From GPS coordinates to a printed atlas

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The aim of the project "Introduction of Health-GIS in TGPSH supported Mbeya Region in Tanzania", realised by the Beuth University of Applied Sciences Berlin in 2008 and 2009, is to introduce a geographic information system (GIS) to the study area. As part of the process of introducing a GIS, we conducted a baseline study with interviews of staff in regional health facilities. Using our findings, Beuth University developed a comprehensive database (DB) and a GIS. To accompany the digital monitoring system, we published all relevant results in the present analogue printed version – *The Health Atlas: Health Service Availability in Mbeya Region – Tanzania*. This atlas is a product of the present Health-GIS. It primarily uses thematic maps to facilitate visualisation of the infrastructure of local health facilities. Topics where chosen and first drafts were discussed collaboratively with local staff of Tanzania's health sector.

GIS for Monitoring of Health Infrastructure

In the field of public health, priority is given to overcoming disparities in access to health care, as well as observing the negative consequences that emerge from such disparities. This is particularly so in developing countries where resources remain limited [Graves 2008]. As such, a great deal of focus has been placed on realizing the most efficient use of resources. Health Information Systems at the community-level are especially important in large countries like Tanzania, where emphasis on the decentralisation of health services requires district level Health Information Systems [Raban et al. 2009]. In recent years, the Tanzanian Councils (LGA) have established and improved the country's decentralised health systems [The United Republic of Tanzania 2008]. A GIS is therefore very helpful for the support of and compliance with the Health Sector Strategic Plan III (HSSP) [The United Republic of Tanzania 2008], itself created to ensure equitable access to health services across the population.

Two types of data are used in a GIS: spatial and attribute data. Despite the regular collection of data from HF, a number of studies have highlighted the limited capabilities of GIS in developing countries due to a lack of pre-existing data for input [Deshpande et al. 2004]. In these cases, both the quantity and quality of data must be taken into account. In light of the Millennium Development Goals as well as the interests of international organisations which monitor and evaluate data of health programmes, a premium must especially be placed on data quality in a GIS [Boerma & Stansfield 2007].

In Tanzania, much emphasis and effort has been geared toward achieving tangible progress in the alleviation of poverty. In this process, public health has come into focus. Specific goals were set in the HSSP III [The United Republic of Tanzania 2008] in 2008 to be achieved in the coming years. In order to succeed, certain tools are needed to enable effective strategic planning and help control existing interventions. Given the emphasis on spatial questions in such plans, a GIS is an appropriate tool.

As noted above, both spatial and attribute data are needed in a GIS. In a preliminary study (2007), we collected, analyzed, and evaluated all free data available in Tanzania, as well as on the Internet. Despite the accessibility of much information, it turned out that for many fields of the project there existed a lack of area-wide data for the Mbeya Region. This applies to HF in particular. Existing spatial and attribute data were both found to be insufficient.

Data Collection in 2008 and 2009

Tanzanian (UDSM and ARU) and German (Beuth University) students were invited to participate in two phases of fieldwork in order to introduce them to the process of data collection. The first round of data collection occurred in September 2008. During this primary stage, we toured the districts of Ileje, Kyela, Mbeya District, Mbeya City, and Rungwe. The second and final round of data collection was conducted in June 2009 and included the three remaining districts – Chunya, Mbarali and Mbozi.

Participating students were divided up into teams of two which included one Tanzanian and one German student per team (see Picture 1). Each partner within a team provided technical support for the other. The Tanzanian students were primarily responsible for Swahili translations. Fieldwork was supported by the district health management teams of Mbeya Region through the provision of cars, local drivers and health supervisors for the interviews. Each team was also given access to a handheld Global Positioning System (GPS) of Garmin, netbook with Access DB, digital camera, the questionnaire forms, a list of HFs, and district maps for orientation.

During fieldwork three data types were collected: spatial data, extensive attribute data, and photo-documentation of all HF. Spatial data: Geographic coordinates of HF (Longitude, Latitude and Altitude) were collected with a handheld GPS with a positional accuracy of ±10 m. The roads leading to each HF were tracked with the GPS. The GPS saved track points every 50 m of the roads. Tracks were repeatedly recorded, resulting in a multitude of parallel lines. These lines were then generalised in the GIS and replaced by one single line (see Figures 1 and 2). This new line was designed cartographically according to surface conditions. The represented road network is not complete, but is limited to the tracks which lead to HF.

In all, HF attribute data was collected using the questionnaire. In every HF one of the medical staff was

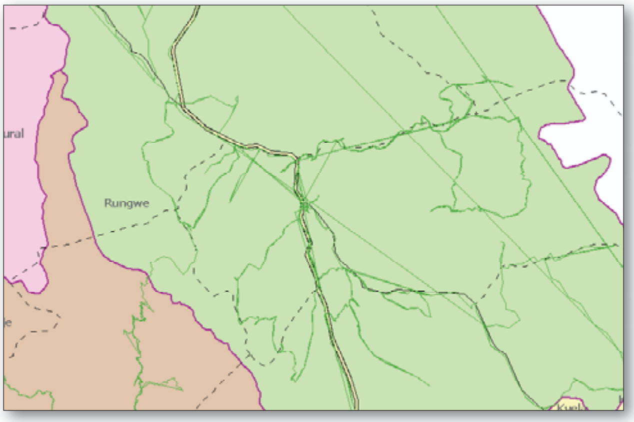

Figure 1: Tracks collected by GPS without cleaning

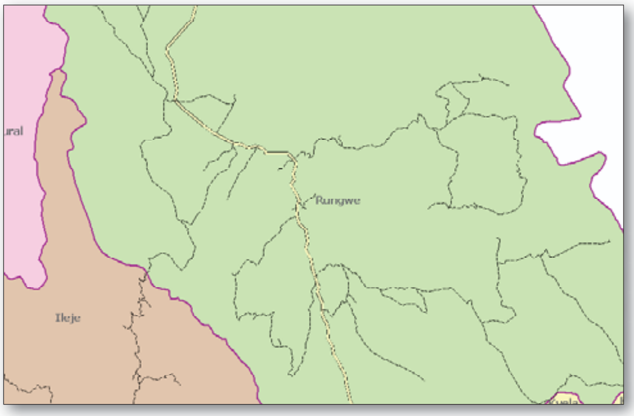

Figure 2: Tracks collected by GPS after cleaning

Picture 1: Data collection in Mbarali District – Mbeya Region, GPS handling of students

Picture 2: Data collection in Mbeya District – Mbeya Region, interviewing

District Name	HF Total[1]	HF No function	HF with Coordinates	HF with Coordinates in %	HF with Interviews	HF with Interviews in %
Chunya	41	4	39	95	36	97
Ileje	25	-	25	100	25	100
Kyela	36	3	32	89	32	97
Mbarali	55	16	41	75	39	100
Mbeya District	56	9	51	91	44	91
Mbeya City	61	13	47	77	46	96
Mbozi	87	18	86	99	69	100
Rungwe	66	5	64	97	61	100
TOTAL	427	68	385	90	352	98

Table 1: Realized questionnaires on the level of districts

interviewed (see Picture 2). The interviews were based on a questionnaire which is developed by the "Mapping Task Force Committee"; MoHSW is the head of this committee. The questionnaire has eight sections:

- *Section 1: General characteristics*
- *Section 2: Services and General purpose equipment*
- *Section 3: General purpose equipment (only for Hospital)*
- *Section 4: Injection and sterilization equipment*
- *Section 5: Human recourses*
- *Section 6: Drugs and commodities*
- *Section 7: Lab test*
- *Section 8: Buildings*

In the photo-documentation phase all buildings and special features were photographed in order to document the state of repair of the facilities.

In 2008 there were 427 HF registered within the Mbeya Region. 97.6 % of all open HF were interviewed between 2008 and 2009. Only seven HF could not be interviewed, because either no staff was present or interviewing was prohibited. Geographic coordinates were collected of 385 HF via GPS which covers 90 % of all HF in the Mbeya Region. Partially geographic coordinates were recorded by HF which were closed. As the possibility of reopening remains, these HF were included in the database (see Table 1).

All attribute data was stored in a Microsoft (MS) Access DB created by a database management system. In a Personal Geodatabase all spatial and attribute data were jointed and presented in the Health-GIS (see Figure 3). We displayed the preliminary results of the Mbeya Health-GIS in selected thematic maps, printed in the present Health Atlas.

Geographical Data from Public Institutions

At this moment there is no spatial data infrastructure in Tanzania. Each ministry develops its own database, which remain inaccessible to other ministries. It is, however, possible to receive products from these databases, e.g. cadastral maps, boundaries, settlement markers, etc.

Furthermore, topographical maps in different scales are available, despite the fact that most of them are more than 25 years out of date. Until recently, there has been no motivation to create a centralized database bridging different institutions. Currently, however, policy makers are discussing the initiation of a corporate geodata infrastructure at the ministerial level. The "Ministry of Education and Vocational Trainings", the "Ministry of Lands and Human Settlements Development"

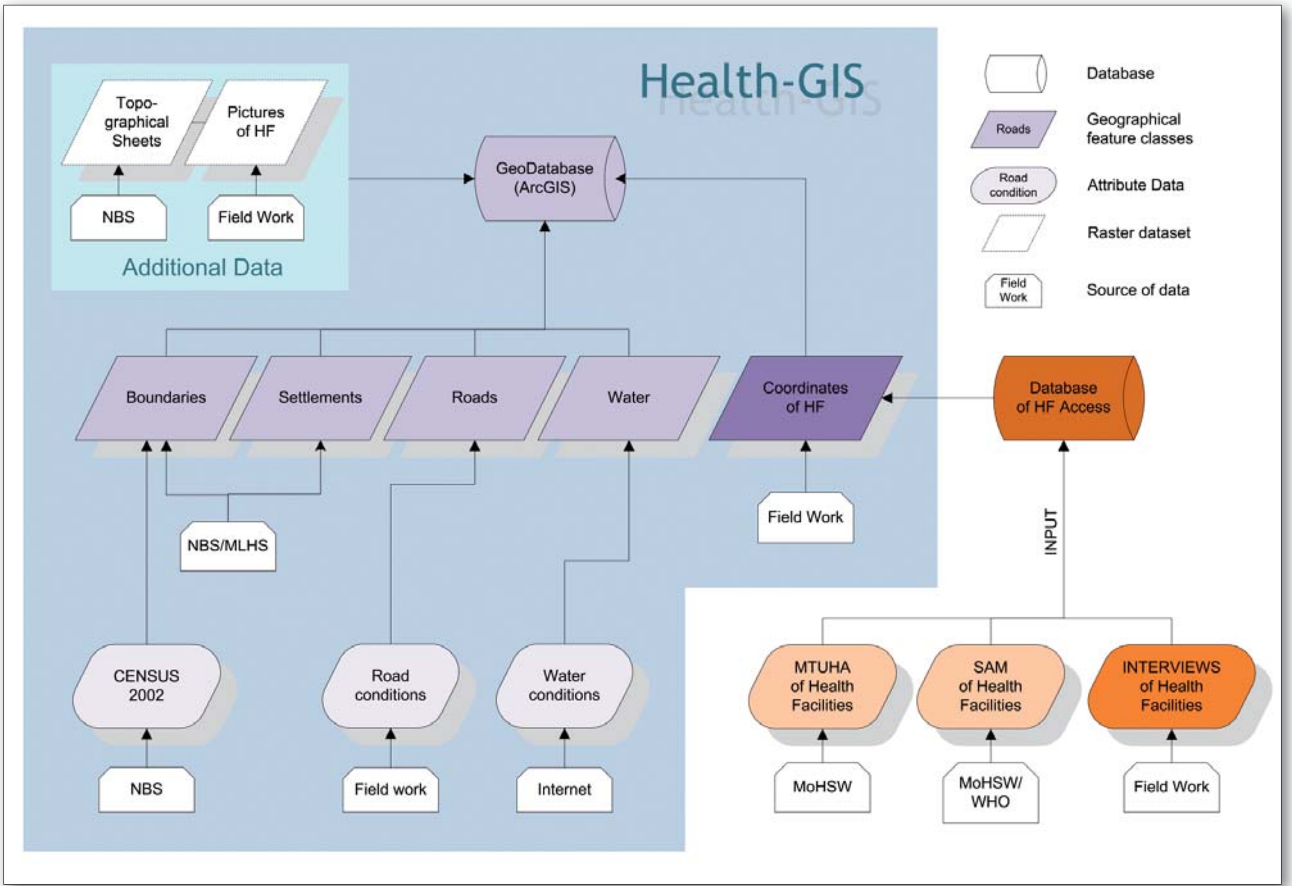

Figure 3: Structure of Access database and GeoDatabase

(MLHS) and the "Ministry of Planning, Economy and Empowerment" intend to create a uniform "National Data Infrastructure". Results from this consolidation are not expected before the middle of 2010.

A primary source of attribute data, like demographic and socioeconomic data, is the "National Bureau of Statistics" (NBS) Tanzania. In August 2002, the United Republic of Tanzania conducted a population and housing census with reference dates. At the same time, administrative boundaries of Tanzania were mapped and digitised which formed a reference basis for regional, district and ward boundaries for the Health Atlas.

Associated with the MLHS is the "Surveys and Mapping Division". The latter is the acting division of cadastral measurements whose responsibilities include monitoring, regulation and supervision of the land register. The "Surveys and Mapping Division" digitises all cadastral maps. For selected regions of Tanzania, the "Surveys and Mapping Division" also prepares spatial data based on vector data. This covers administrative boundaries including village boundaries as well as village centres. The village boundaries are formed on the one hand from natural features in the terrain like rivers, which are digitised based on topographical maps in the scale of 1:50,000. Boundaries are also mapped based on station points, which are then pegged by stones with identifiers (ID) and surveyed through the Surveys and Mapping Division.

A digital terrain model for the background of every map was generated using publicly available and free data – Shuttle Radar Topography Mission (SRTM) (see Figure 4). Access to SRTM data can be found here free of charge: http://srtm.csi.cgiar.org/. The Digital Terrain Model (DTM), derived from SRTM data, has an original resolution of approximately 100 m x 100 m. In scales greater than 1:300,000 SRTM data show nu-

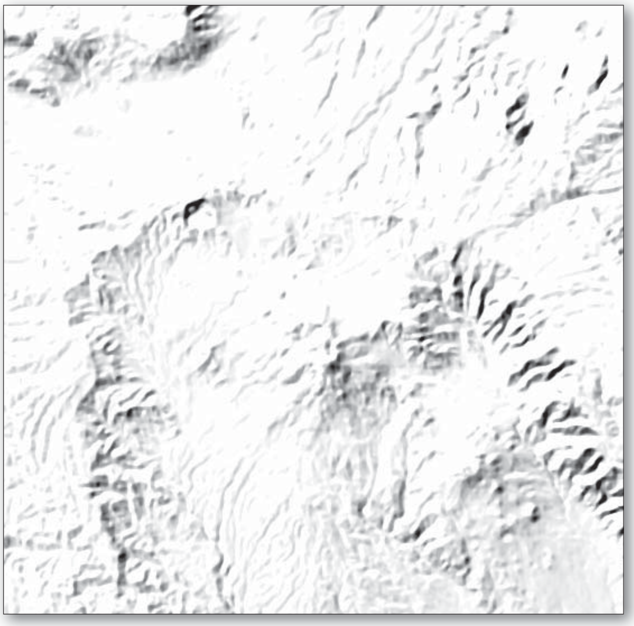

Figure 4: Terrain model of SRTM data

merous abrupt rises on steep, high hillsides which result in a horizontal or vertical striation. For scales smaller than 1 : 500,000 the DTM is too detailed and generates a bumpy surface of the digital shading. In order to provide a reasonable digital shaded 3D-visualisation of the relief a newly generalised DTM was created for each scale. Various shading methods, which simulate diverse light sources, were applied to the DTMs.

Workflow of the Health Atlas

Data from the Health-GIS has provided the basis for all maps in the atlas. In order to make high-quality maps, several production steps have occurred which led from a preliminary GIS-generated map to a final printed map. The first step required exporting all necessary data as a preliminary map from software "ESRI ArcGIS" (see Figure 5). It then continued processing with the graphic software "Macromedia Freehand". Preliminarily, generalisation and thematic supplementation of the topographic features took place according to the desired scale proper signatures and symbols were designed for all map contents and placed on the maps. In the next step all map elements were labelled from a cartographic viewpoint in order to achieve good readability and the accurate placement (see Figure 6).

A first version of the maps was checked, corrected and supplemented in Mbeya with employees of various positions in the health sector (see Picture 3). Emphasis was placed on employee understanding of the maps, as the main priority was to produce clear-cut and usable maps and texts. Every map was therefore tested and proofread by several representatives of the health sector before the final printing of the atlas. Maps were

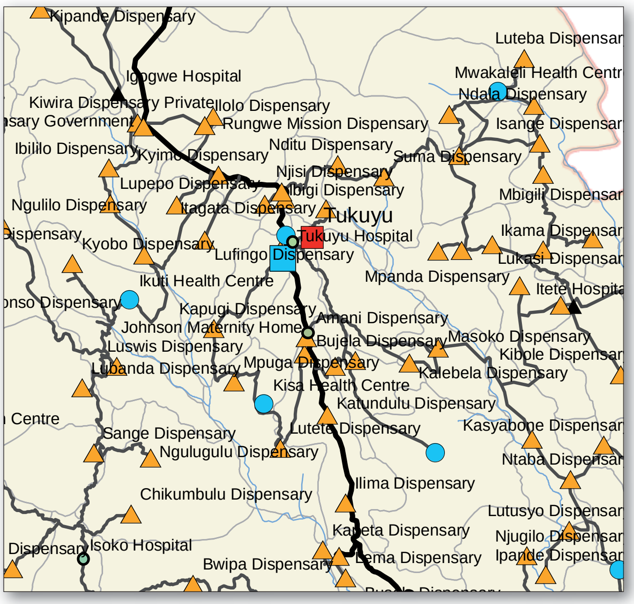

Figure 5: Tracks from ArcGIS before Generalization

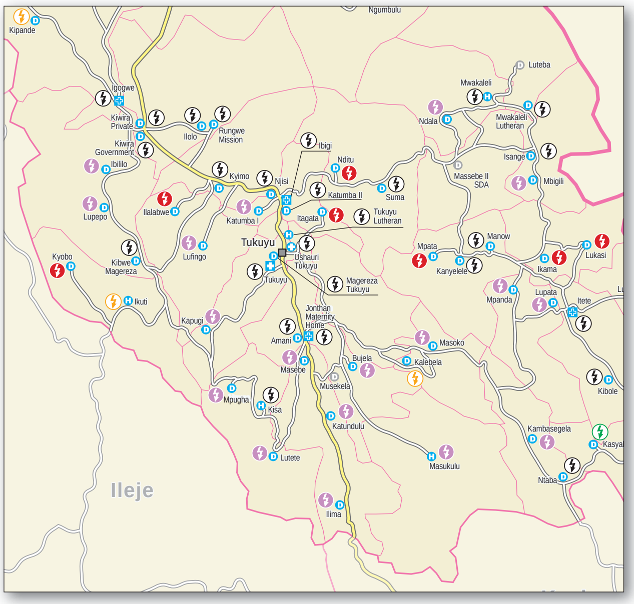

Figure 6: Tracks after Generalization

revised on the basis of these interviews. In addition to the maps, photos were chosen and diagrams created during this stage.

Great importance was attached to the adaptation of intercultural modes during the creation of map contents and signatures. As noted, we believe that all maps and important texts should be understandable to every local health worker. We accordingly published the legends and introductive texts bilingually – in English and Swahili (see Figure 7).

Picture 3: Proof reading of the maps with health workers

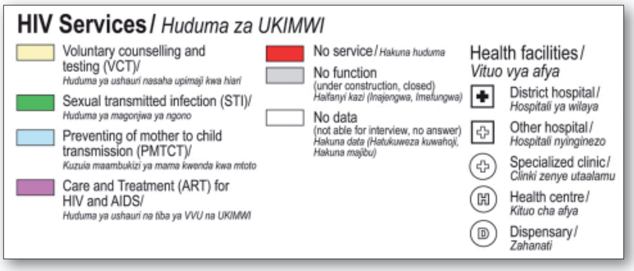

Figure 7: Example of the legend in two languages – english and swahili

In order to improve readability cartographic problems were solved. For instance, regional HF are not uniformly distributed over the map. The emerging shortage of space for the signature and text placement was solved in the following way: the HF is localized by a respective thematic signature and the name of the place is joined to the symbol by a connecting line (see Figure 8 Point 1). If there was neither enough space for the signature nor the text, the HF was localised by a black dot and both forms of information were displayed with the aid of the connecting line (see Figure 8 Point 2).

Chart maps (see Figure 9) provide the possibility to compare data of districts in the Mbeya Region. The diagrams summarize on district level data presented in the detailed maps. While the latter show qualitative information, the chart maps provide quantitative data.

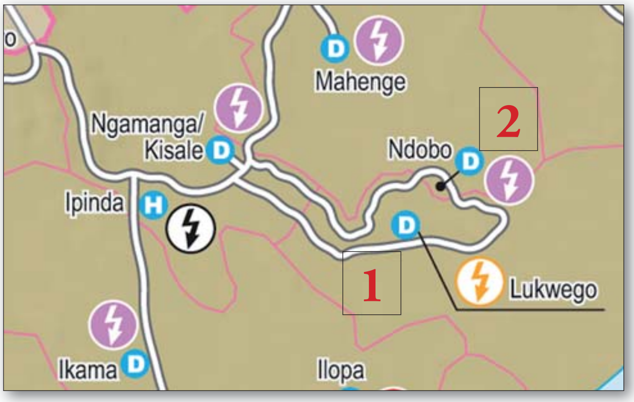

Figure 8: Example of the HF labelling in the district maps

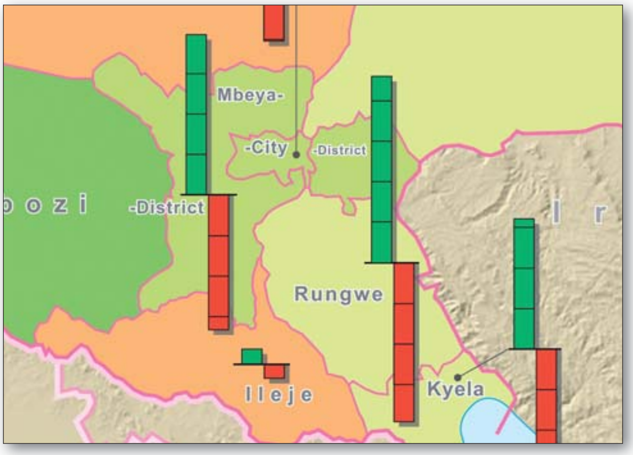

Figure 9: Example of a digramm map