Exploiting available data sources: location/allocation modeling for health service planning in rural Ghana

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Abstract

The preconditions for applying GIS-based location-allocation analysis for health service planning in rural Ghana are examined in terms of data availability and quality. A population map is established from the latest available census using geo-coding methods and digital topographic sheets. A vector-based transport model of the region is established by merging data from several sources including GPS. It is suggested that a hybrid transport model is required. This model combines the possibilities for all-direction transportation inherent in the raster-based approach with the possibilities for road/path transportation inherent in the vector-based approach. All-direction movements are expected to take place close to the villages in order to reach a suitable linear transport corridor represented by a vector. Several scenarios for improving the accessibility aspects of the health service provision are examined in light of Ghana's current health service policy. Location-allocation modelling tools are used to select optimal locations and provide statistics on average distance to health centres and percentage of population covered.

Keywords

Location-allocation, health care accessibility, transport model

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The aim of this paper is to discuss several methodological issues related to the application of location-allocation methods in health service planning for a specific area of rural Ghana - the Ga district located northwest of the Accra metropolitan area. The issues discussed concern data availability and how to establish a suitable transport and population model. A secondary aim is to present some examples of the results that can be obtained using location-allocation methods in this context.

Oppong and Hodgson (1994) presented a study on spatial accessibility to health care facilities in Suhum District, Ghana. A later study (Oppong & Hodgson, 1998) focused on the effects of bypassing, i.e. situations where proximate facilities for some reason are ignored in favour of more distant ones. These studies regard location-allocation modelling as a highly relevant tool for evaluating current conditions as well as different planning strategies. They support the view that the 'data availability and reliability problem', based on which some researchers question the usefulness of such modelling in the Third World, tends to be exaggerated. It is clearly not our intention to claim that failure to meet the digital data standards of the most advanced countries implies that location-allocation methods cannot be used in developing areas. Data availability will, however, influence the choice of modelling strategy and will also affect the reliability of the results. The fact that Euclidean distance matrices are used for location-allocation in the above-mentioned studies (Oppong & Hodgson, 1994,1998) is explained briefly by referring to walking as the main means of transportation in the area.

It is our claim, however, that people seldom will be able to walk along the straight line between two points for the magnitude of distance that we are considering here (5-10 km), nor will they wish to. Differences may arise from region to region caused by infrastructure standards and land cover. For the Ga district area - a largely rural area covered with trees and other vegetation - barriers of varying 'strengths' created by vegetation, rivers etc. in the majority of cases force people to select footpaths, tracks and roads even when walking. Moreover, for distances exceeding a few kilometres and considering that people are seeking health service, selecting a path towards the nearest road serviced by *trotros* (small private busses) will often be an attractive alternative.

There are no computational problems in defining a network of feasible transport corridors (paths, tracks and roads) that people actually choose, and using this as the basis for the distance measures included in the location-allocation modelling. The problems are connected with establishing a digital map of the transport corridors and - even more importantly - with the transformation of distance into an accessibility parameter by taking the means of transportation as well as transport behaviour into account. The possibilities of doing so for the case of a rural area in Ghana are elaborated below.

The other key issue for location-allocation modelling - the location of the population and the actual up-to-date population figures - is also discussed below. The main concern of this paper is to measure physical accessibility of the 5 health centres and to demonstrate ways of computing the consequences - in relation to accessibility - of establishing a number of additional facilities at optimal locations. Obviously good health care provision involves many other issues such as cost of health care, level of skills, equipment and building facilities and capacity of health facility compared to demand. The capacity of each facility can easily be incorporated in a location-allocation model to provide a measure of health service coverage in terms of ability to meet local demands, if reliable capacity and demand data are available.

This paper will not go into details concerning the general problems of health care provision in Ghana and the different proposed approaches to solving these (these issues are discussed more thoroughly in Kofie, 2000). Underlying this paper is the assumption that information on accessibility of health care is of vital importance even though, naturally, availability of information does not alone improve the situation.

Data and methods

Data availability

The study area represents a situation not uncommon to many areas in Africa: maps are generally out of date and the set of more recent ad-hoc maps (e.g. for planning) is very heterogeneous and unreliable. The latest available census data from 1984 can only be regarded as an estimate in light of recent years' rapid development. The particular study area is located close to the Accra metropolitan area, but while some areas are experiencing urbanization and rapid growth other areas have remained rural with a considerably slower growth rate.

The presence of suitable digital data will normally be considered a prerequisite for performing GIS analysis. A possible conclusion is therefore that a lot of work has to be put into the generation of digital data before any analysis can take place. Production of digital maps in Ghana is in its initial phase and until now based on older analogue maps. This excludes land cover and land use maps derived from remote sensing data and a number of maps of larger towns which have been prepared recently under the Ghana Environmental Management Project. Is it difficult to foresee whether digital map production in Ghana will gain momentum in the short term. A considerable number of organizations are now involved in digital data production and acquisition; this, combined with the improvements concerning hardware and software, suggests that the body of digital data may improve in the coming years.

Census data

The most recent complete census of Ghana from which published data was available at the time of this study was conducted in 1984. It should be noted that a new census has taken place very recently but any validated results are not available at this time. The results of the 1984 census have been published in several reports. It was based on a number of enumeration districts established in 1970 with some later modifications. Each district contains a number of settlements for which the population is counted. The variation in settlement size within the Ga district is extremely big ranging from townships with almost 30,000 people down to individual households, as reported in Statistical Service (1989).

Obviously, the 1984 census was done without any considerations for future analysis in geographical information systems. The boundaries of the enumeration districts are sketched out on a map, which is originally based on older 1:62500 topographic maps. The main emphasis is on the location of the settlements within the districts and how the enumerator finds his way from one settlement to the next. It is, therefore, not a trivial task to assign precise geographic co-ordinates to all the settlements contained in this census. This will be discussed further below.

It should be noted here that older census data combined with estimated growth figures can only guide the local health care planning process by providing general indicators. Obviously it is of vital importance to establish an administrative system that supplies the regional health authorities with frequently updated population data required by a number of healthcare planning purposes, e.g. to be able to plan immunisation campaigns effectively (Douven & Scholten, 1995).

Health facilities.
The Ga District as a whole has 15 institutions providing healthcare services. These include quasi-government institutions and facilities established by NGOs (non-government organisations). There are also a number of private health facilities but information on them is incomplete (MOH/GHS, 1998). The various levels of healthcare facilities in Ghana are based on a three-level hierarchical structure designed by the Ministry of Health (Ministry of Health, 1978, 1982) designating A-level, B-level and C-level facilities. A-level facilities are located in the communities and are usually staffed with minimally trained health workers. B-level facilities are usually staffed with a medical assistant, a community health nurse/midwife, a health inspection assistant and a senior field technician for communicable diseases control. C-level facilities represent the management level for the entire system and based on the district hospital. The Ga district, specifically, is subdivided into five health catchment areas or sub-districts namely Amasaman, Danfa, Madina, Obom and Weija. The five B-level facilities under the Ministry of Health are located in settlements after which these sub-districts have been named (see map in Figure2). Geocoding of each location can easily be done from a map or using a GPS.

Transport network data
The transport network of Ga district is established by combining existing road maps and new data recorded by GPS. The digital version of the 1974 topographic map sheet covering the Ga district contains information about roads, tracks and paths as they were identified when the original map was produced. Although some new roads have been built, field studies show that the 1974 data are still valid especially for the rural part of Ga district. Another digital road data source is the maps created by the feeder road project executed by the Remote Sensing Applications Unit of the University of Ghana. The aim of this project was to create an updated map of so-called feeder roads using satellite images and GPS to assess the location, type and quality of each road.

In order to assess the accuracy of the two existing data sources, field surveys using a continuously logging Garmin 12XL GPS has been conducted on different types of roads and tracks. A total of 160 km were covered. 16% of the roads covered were not found in the 1974 topographic map. These roads are included in the total transport network as they were recorded by either the feeder road project or during the field survey. Field surveys also revealed some errors in the feeder road project data, probably due to the fact that an older generation GPS without the possibility for continuous logging of track points was used.

In order to establish the total network of transport corridors, a selection process was carried out to identify the data source believed to be most accurate for each road segment. Based on the field survey the digital version of the 1974 topographic sheet was selected in most cases since it was produced by traditional, accurate methods based on aerial photography. The total length of the network - excluding the artificial corridors radiating from each village - is approximately 7000 km. The basis of this network is formed by the 1974 topographic sheet, which accounts for approximately 94% of the roads. New roads, which are mapped exclusively by the feeder road project accounts for approximately 4% while field survey data accounts for the remaining 2%.

Choice of model

Martin (1995) examines various ways of modelling population for the purpose of GIS analysis, and argues that 'any attempt to represent the socio-economic environment in a GIS involves some form of implicit or explicit modelling, and users need to be fully aware of the implications of their action'. The purpose of the population model within the location-allocation context is to provide precise information about the location of the population in order to assess the level of accessibility to health care. Accessibility may be quantified in many ways. The total (or average) travel distance or travel time for all people attending health care in the area may be used either as an absolute figure, which is compared to political/administrative goals, or as a relative figure, which is compared to scenarios where health clinics are opened, closed, moved or where district boundaries are changed. The total travel distance figure is not very sensitive to errors concerning the location of a limited number of individuals. The accuracy of the population model (i.e. the geo-coding of the population) becomes more critical, however, if the goals for accessibility to health care are stated more rigorously in terms of maximum allowable travel distance for any individual.

Establishing the population model
The population model is established by geo-coding each

enumeration district. Automatic geo-coding based on settlement names is technically possible provided that a digital map with settlement names exists and provided names are unique and spelled almost the same way. For the current analysis a digital version of a 1974 topographic map sheet covering the Ga district was acquired from the Ghana Survey Department and an automatic geo-coding process was attempted using the ArcView software from ESRI, USA. Geo-coding software will often be able to fit names that are spelled differently based on linguistic rules. These rules are normally designed specifically for a given language - English in this case - and the Ga district settlement names are characterised by many similar looking derivations from older settlement names, which impede the matching of differently spelled identical names. The automatic geo-coding function works well in matching names regardless of the use of capital letters and spacing. Match suggestions based on more advanced linguistic considerations, however, are more likely to be incorrect.

From the total of 596 settlements reported by the 1984 census 126 (21%) were placed automatically or with minor assistance on the map at the location of the text label. The 126 settlements represent 60% of the total population in the Ga district. The rest of the population data are geo-coded manually and some name confusion is unavoidable even when involving a person with detailed knowledge of the area. The first step is to try to identify settlements manually from other map sources. Any remaining problems have to be solved by field observations. The rural parts of the district contain a number of traditional villages, often located at a small distance from the road system with no postal system or roads signs. These physical characteristics imply that geo-coding the name of a village, even for people who know the district well, involves driving or walking to the village to ask for its name and record its geographical co-ordinate using a GPS. Each settlement is assigned an 8-digit locality code in the census report (Statistical Service, 1989). Part of this code is the number of the district that the settlement is a part of. This information may be used for error checking, since settlements within the same district should be relatively close together. The names of small settlements are sometimes given 'on the fly' by the enumerators using the name of the first settler or oldest member of community. The only way to geo-code these settlements is to assign the co-ordinate of another settlement within the district - either the largest settlement of the district or one with a similar name. In this way however the population will appear more centralised in the model than is actually the case. The use of aggregated demand data will always lead to some errors in the results of location modelling process, as described by Casilas (1987).

These errors arise from the fact that the distance measurements are made from an aggregation point to a centre instead of from each individual demand location point. One effect of this is that the total travel distance for all demand in an aggregation point will be reported as zero in the special case that a centre is located at the same point. In the worst case, some demand may be assigned to the wrong centre.

It is important to assess the potential influence of these error sources. The magnitude of error depends directly on the pattern of the non-aggregated demand. Based on an examination of the actual population pattern in the Ga-district, we will argue that these errors will play a minor role, especially in the predominantly rural parts of the district. The reason is that each settlement was counted individually by the enumerators even if it only consisted of one household. Given the scale of this particular study, the inter-settlement distance is the important factor, while the travel distance within each settlement may be ignored. The relatively detailed population mapping of the rural areas should benefit the location-allocation modelling process.

The strategy described above has been pursued to establish an approximate population model of sufficient accuracy to form the basis for location/allocation modelling. The main drawback is that it cannot be accurately modified until the next census is available. Satellite-based remote sensing techniques have been suggested as a tool for demographic monitoring on a more frequent basis. Baudot (2001) suggests SPOT P+XS data for surveying urban population. The satellite images will only be able to divide the study area into 'homogenous housing areas'. These data are combined with information about the population characteristics of different types of housing areas obtained from large-scale aerial photographs and field surveys to produce a population map. The precision obtained by this method is difficult to assess, and it is clearly limited due to the heterogeneous nature of many areas, but the alternative - no data at all – makes it worthwhile considering. In order to be able to plan public service based on accurate figures, two possibilities exist. One is that census data are collected more frequently, the other that administrative procedures are established that record population changes in real-time on the individual level. The next census to be conducted in Ghana is expected to take into account that the population data should be available for further analysis within a GIS. The census will be based on revised districts with clearly defined boundaries that may be identified in a digital map.

Transport model

As indicated in the introduction, it is our claim that people will not be able - or wish - to walk along the straight line between their settlement and the health centre. Various barriers and terrain compel people to select footpaths, tracks and roads even when walking. Moreover, a survey concerning the mode of transportation to healthcare facilities in Ga district by patients showed that public transport (mainly trotros) are frequently used (Kofie, 2000). In 2 of the 5 facilities the number of patients who arrived walking constituted less than 15%. This figure is considerably higher in the 3 remaining facilities.

The transport model used by the location-allocation model has to be designed with specific modes of transportation in mind in order to be useful. It may be discussed whether accessibility should be measured based on observed user behaviour or based on optimal behaviour. In any case, the transport model must reflect the choices that are actually available and affordable to the people who are seeking healthcare services. The transport model must change over time as the general mode of transportation changes. Location-allocation models can also be used to evaluate scenarios, e.g. to predict future accessibility if better public transportation service is provided.

Frequently changing road condition, e.g. when barriers to movements are created during the rainy season, is another important factor. Oppong (1996) examines accessibility to health care in a rural district in Ghana during the rainy season. While the present average weighted distance (AWD) to level A facilities - under dry conditions and using Euclidean distances - is calculated to 1.38 km, this figure increases 76% during the rainy season. This is chiefly because many A-facilities close down, dependant as they are on regular visits from level B-facilities personnel that cannot or will not be made due to impassable roads. Location-Allocation modelling aimed at producing an optimised all-season solution, by restricting potential facility locations to all-season roads, results in improved AWD values that are even lower than the present dry-season level.

A hybrid transport model is proposed

A digital transport model in GIS is normally implemented either as a vector-based solution or as a raster-based solution. For the vector-based (network) solution, transport corridors are represented by vectors and no movement is possible between vectors. A raster-based system, on the other hand, allows modelling of transport in all directions. It is normally less effective in terms of data storage in order to represent the details of the system of roads and paths than a vector-based system. It is in both cases possible to assign cost factors to any movement. Most traditional location-allocation modelling software will only work on the network transport model since the Euclidean distance is of little interest in cities and other areas where any movement of people is restricted by various barriers and therefore has to follow existing roads or paths. Even where straight-line transportation is possible, it may often involve such an increased effort that the existing tracks are preferred.

The network model approach assumes that the demand points (i.e. the people seeking health care) are located right on the network (usually by adding an attribute value to each vector indicating the number of people living there). Villages and settlements in the Ga district are in many cases located remotely at some distance from the road system and people seeking a health service centre will often walk in a more or less straight line towards the nearest road that leads in the right direction. It is, therefore, suggested that a kind of hybrid solution is required, i.e. one that combines the free movements of the raster-based approach close to the village with the road, path, track-movements assumed by the vector approach.

The method applied in this study is to emulate a raster model by creating 24 artificial transport corridors radiating for 1 km from the geo-coded location of each settlement, see Figure 1. These vectors represent the possible directions of people walking from the village and connect the village to the road system. In the majority of cases a major road is found within 1 km. Each of the transport corridors surrounding a settlement connects to the general transport network if a major road is within reach. A local pseudo raster net surrounding each village implemented by parallel and orthogonal vector lines constituting a net would also have been a feasible solution.

An important issue when establishing transport corridors for the purpose of location/allocation modelling is presented by the barriers that may exist in an area, either constantly or at certain times. A barrier may in some cases - or for some travellers - act as a complete roadblock. In other cases a barrier at a certain point may require an increased effort to cross and encourage travellers to consider alternative routes. A useful transport model must take such barriers into account. They are however sometimes difficult to monitor if for example created by a stream with varying level of water flow. In this case it could be argued that a strong barrier present only a part of the time must for planning purposes be regarded as a constant barrier - since people should always have access to health care service. For the current study, the barrier issue has been implemented only

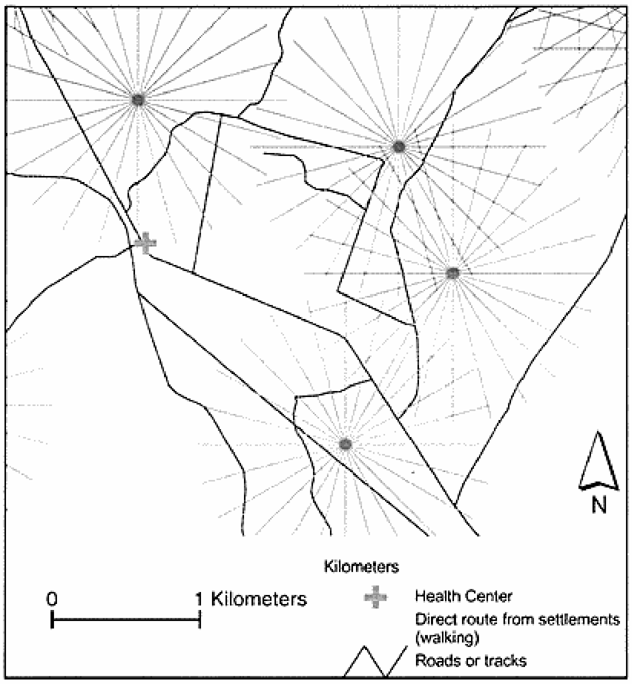

Figure 1: *Straight line routes are appropriate for short distances only. People may choose to walk from a settlement towards the nearest road or track leading in the desired direction. Each settlement location point is therefore linked to the transport network by a number of artificial transport corridors radiating in all directions. This can be seen as a pseudo-raster transport model surrounding each settlement, implemented in a vector-based system.*

by recognising the fact that the Densu River, which divides the district into two areas, can only be crossed using existing bridges.

Impedance values

Choosing a specific route between a settlement and a health facility usually means selecting the set of transport links that will require the least efforts and/or consume the shortest amount of time. As indicated above this route will likely follow established roads or tracks and in some cases prefer roads serviced by public transport. In order to perform a detailed accessibility analysis it is necessary, therefore, to assign an impedance value or 'effort/speed factor' to each link. This impedance value must naturally take into account the means of transport available to the people in question. A solution could be to use walking speed as the basis for computing impedance values for footpaths, tracks as well as the links between settlement and nearest road. The effort/speed of travelling along a road depends on the means of transportation. Vehicle speed will normally depend on the road type, level of maintenance, traffic and weather conditions as well as the condition of the vehicle in question.

Detailed measurements of transport time and efforts on different types of roads and tracks have not been a part of this study. The location-allocation analysis described in the next paragraph assumes, therefore, that the shortest route through the network is chosen. This is not an optimal solution since the existence of affordable means of public transportation may make a greater distance to health care acceptable. An impedance value that includes both time and effort is preferable. The shortest route assumption is however in accordance with official goals concerning health care provision which are based on distance rather than time/effort concerns.

Location-allocation analysis - results

The process of establishing a digital map of both the spatial distribution of the population and the available transport corridors leads to the implementation of the actual location-allocation models. This section describes the consequences - in relation to accessibility - of establishing 1 to 4 new facilities and compares these scenarios with existing conditions. Health centre capacity constraints are not taken into account. Two different objectives are evaluated: a) Minimising the total weighted distance from the settlements to the health centres. The weighted distance is the actual network distance multiplied by the number of people living in the settlement. b) Minimising health care coverage under the assumption that any person within an 8 km network distance from a health centre enjoys an acceptable level of health care provision while any person outside this limit does not. Refer for example to ReVelle & Swain (1970) and Church & ReVelle (1974) for formal model formulations.

The present situation

The first step is to evaluate the present situation. The location of the 5 existing health centres in Obon, Danfa, Madina, Weija and Amasaman can be seen in Figure 2. The thick lines radiating from each centre are connected to every settlement in the area that is closest to this centre and, therefore, supposed to be served by it. The corresponding statistics concerning accessibility can be found in Table 1. Note that all statistics are, of course, based on distances through the transport network. The average distance between a settlement and a health centre is 6.75 km. Due to the smaller size of remote settlements, the average weighted distance - or average person distance - is 5.35 km. The distance from the furthest settlement in the area to its nearest centre is more

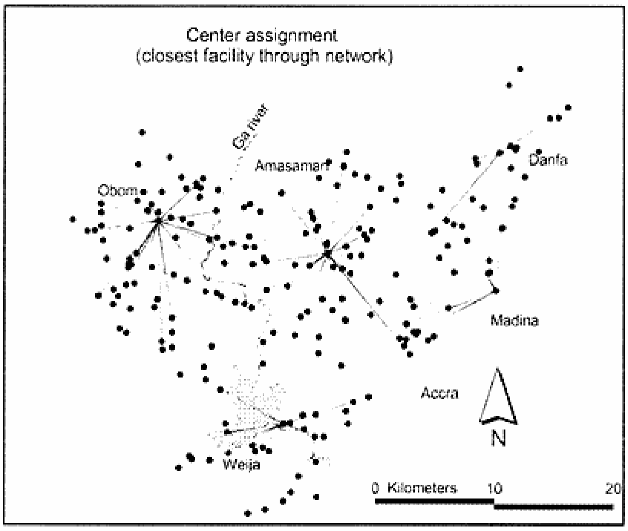

***Figure 2:** Existing health centers in Ga district. The spider diagram indicates which health facility a settlement is closest to in terms of distances through the transport network.*

than 15 km. Almost 30% of the population is outside an 8 km distance limit indicating acceptable health provision.

Objective: Minimise total weighted distance
The accessibility consequences of adding 1 to 4 new facilities in the Ga district using a 'minimise total weighted distance' objective can be seen in the first column of Figure 3 and Table 1. Any settlement is regarded as a candidate site for the new facility. The location that provides the lowest total weighted distance is chosen. One additional, optimally located centre will reduce the average person distance from 5.35 km to 4.60 km while 4 new centres will reduce this figure to 3.28 km. Furthermore the population living outside the 8 km limit will decrease to 22.0% and 12.1% respectively.

***Table 1:** Accessibility statistics under current conditions and following location of 1 to 4 new health centers based on the 'minimize total weighted distance' objective.*

Number of Facilities Added	Average settlement distance (km)	Average person distance (km)	Furthest (km)	Population outside 8 km range (%)
0	6.75	5.35	15.22	29.7
+ 1	6.17	4.60	15.22	22.0
+ 2	6.00	4.09	15.22	16.9
+ 3	5.31	3.62	12.76	13.5
+ 4	5.18	3.28	12.76	12.1

Objective: Maximise health coverage within 8 km
The main goal is to find locations for new centres in a way that ensures that the fraction of people living within an 8 km distance limit is maximised. Compared to the results of the above-described minimum distance objective, it is clear that the average weighted distance may be higher, indicating that centres are located closer to remote areas. Some people in central settlements may have to travel a little further in order to secure that a larger portion of the remote areas are covered satisfactorily. The consequences of adding 1 to 4 new centres based on this objective can be seen in the second column of Figure 3 and Table 2. Four additional centres will result in an average weighted distance of 3.79 km and a coverage - within the 8 km limit - of almost 95% compared to the present value of 70%. Two additional centres will provide this level of service to 87% compared to 83% for the 'minimise total distance' approach.

Conclusions

Although good health care provision involves much more than location-allocation aspects, these are clearly important issues to include in a planning process. Vector GIS containing location-allocation modelling software provides the tools for rapid evaluation of various scenarios. It does require, however, that a suitable digital database is established. This is not necessarily the case in developing countries, but there seems to be an increased awareness of the many benefits that the application of GIS analysis could have to the planning process, and a number of projects aimed at creating various kinds of digital maps have been

***Table 2:** Accessibility statistics under current conditions and following location of 1 to 4 new health centers based on the 'maximize health coverage within 8 km' objective.*

Number of Facilities Added	Average settlement distance (km)	Average person distance (km)	Furthest (km)	Population outside 8 km range (%)
0	6.75	5.35	15.22	29.7
+1	6.33	4.89	15.22	20.0
+2	6.15	4.38	15.22	12.9
+3	5.43	4.15	12.76	7.6
+4	5.15	3.79	12.76	5.4

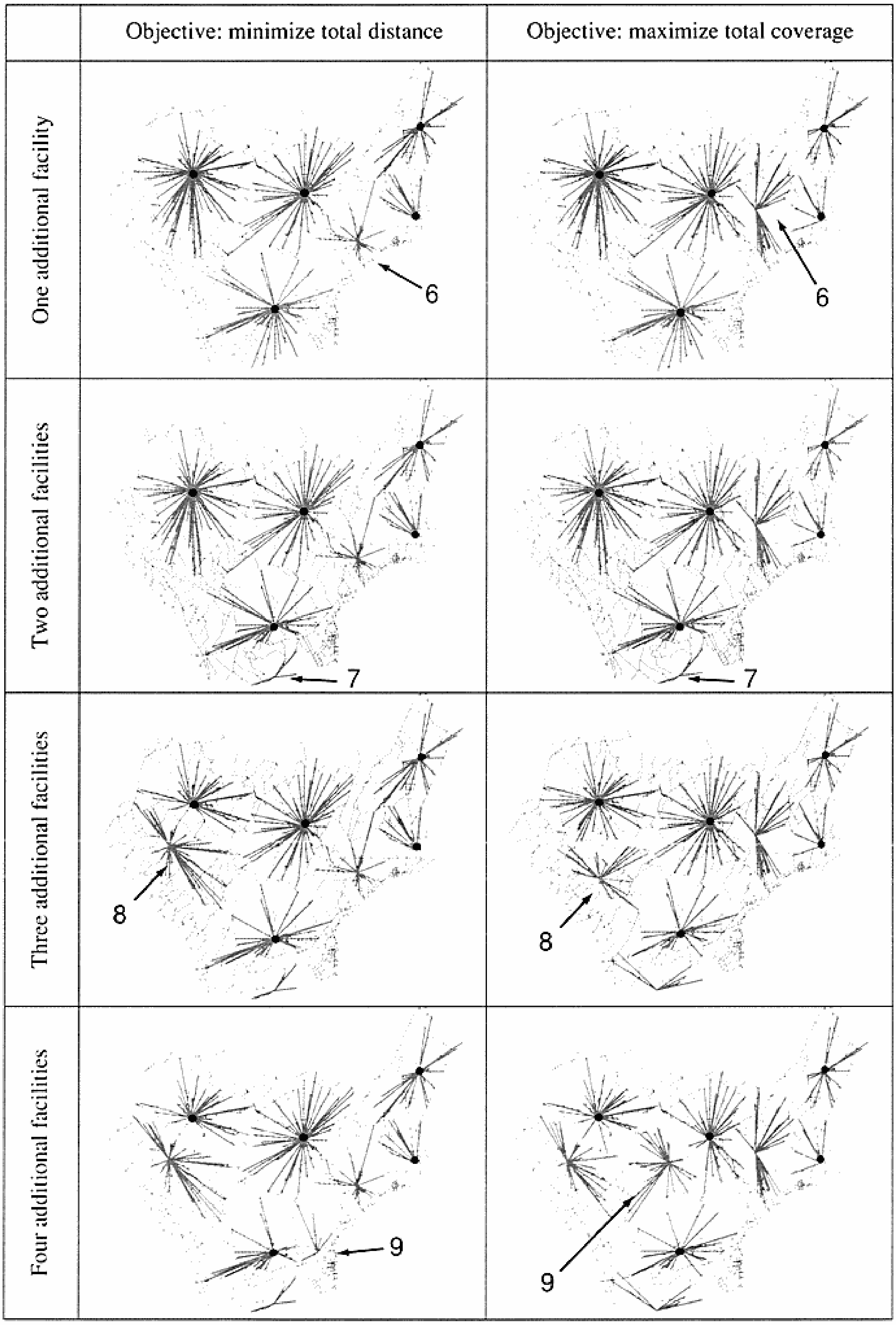

Figure 3: Best location of 1 to 4 additional health centers based on 2 different objectives - a) minimize total weighted network distance and b) maximize number of people living within 8 km (network distance) from a health center.

launched. Since population data needs frequent updating, it is necessary to investigate and improve administrative procedures in order to gather this information on a more regular basis. GIS research projects - such as the present one - that depend on data that is not yet available in their most accurate form may be looked upon as pilot projects. The results obtained may be used to demonstrate some of the future possibilities if resources are committed to collecting the necessary data. The current study also demonstrates an adaptation of the network-based transportation model to the conditions of many areas of in rural Africa where people for a shorter distance may walk in any direction without requiring the 'transport links' demanded by the network model.
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Note

Meteorological Observations in 2000 at the Arctic Station, Qeqertarsuaq (69°15'N), Central West Greenland

Niels Nielsen, Ole Humlum & Birger Ulf Hansen

Abstract

An automatic meteorological station has been operating at the Arctic Station (69°15'N, 53°31'W) in West Greenland since 1990. This paper summarizes meteorological parameters during 2000 including snow and sea ice cover, ground temperatures and active layer development, and presents comments on the local permafrost thickness.

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Outline of the Meteorological Year 2000

Climate, arctic, permafrost, active layer, snow cover, sea ice cover, Greenland, Disko. Manuscript closed 30 May 2001. Outline of the Meteorological Year 2000. The mean annual air temperature (MAAT) at the Arctic Station in 2000 was -2.5°C (Table 1), somewhat higher than the average since the station's establishment in late 1990 (Nielsen et al., 1995), but equal to the mean temperature in 1998. The MAAT at the station is -4.4°C for the whole period 1991-2000. According to official meteorological data 1961-1990 the MAAT at nearby Qeqertarsuaq is -3.9°C. Since 1996 the winter temperature has increased continuously and the higher MAAT 2000 is primarily the result of higher winter temperatures, while summer temperatures were close to normal. The lowest 2000 air temperature (-22.8°C) occurred on 1 March, while the highest air temperature (18.6°C) was registered on 7 July. This maximum temperature occurred within a 3-week warm period from the last week in June to mid-July, where the mean temperature was 9.8°C. The remaining part of the summer was cooler (mean: 6.7°C) except for a 5-day 'Indian' summer in late August, where the mean temperature was 9.0°C (Figure 1). A maximum solar radiation of 1103.7 W/m^2 was registered 1 June, before the warm period mentioned above. Notice also the pronounced minima in the incoming SW-radiation in July and August, indicating prolonged 'poor' weather periods during the summer.

The mean annual wind speed was 3.6 m/s, the same as in 1999. On 19 February a maximum wind speed of 14.5 m/s (daily mean), with wind gust of 25.6 m/s which was recorded in connection with a foehn situation with easterly winds. Several foehn events with high wind velocities can be observed during the year especially during the winter and early spring. Characteristically the temperature rises dramatically during these events (Figure 1). Easterly winds due to air masses flowing off the Greenland Ice Sheet to the east prevailed during periods of the winter and autumn, while southwesterly winds were more frequent during the summer.

2000 was a very rainy year. Liquid precipitation was registered on 74 days throughout the year except for February and December with an annual total of 476.7 mm. This amount exceeds the official (DMI) annual mean precipitation, which, including snowfall, was 447 mm in the area

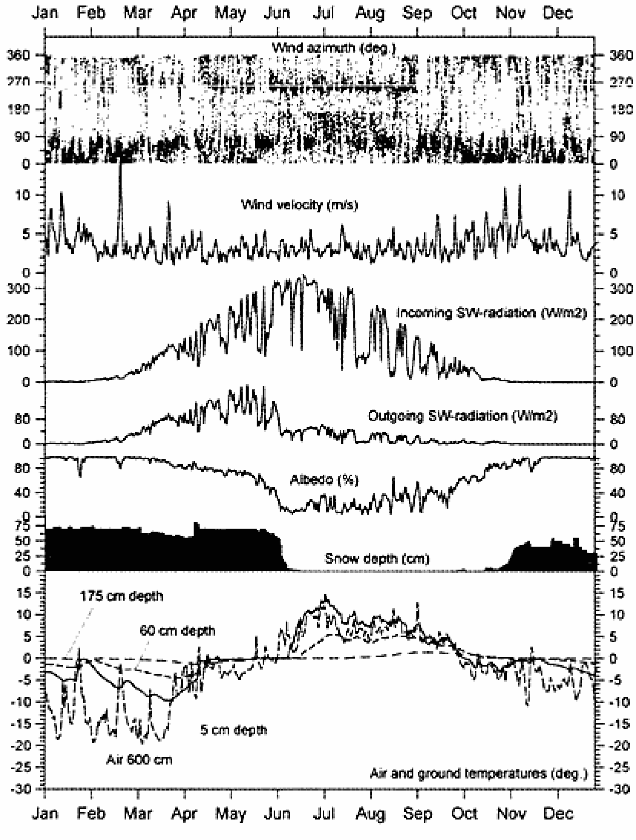

Figure 1: Diagrams showing various mean daily meteorological parameters and ground temperatures at the Arctic Station 1999. The snow cover thickness was measured daily.

launched. Since population data needs frequent updating, it is necessary to investigate and improve administrative procedures in order to gather this information on a more regular basis. GIS research projects - such as the present one - that depend on data that is not yet available in their most accurate form may be looked upon as pilot projects. The results obtained may be used to demonstrate some of the future possibilities if resources are committed to collecting the necessary data. The current study also demonstrates an adaptation of the network-based transportation model to the conditions of many areas of in rural Africa where people for a shorter distance may walk in any direction without requiring the 'transport links' demanded by the network model.
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