutes are engaged in research on the water sector. The spatial cluster analysis will give an indication of agglomeration tendencies. Such an analysis makes sense if we follow the assumption that clusters of research institutes and knowledge-based firms are more productive. The analysis can be

[4] This data was compiled by Tatjana Bauer in 2008-09 in the course of her doctoral thesis research within the WISDOM project

further enhanced by adding qualifying variables like for example “staff numbers”, “publications” and “year of establishment” etc.

In a first approach we used all “water-related universities and colleges” to analyse their straight-distance (Euclidean) to each other. The result is a “cluster map” (Figure 3) where each point is surrounded by a radius of 2000 meters. The map finally represents the quantity of overlaps of radii by a simple classification. Thus the differences between high and low-density areas can be worked out very well. A more detailed approach of clustering spatial data is given in the following section.

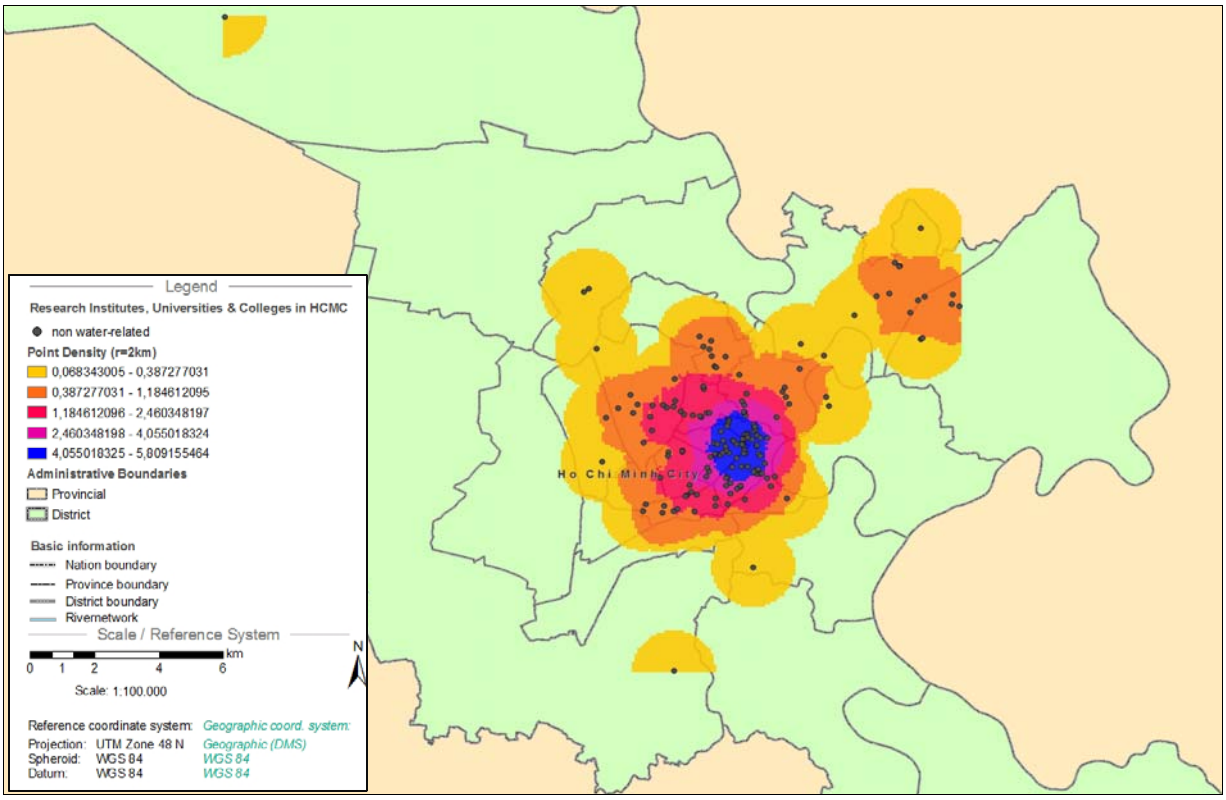


Figure 3: map of water-related Universities and Colleges in HCMC.

For a comparison of the effect of government strategies on cluster formation, maps of different regions can be visually examined. For a more sophisticated analysis statistical measures have to be employed which we are going to discuss below. The following map (figure 4) shows the low degree of organisational knowledge clustering in the Mekong Delta of Vietnam.

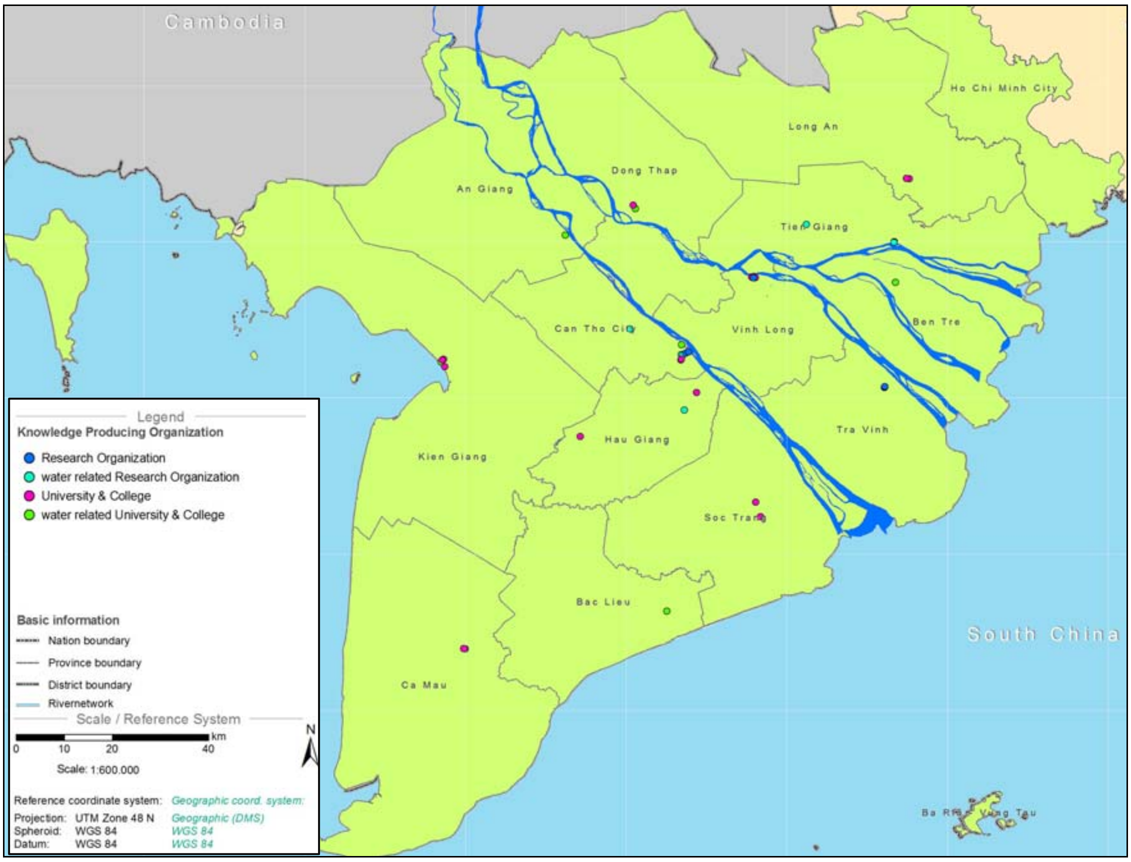


Figure 4: Mapping of knowledge producing organisations within Mekong Delta Provinces.

2.2 Distribution of Knowledge Assets

The third example of a map (Figure 5) uses the distribution of Can Tho University (CTU) students within the Mekong Delta provinces according to their home province between 1995 and 2008 as an indicator for knowledge assets. For Vietnam this data is state-wide available. Besides an absolute distribution of students, the map contains a gender classification. This separation is displayed by pie charts for each province.

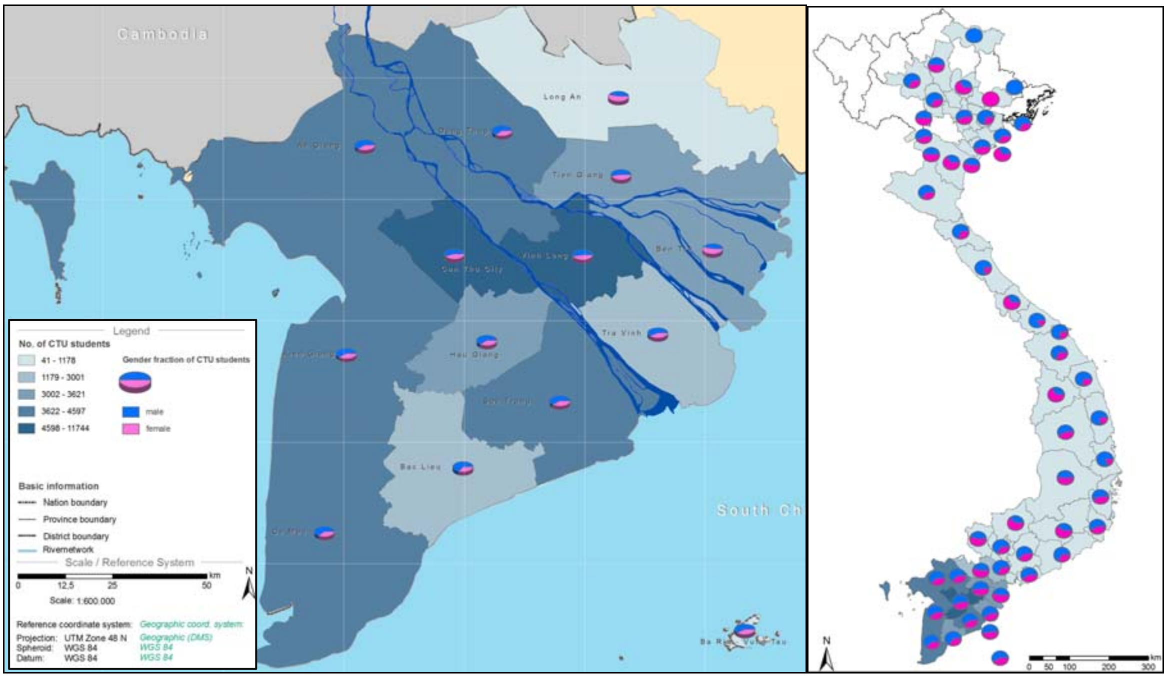


Figure 5: CTU students according to their home provinces, regional and state-wide.

Finally this map offers a predication about the degree of centralization and surplus capacity of Can Tho University. Here it is possible to distinguish if the university either has a regional or a national relevance. As shown in graph no 4 the university tends to the latter assumption.

In the long run more knowledge assets could be added or combined so that we are able to come to a more comprehensive conclusion about the distribution of “knowledge gaps” and “knowledge hubs”.

2.3 Distribution of Students in 3D

In the terminology of knowledge management we often talk about “landscapes”, “knowledge gaps” and “knowledge hubs”. All these terms are metaphorically touched.

Via the illustration of data by maps, we are able to display those metaphoric terms as graphical representations. For this purpose we create an artificial landscape in a geographical sense in which the surface characteristics are determined by the respective data set. So, the altitude of a given landscape element will be based on the quantity of a certain variable or attribute.

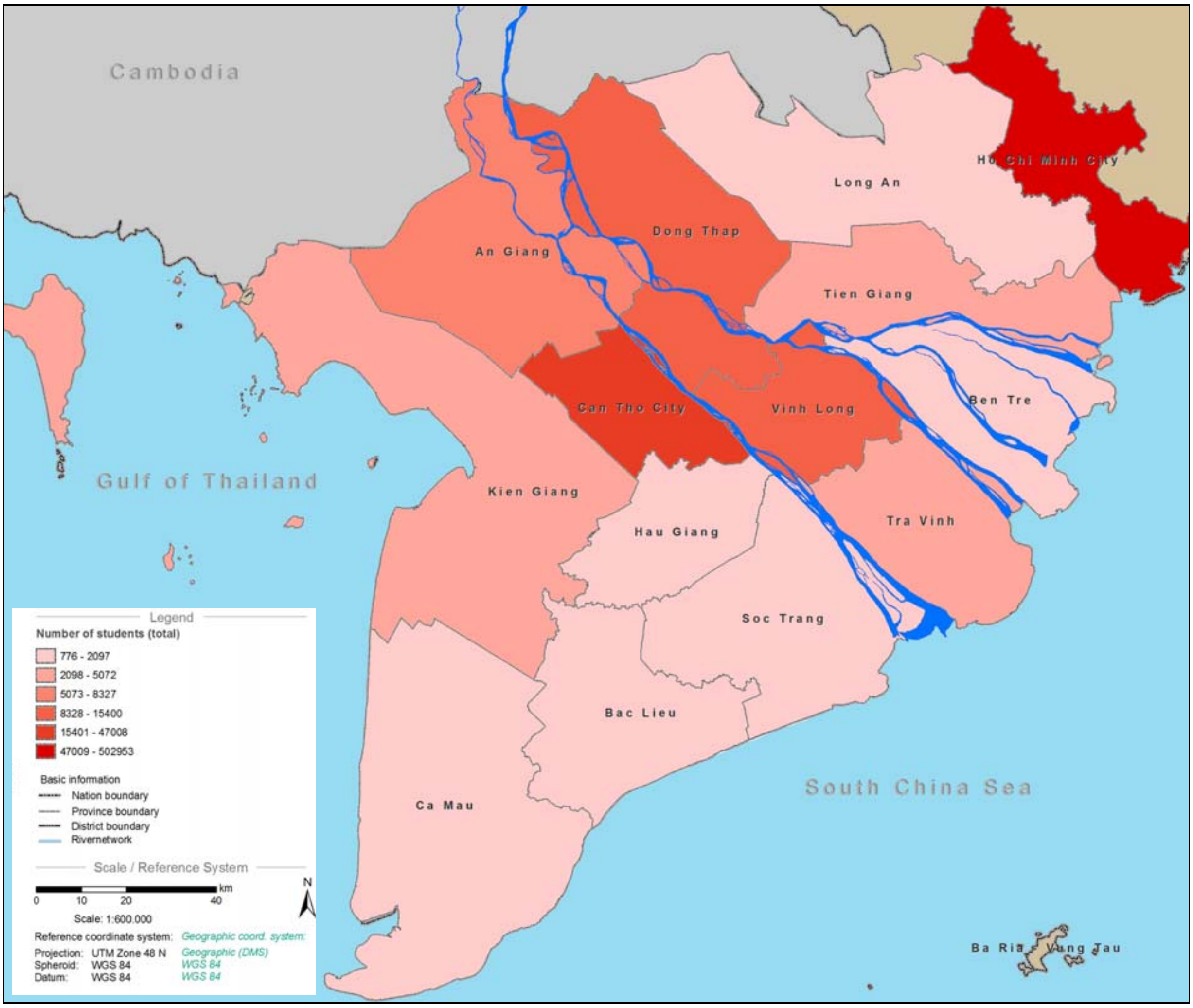
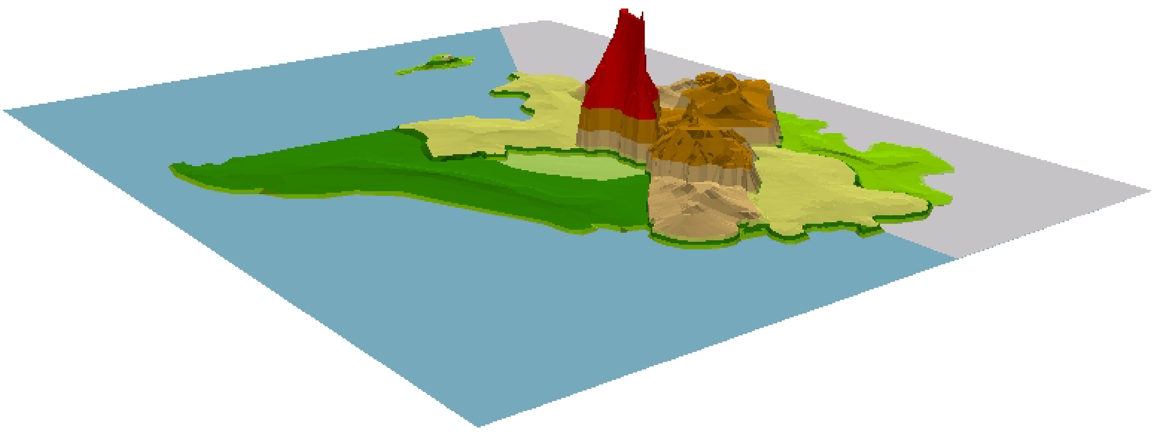


Figure 6: Distribution of students, Mekong Delta and Ho Chi Minh City; data © General Statistics Office Vietnam, 2007

In our example we choose to represent the altitude of the landscape by the number of students. Students, graduated from a university or college, are here interpreted as knowledge assets. By doing so, data peaks became (knowledge-) hubs and data downs became (knowledge-) gaps.



Finally it must be mentioned that there is little additional information benefit by using the third dimension, but it is a vivid representation of data that enhances the understanding of complex issues. Three dimensional representations are therefore increasingly used in advertising and in science centres like the recently opened knowledge cluster Fusionopolis in Singapore. In a later section we shall discuss some problems of creating three-dimensional landscapes in greater detail.

3. The Spatial Distribution of Knowledge Attributes

3.1 GIS: linkage of space and content

Attributes of data can be personal, institutional or regional and national (etc.), so that data can always have a geo-reference. The linkage between spatial attributes and content makes it possible to map the data.

Working with a GIS means first of all to start the management of geo-data. This includes the storage, the transformation, the structuring, and the creation of new geo-data, which attributes, properties and ranges of values have to be defined as well.

Before creating a map it is important to always check whether one can use an already existing map instead. Once that has been done the data gathering comes into play. For this, a determination between primary, i.e. self-generated, and secondary, i.e. available data, is of importance. Even though the process of gathering primary data usually is very time-consuming, it is more detailed and represents the attributes with much contextual depth. Secondary data on the other hand are easier to find and at lower prices to get, even though it often lacks contextual quality. Since the gathered data alone do not represent any kind of information yet, the gathered data set then will have to be transformed into a meaningful map by using knowledge and transformation rules.

Because of the vast amount of information consisting in the primary as well as in the secondary data set, one will have to fulfil a reduction of complexity, in order to create the aspired map. This can also include building data classes (before or after collecting data).

3.2 Data Input Formats

With the exception of the geo-reference, there are almost no other restrictions of data input. Geo-reference is the strongest requirement and standard for mapping any kind of information within a GIS!

The scale levels of the attributes can vary. Their content may contain nominal, ordinal, interval or ratio scaled information. Furthermore data can be raised on different spatial scales.

More examples of different scaled geo-references are: coordinates, a city, a district, a province, a state, a continent, (etc.). The different scaled geo-references are arranged in a hierarchical manner. An up- and downscaling of data depends on their resolution.

Another important guideline is the usage of a coherent geographic and/ or reference projection. If various shape files within a map project are of different projection, their visual display could be incorrect.

In case of the simple purpose of adding additional information to already existing geo-objects there are possibilities of importing data without a manual entry. For example, to merge a table with data (i.e.: excel, dBase) to already available attributes, one just has to set up identical table structures (keys). This functionality increases the collection of data by saving a lot of time.

Another useful application is depicted by the import of GPS-coordinates. For instance ArcMap[5] offers such a feature for an easy and automatic integration and display in shape-file[6] format. By opening and

[5] ArcMap is component of ESRI´s ArcGIS. It is the central application for the creation of maps. For this approach ArcGIS 9.2 was used.

[6] A shapefile stores nontopological geometry and attribute information for the spatial features in a data set. It consists of a main file, an index file, and a dBASE table. (ESRI 1997)

editing the shapefile´s attribute table again a quick alteration of numeric and/or textual data can be done with ease.

3.3 Spatial Data Representation

As stated above, the representation of data is realised by points, lines, areas or volumes. Furthermore table- and text-based data can be added. For a more detailed illustration classification of data should be undertaken. By doing so, the core statements of the data set move into focus and more precise conclusions can be drawn.

Alongside the representation of data via "simple" or "nested" queries, which are characterized as direct requests without modifying data values by showing single or logical combined attributes, the data also can be manipulated by creating new geo-data from the existing geometrics.

For the last mentioned approach, the cluster analysis of our water- or non-water related organizations can be used as an example.

3.4 Problems of Using the Third Dimension

For the creation of the three-dimensional map (section 3.4 above) we used data, which have been collected on a provincial scale, such as the number of students in Can Tho City. Obviously students are not distributed equally across provinces, but are concentrated in certain heavily populated areas. In fact we do not have any information about how students are distributed within this spatial reference unit.

In our map it is obvious that we carried out a more or less random interpolation within this given reference. This problem is common to most thematic maps, but from the standpoint of statistics this approach is, strictly speaking wrong because we did an assessment without any references of how the data could be distributed in space. In the long run we hope to find a solution, which enable us to interpolate the data within the spatial reference of collected data. The question still remains: How to handle the space, for which data are not available?

4. Results: Knowledge Maps or Epistemic Landscapes

4.1 Knowledge Maps as Analytical Tools

So far we have shown how knowledge related data sets can be visualized in thematic maps. They have one thing in common: they all use space or distance as an additional variable or, to put it differently, to geo-reference data on knowledge production, knowledge assets and knowledge flows. Data sets and maps all represent aspects of what we have termed "epistemic landscapes". The term "map" is used in the strict literal geographical sense. Our knowledge maps represent real geographical knowledge landscapes. Knowledge maps offer broad information about the spatial distribution of knowledge assets and knowledge production.

So far we have used knowledge maps mainly to study the process of clustering. The underlying hypothesis is, as explained elsewhere (Evers 2008), that a cluster of firms and organisations producing, transmitting or using knowledge enhances innovation and productivity and thus provides a competitive advantage over other regions that show a lower degree of knowledge clustering. Knowledge maps visualise the degree of clustering. We have tried to enhance the "visibility" of knowledge by using three-dimensional maps or even animations. The didactic value appears to be evident but the analysis has to go beyond visual impressions. We have therefore tried to use various statistical tools to measure the degree of clustering, or in other words to test the quality of epistemic landscapes and asses how they may contribute to social and economic development.

4.2 Statistical Measures of Knowledge Clusters

An adequate indicator for the spatial density of a cluster will have to be developed to describe the “quality” of a knowledge cluster. In the following some selected approaches shall be introduced. The density measures often used in the natural sciences (e.g. the stand density index SDI used often in forestry (Reineke 1933), which basically work according to the function “elements per unit of area/space” are not really applicable for the measurement of spatial density of knowledge clusters. In the case of knowledge clusters, it obviously makes much more sense to use the internal distances within a cluster for the construction of a density measure.

One imaginable and very precise approach of doing this is based on the Euclidean or linear distance of each knowledge-producing organization to any other knowledge producing organizations within a knowledge cluster. Therefore, a data matrix with all coordinates of the involved organizations on both the x-axis and the y-axis has to be generated. In the matrix the Euclidean distances have to be calculated whereas the distances of the organizations to themselves have to be excluded.

Table 2 Example of a data matrix for the calculation of the Euclidian distances between selected knowledge producing organizations of a knowledge cluster

		Name of institute	An Giang Universitas	Bac Lieu University	Can Tho University	Dong Thap University	...
		Latitude	547768	579406	584535	568901	...
Name of institute	Latitude	Longitude	1147099	1026762	1108858	1156715	...
An Giang Universitas	547768	1147099		124427	53049	23218	...
Bac Lieu University	579406	1026762	124427		82256	130377	...
Can Tho University	584535	1108858	53049	82256		50346	
Dong Thap University	568901	1156715	23218	130377	50346		...
...	...	...	...	...	...	...	...

Table 2 shows the data matrix that needs to be constructed for the determination of all Euclidean distance between the organizations of a knowledge cluster. The total number of distance values, which is generated by the matrix, is always determined by the equation n^2-n, whereas n is the total number of organizations. With the generated values a new variable can be constructed whereby all in all one variable per knowledge producing unit are produced. These variables contain all distances of the respective unit to all other units of the knowledge cluster. With the mean value (and additionally the standard deviation, standard deviation of the mean, variance, range etc.) a coefficients can be calculated to measure the spatial density of a knowledge cluster. The disadvantage of this approach is that there is a high vulnerability towards outliers and extreme cases. Practically, this means that if a knowledge cluster has one organization, which is located in a great distance to the rest of the cluster, this cluster will have a very high value, especially for its standard deviation even if the rest of the cluster may be located very close together.

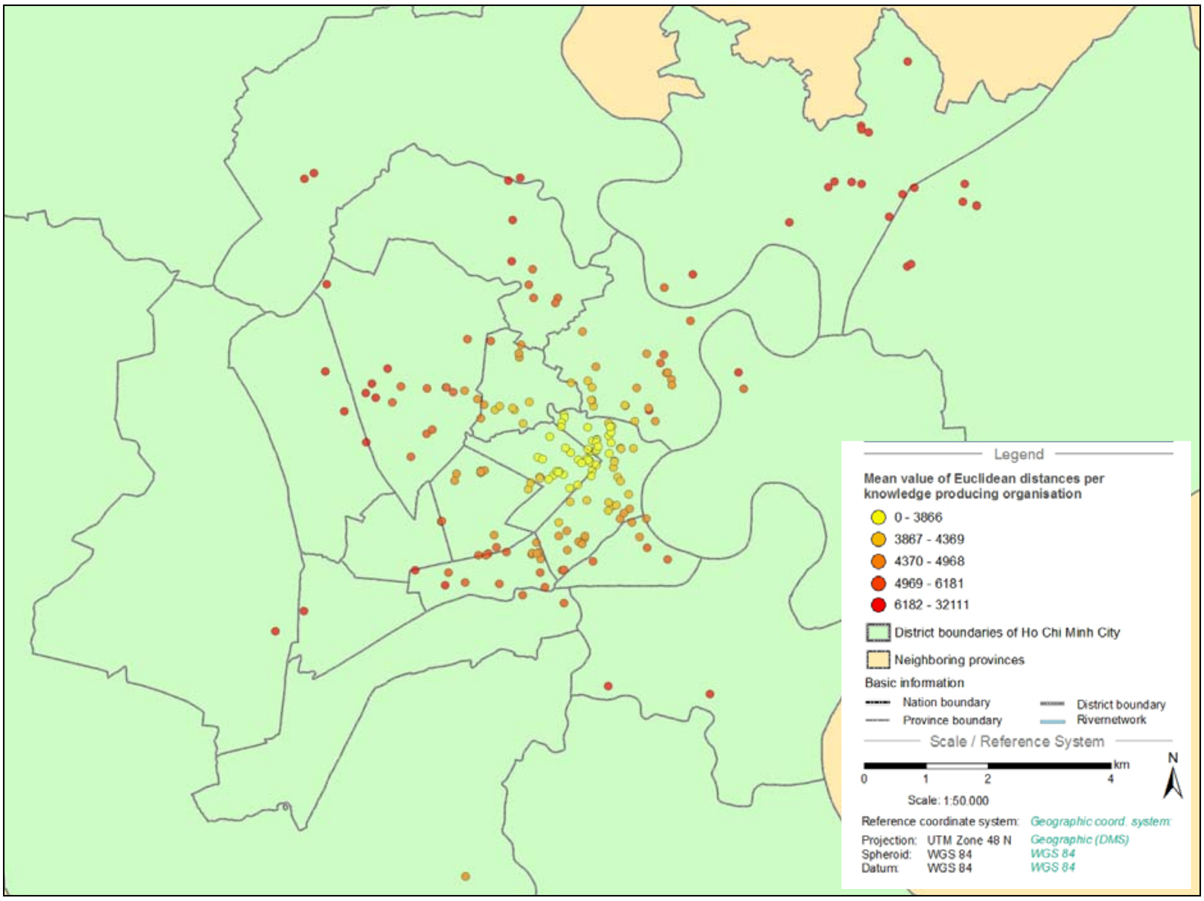


Figure 7: Spatial distribution of knowledge producing organisations in Ho Chi Minh

If we take the example of research institutions in Ho Chi Minh City (n=218) and the Mekong Delta (n=42), the average distance value for the first mentioned is 66.7 kilometres and for the last mentioned 5.6 kilometres with standard deviations of the mean of 5.6 kilometres and 0.37 kilometres. Principally problematic with this approach is the relative sensitivity for outliers and extreme cases. This is not really true for the example: the Ho Chi Minh City cluster has one institution, which is located in some north-western distance to the rest. But this outlier has only some (soft) impact on the density score for this cluster since without this institution the cluster would have a density score of 5.4 kilometres in average.

To totally overcome this potential bias caused by outliers another third approach, which can be called the “neighbourhood per radius approach”, can be applied. For this method the same data matrix for the calculation of the Euclidean distances between the organizations of a knowledge cluster has to be generated. The next step is to check all the distances whether they are bigger or smaller than a pre-defined distance value (e.g. 1.5 km, 2 km, etc.). If they are smaller, the distance value has to be transformed into the value 1, if not it has to be transformed into the value 0 (see table 3 for the Ho Chi Minh City cluster). If then the sum per column or per row is counted, the outcome is the number of neighbouring organizations within the pre-defined radius for every organization of the cluster. The predefined distance is not totally arbitrary, as an ideal distance for face-face communication can be assumed or calculated. Network data could be a possible source for this calculation, as we shall argue below. With the statistical measures mentioned above coefficients measuring the spatial density of the respective knowledge cluster can be constructed (for instance the average number of neighbours per institute or the standard deviation of neighbours per institute).

Table 3 Example for the “neighbourhood per radius approach” for the value of 2 kilometres

		Name of institute	Academy of Politics - 2nd Base	Posts and Telecommuni-cations Institute of Technology	Vietnam Aviation Academy	National Academy of Public Administration - HCMC Branch	...
		Latitude	695393	685946	682968	683799	...
Name of institute	Latitude	Longitude	1199990	1193259	1193970	1191896	...
Academy of Politics - 2nd Base	695393	1199990		0	1	0	...
Posts and Telecommuni-cations Institute of Technology	685946	1193259	0		0	0	...
Vietnam Aviation Academy	682968	1193970	1	0		0	
National Academy of Public Administration - HCMC Branch	683799	1191896	0	0	0		...
...	...	...	...	...	...	...	...

Contrary to the first described approach, the higher these values are the denser is the cluster spatially. The disadvantage of this approach is that the value for the respective radius has to be chosen purposely in order to get sound results. The radius size is severely determining the results for the density score what can easily be demonstrated by taking the example of the non-water research cluster of the Mekong Delta: the score value (=the mean number of neighbours) is 0.04 with a radius of r=1 kilometre and is 2.6 for r=2 kilometres (for Ho Chi Minh City the value changes from 13.6 for r=1 kilometre to 39.7 for r=2 kilometres). A solution for that could be – if existing - the analysis of respective social network data, which for instance indicate how often a member of one knowledge producing unit communicates face to face with a member of another unit. Based on that, a critical maximum distance for direct face to face communication within a knowledge cluster can be estimated. Another disadvantage is that distances are only indirectly integrated into this measure. What in the first introduced approach has a very high impact on the score values has a very low impact on the accordant measure in this approach.

A “compromise” position between these two approaches can be a third method, which can be called “nearest neighbour”-approach – based on the related cluster analysis method. For this approach, an Euclidean distance matrix (as the one of table 2) is used and only the lowest or minimal value for each knowledge-producing unit is taken into consideration. Accordingly, the accordant values show the distance to the nearest neighbouring unit for every observation. The so established distribution with its statistical attributes (mean value, standard deviation, median, etc.) can be used to describe the spatial density of the knowledge cluster. For the Ho Chi Minh City cluster the mean minimal distance has a value of 0.4 kilometres whereas the value for the Mekong Delta is 4.7 kilometres. Generally, the sensitivity towards outliers and extreme cases cannot be reduced with this approach completely.

Another fourth method, which strongly mitigates the impact of outliers, is based on the natural logarithm. The values of the Euclidean distance matrix simply have to be transformed with the natural logarithm function, whereby the impact of the outliers and extreme values will be strictly mitigated (see table 4). The mean for all average values per knowledge producing unit can be taken to construct a density measure for this approach. The respective density score value for the knowledge cluster in the Mekong Delta would be 10.7 whereas the value for the Ho Chi Minh City cluster would have a value of 8.3. A disadvantage of this approach is that the distances between two clusters with very different measures of spread are not adequately reflected - as in the example of Ho Chi Minh City and the Mekong Delta where the accordant score values only differ by the factor of 1.3.

Table 4 Example for the logarithmic transformation approach

		Name of institute	An Giang Universitas	Bac Lieu University	Can Tho University	Dong Thap University	...
		Latitude	547768	579406	584535	568901	...
Name of institute	Latitude	Longitude	1147099	1026762	1108858	1156715	...
An Giang Universitas	547768	1147099		11,7314705	10,8789695	10,0526791	...
Bac Lieu University	579406	1026762	11,7314705		11,3175924	11,7781848	...
Can Tho University	584535	1108858	10,8789695	11,3175924		10,8266734	
Dong Thap University	568901	1156715	10,0526791	11,7781848	10,8266734		...
...	...	...	...	...	...	...	...

A last and fifth method, which takes all possible distances within a cluster into consideration and at the same time mitigates the impact of outliers, is the normal distribution probability index. In this approach the latitude and longitude variables are used. With the means and the standard deviations of both variables as well as the correlation coefficient between the latitude and longitude variables the probability that the accordant point is part of a normal distribution in the two-dimensional vector space is calculated. The probability values are then multiplied with the distance between the latitude and the longitude values to the accordant mean values (see below for the exact equations). The mean value of the so created values is then used as a density score, which is sensitive only towards very extreme outliers. The accordant value for Ho Chi Minh City is 973.1 and for the Mekong Delta it is 15268.3.

All in all, we have thus proposed the following five measures of spatial or distance density:

1. The “Mean Euclidean Distance Index” (EDI)
2. The “Neighbourhood per Radius Index” (NRI)
3. The “Nearest Neighbour Index” (NNI)
4. The “Mean Logarithmically Transformed Euclidean Distance Index” (LTEDI)
5. The “Normal Distribution Probability Index” (NDPI)

Measure of density / clustering index	Value for HCMC	Value for Mekong Delta	Equation (for d_{ij} =Euclidean distance between x_i and x_j)
1. EDI	5.6	66.7	$A = \frac{1}{n}\sum_i a_i$ whereas $a_i = \frac{1}{n-1}\sum_{j \neq i} d_{ij}$
2. NRI (for r=1 km)	13.6	0.04	$B^r = \frac{1}{n}\sum_i b_i^r$ whereas $b_i^r = \frac{1}{k_i - 1}\sum_{\{j \mid j \neq i \wedge d_{ij} \leq r\}} d_{ij}$
3. NNI	0.4	4.7	$C = \frac{1}{n}\sum_i c_i$ whereas $c_1 = \min_{j \neq i} \; d_{ij}$
4. LTEDI	8.3	10.7	$D = \frac{1}{n}\sum_i ld_i$ whereas $ld_i = \frac{1}{n-1}\sum_{j \neq i} \ln(d_{ij})$
5. NDPI	973.1	15268.3.	$E = \frac{1}{n}\sum_i d_{i\bar{X}} * \mathrm{Pr}ob(N^2 \geq (X_i - \bar{X}))$ whereas N²=*bivariate normal distribution* and $d_{i\bar{X}}$ =*Euclidean distance of* x_i *to the cluster mean*

5. Conclusion: The Use of Epistemic Landscapes

In this paper we have demonstrated how knowledge attributes of various kinds can be made visible in a knowledge map. Knowledge is not evenly distributed in space but shows discontinuities, gaps and heights. We use the concept of "epistemic landscape" to allude to the complex tapestry of knowledge assets, institutions, organisations, hubs and clusters. Since antiquity maps have been used to provide orientation and direction. Moreover they "can bridge the gap between language and culture in terms of communicating" (Hatfield, 2006). Maps are thus powerful tools in aid of decision making, proper planning and resource allocation. They are put into practice by indicating "how to get from here to there". They are in themselves repositories of knowledge, which can be retrieved and put into action. Epistemic landscapes and knowledge maps are therefore important parts of any information system. By additionally computing statistical measures of the density of knowledge clusters, comparative data can be interpreted. By correlating indicators, i.e. on knowledge output (like research papers or patents) with our knowledge density measure, the effectiveness of knowledge clustering can be studied. So far a similar approach has been used to study the competitive advantage of regions, following the earlier studies of Porter and others (Porter 1990; Sölvell 2009).

Last not least we refer to the didactic value of maps. Information and knowledge, in our case the potential use of knowledge for development, have to be distributed to those that either benefit or suffer from the application of knowledge for development. The concept of epistemic landscapes and maps showing the complex and complicated business of producing and using knowledge enhance, we believe, the chances of government agencies, companies and civic organisations to understand and use knowledge for development.

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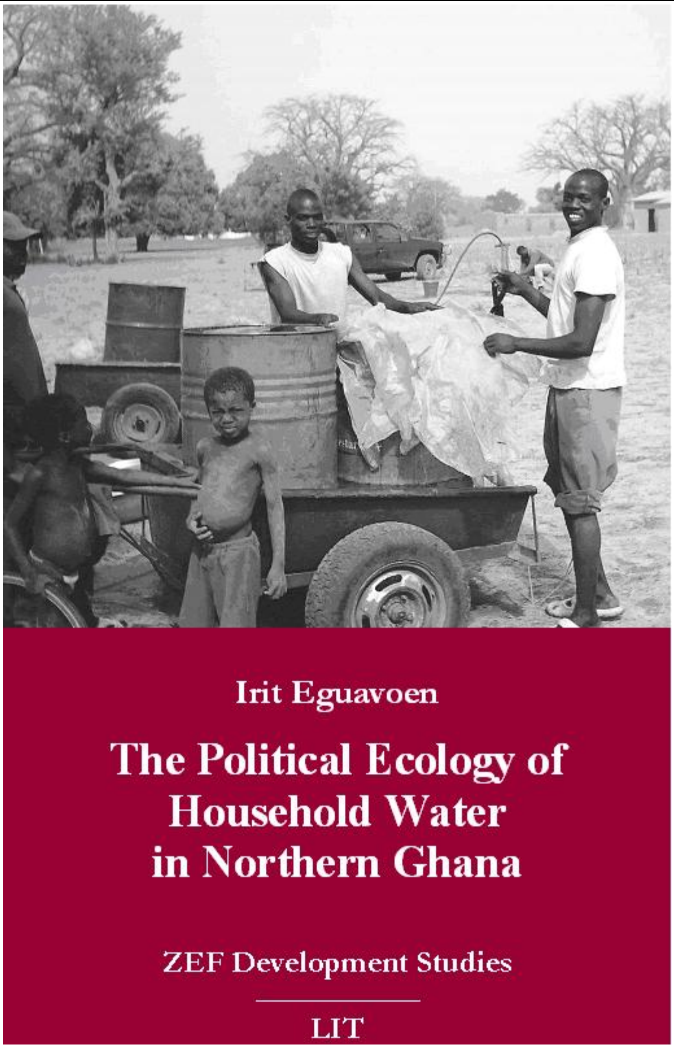

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