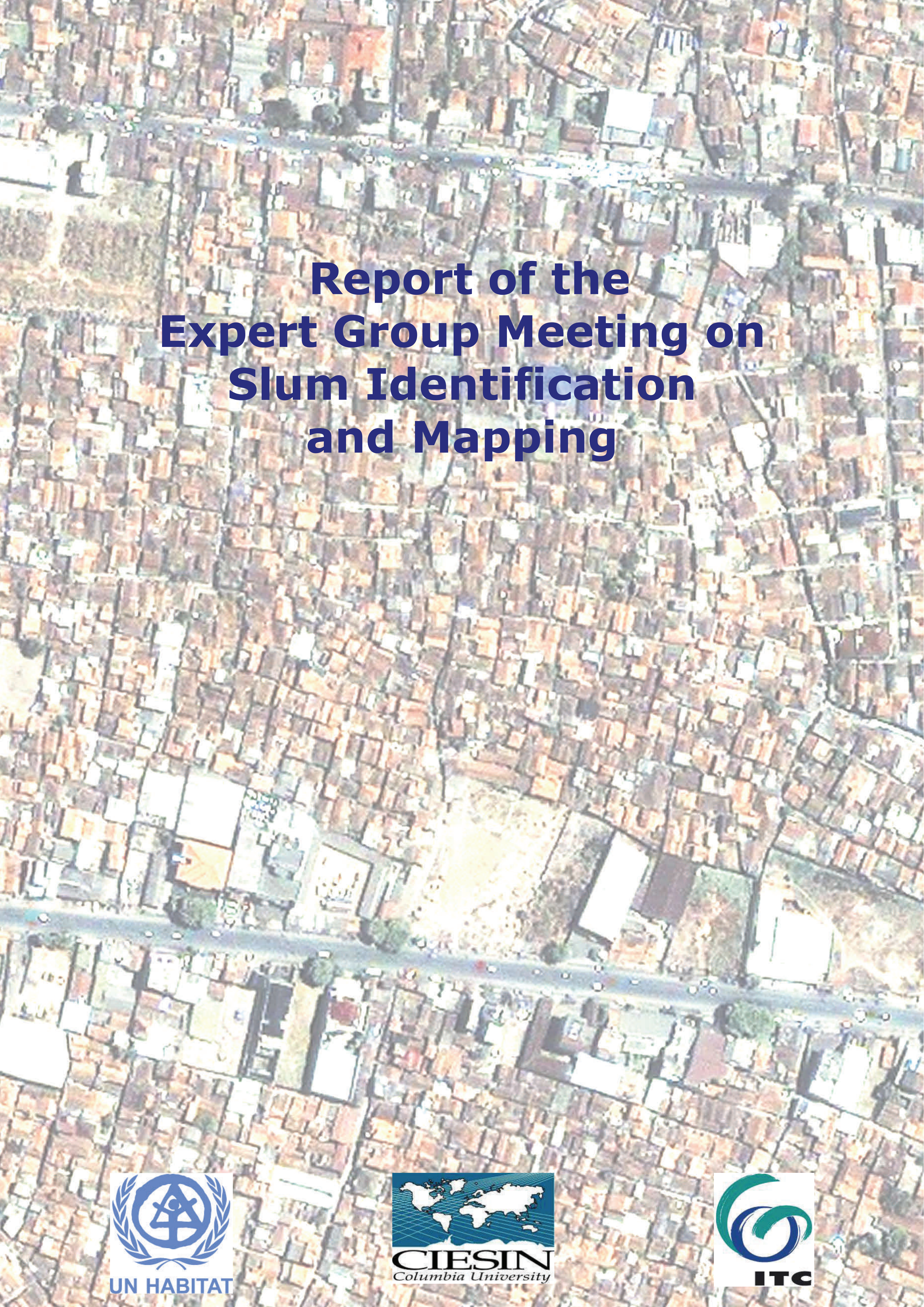
Report of the Expert Group Meeting on Slum Identification and Mapping



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ITC

Report

Expert Group Meeting on Slum Identification and Mapping

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18 November 2008

Meeting organized by:
International Institute for Geo-Information Science and Earth Observation (ITC), Netherlands
UN-HABITAT, Global Urban Observatory, Kenya
Center for International Earth Science Information Network (CIESIN) Colombia University, USA

The support of the following organizations is also gratefully acknowledged:

Center for Environmental and Geographic Information Services (CEGIS), Dhaka, Bangladesh
University of São Paulo, Brazil
Federal University Federal of Pernambuco (UFPE), Brazil
School of Urban Studies, Wuhan University, China
University Louis Pasteur, France
Leibniz University Hannover, Germany
University of Dortmund, Germany
Ruhr-University Bochum, Germany
Shelter Associates, Pune, India
Indian Institute of Remote Sensing, Dehra Dun, India
European Commission - Joint Research Centre, Italy
Socioeconomic Data and Applications Center (SEDAC), CIESIN, Columbia University, USA
Lamont-Doherty Earth Observatory, Columbia University, USA

Acknowledgements:
The Expert Group Meeting on Slum Identification and Mapping was partially sponsored by the Netherlands Ministry of Spatial Planning, Housing and the Environment (VROM).

Satellite imagery was provided by the GeoEye Foundation.

Slum identification and mapping

Purpose of the meeting

From 21-23 May 2008 a group of 21 international experts on remote sensing and slum monitoring met at the International Institute for Geoinformation Science and Earth Observation (ITC), The Netherlands (see appendix A for details of participants and the programme of the meeting). The focus of the meeting was to document methods for the identification and delineation of slum areas based on very high resolution (VHR) remote sensing and supplementary data sets (e.g. census and related GIS data on infrastructure and services). A major goal was to explore the potential of satellite imagery to assist the UN-HABITAT Global Urban Observatory (GUO) in producing global statistics on slums in support of Millennium Development Goal 7, Target 11, "improving the lives of 100 million slum dwellers".

The main purpose of the meeting was to:

1. establish requirements for slum mapping for the Global Urban Observatory (GUO) of UN-HABITAT;
2. present state of the art methods using VHR imagery for slum mapping;
3. identify suitable methods for further development, knowledge transfer, and capacity building.

The main findings of the meeting in relation to each of these 3 points are presented below.

Requirements for slum mapping

The monitoring of slums as part of the global monitoring exercise of the slum target of the Millennium Development Goals (MDGs) has been done by GUO through a statistical approach, using 5 slum indicators. UN-HABITAT developed a methodology and the operational approach to estimate the number of slum dwellers world-wide and has been applying it since 2002. The methodology made extensive use of existing data sources, particularly the Multiple Indicator Cluster Surveys (MICs) and the Demographic and Health Surveys (DHS), and in some cases Census data. This has enabled UN-HABITAT to begin to regularly publish figures on the number of people living in households that lack the following: improved water, improved sanitation, durable housing or sufficient living area at country level. The data has also been extended to include the production of more data sets on slums in a growing number of cities around the world. Currently data for 20 urban indicators related to the Habitat Agenda are available for 353 cities from the various world regions.

The 5 main slum indicators and their definitions are given here (full details of definitions are given in Appendix B):

1. Access to safe water
Proportion of the population with sustainable access to an improved water source is the percentage of the urban population who use any of the following types of water supply for drinking: piped water, public tap, borehole or pump, protected well, protected spring or rainwater.

2. Access to improved sanitation
Proportion of the population with access to improved sanitation or percentage of the population with access to facilities that hygienically separate human excreta from human, animal and insect contact.

3. Durable structures
Proportion of households living in a housing unit considered as 'durable', i.e. built on a non-hazardous location and has a structure permanent and adequate enough to protect its inhabitants from the extremes of climatic conditions such as rain, heat, cold, humidity.

4. Sufficient living area (overcrowding)
Proportion of households with more than three persons per room.

5. Access to secure tenure
This indicator is not in use as there is no suitable source providing a uniform data set for international comparison purposes.

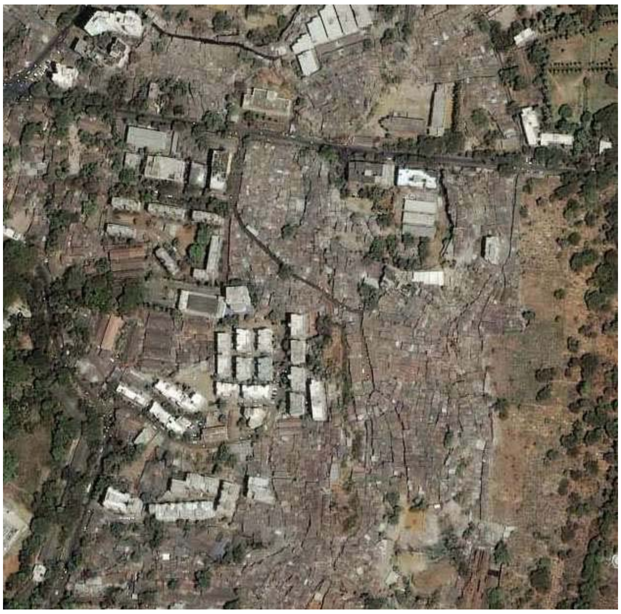
The statistical data that are currently used for generating these slum indicators are derived from multiple sources: World Urbanization Prospects; WHO/UNICEF Joint Monitoring Programme on Water Supply and Sanitation (JMP), demographic and health surveys (DHS), Multiple Indicator Cluster Survey (MICS), other specific surveys such as UN-HABITAT's Urban Inequities Surveys (UIS) and census data.

One of the most important messages from the current work is that households suffering more than one deprivation relative to the five indicators are significantly worse off than households that have no or only one deprivation. Further, it is realised that there is a lack of data on several aspects that define the durability of housing. Current figures for this indicator are based solely on data on building materials, but other components such as compliance with building standards and hazardous location are not considered as these are not universally covered by the available survey data.

The current practice in spatial analysis related to slums is based upon fairly simple aggregations of slum household data according to Enumeration Areas (EAs) in which the households reside. Any EA in which more than 50% of the population is deprived in terms of one of the four operational slum indicators is considered to be a slum. This fairly crude approach to spatially defining slums has been adopted out of pragmatic considerations largely relating to available data. Interpretation of the output should be done carefully as EAs can also have multiple deprivations, as the following example shows. If two EAs have the same proportion of deprived shelter (say 60% of the population) they will both be considered as a slum EA. However, if one EA has multiple deprivations its population will likely suffer more than the other which only has a single deprivation.

Some examples of very high resolution images

Above: Ikonos image(1m) of Kalyan-Dombivli, India. Slum areas can be distinguished from planned developments but individual buildings cannot be distinguished



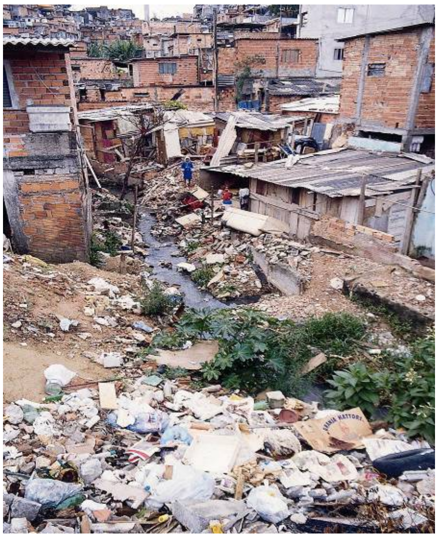
Above: Ikonos image(1m) of Bandung, Indonesia, showing very compact and complex settlement patterns mixed with regular, planned development

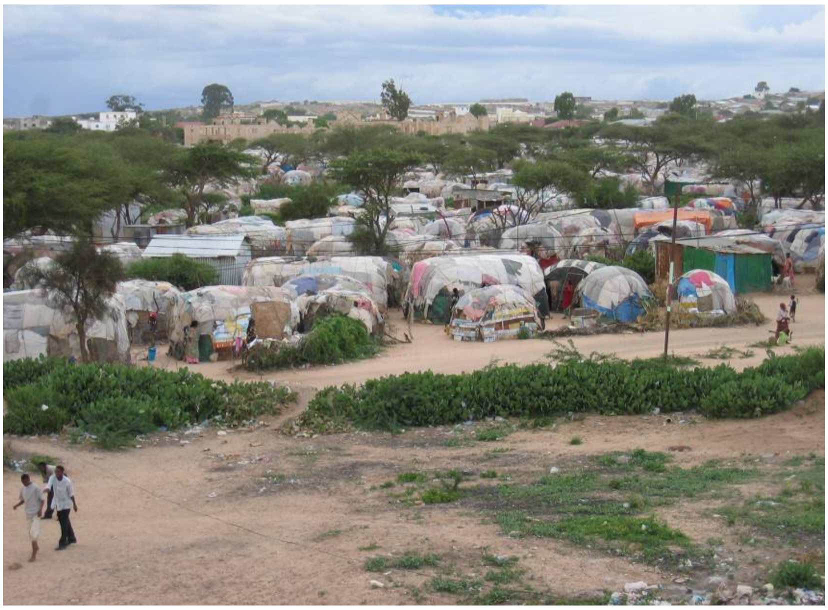
Above: Colour orthophoto (60cm resolution) of Dar es Salaam, Tanzania. Dense and complex structure of unplanned housing is clearly distinguishable from planned residential and industrial development. Individual buildings can be identified and counted.

Above: Ikonos image (1m) of Cairo, Egypt. Extensive, high density, multi-storey unplanned development. Public infrastructure and services lag behind development. Some pockets of agricultural land remain but are under high development pressure.

Several problems arise in this approach: variables or characteristics specific to the settlement level such as condition of the roads, drainage, management of solid waste, air pollution etc. are not considered; nor is the location of the settlement (in or near a steep slope, in or near a flood plain, in or near a toxic waste area, in or near an industrial area, etc.). UN-HABITAT has designed a community questionnaire as part of its Urban Inequities Surveys Programme that capture characteristics of the location of the household, but to date it has only been implemented in a very few cities.

A 2006 peer review of the UN-HABITAT methodology on slum estimation emphasizes the need to be able to identify and define slums spatially in a consistent manner to be able to use geographical targeting for slum intervention programmes. VHR imagery may allow this to be done in an effective and efficient manner.





Slum conditions can take various forms.
Top left: self help housing in Jardim Souza, São Paulo (photo courtesy of P. Machado)
Top right: sub-standard public housing projects in Libya (photo: J. Turkstra)
Left: temporary shelters composed of waste and other light materials constructed by refugees in Somalia (photo: J. Turkstra)

Overview of state of the art using VHR images for slum mapping

Much work is now being done on using VHR imagery for urban mapping, but most of it is focused on cities in the developed world and on general topographic and land use and land cover mapping. Although slum identification and mapping has received relatively little attention until recently, much can be learnt by examining the general developments on urban remote sensing and the limited studies that deal specifically with slums. The papers presented and discussed at the EGM were a combination of case studies in which practical examples of slum mapping approaches and experiences were presented and others in which advanced methods for urban image analysis and information extraction were explained.

The examples of slum mapping that were presented at the meeting demonstrated the great variety of contexts and conditions that can be found in the world's slums. A number of general conclusions were drawn on this aspect of slum diversity:

1. There is no universal model of a slum in a physical sense that would allow the development of a standard method for all slum identification and mapping. Although certain variables are likely to be important in most situations the parameter settings will almost certainly always require local tuning.
2. The diversity of slum conditions is such that even within one city many different manifestations of slums may be found, each of which may require specific methodological adjustments for identification and mapping.
3. It is necessary to understand both the nature of building construction (characteristics such as size, materials, shape), the nature of other objects (such roads, health and social service facilities, open space), the characteristics of the site conditions (such as location in urban area, slope, natural vegetation, hazards), as well as the slum development process itself.
4. Slum development is a process that can take several different forms. Slums can develop through the gradual degradation of formal housing and social filtering processes (examples of this are often found in the developed cities but they are also found in the form of degraded social or low income housing projects in countries such as Libya and Tanzania amongst others). Slums can also develop through a variety of informal housing development processes (e.g. incremental and structured, incremental and unstructured, sudden and structured, sudden and unstructured). Each form has its own distinctive characteristics.
5. The development stage of a slum area (infancy, consolidation, maturity) must be considered when deciding how it is to be indentified and mapped from VHR images. The development of slum identification and mapping methods will need to explicitly consider how slum characteristics may change according to the development stage of the slum.

In terms of methods for identifying and mapping slums using VHR images the main conclusions are as follows:

1. Visual interpretation performed by interpreters familiar with local conditions provides a flexible and useful approach to slum mapping, though it does have shortcomings for repetitive surveys of very large cities due to difficulties in controlling quality over time and between interpreters.
2. Current methods for semi-automated information extraction from VHR rely on object oriented analysis (OOA), often in combination with expert knowledge, multi-sensor data fusion and GIS data integration and field surveys for quality control and supplementary data capture. The combination of approaches – semi-automated OOA in combination with other methods – seems to produce the best results (see Box 1).
3. OOA approaches can deliver robust results although considerable high level image processing expertise and a trial and error approach is needed to establish a workable system for any given locality.
4. Several potentially interesting approaches to slum identification were explained. In addition to spectral information these new methods use elements such as texture, lacunarity (see Box 2 for a brief explanation), object size and shape, and shadow as indicators for potential slum areas. Some models have been developed for one city and have been later transferred and re-calibrated for other contexts (see EGM presentation by Hofmann). Such an approach provides a basis for exploring the scope for up-scaling and diffusion of robust generic methods. However caution is required as some variables may be anisotropic (i.e. values vary depending upon the direction of measurement). Some variables such as shadow will vary according to the sun angle, the orientation and spacing of the buildings and streets, and the slope immediately next to buildings.
5. Much research is done in the form of isolated case studies of individual slums. Potentially useful methods need to be tested operationally in city-wide studies in combination with local professionals and civil society actors.
6. Field surveys by technical teams and through community based approaches (see Box 3) are important. Field surveys can be done rapidly with the right local resources and they contribute to the local information base in a very effective manner.
7. Accuracy requirements for slum mapping are currently not fixed. What is clear is that it should be possible to quantify accuracy and that it should be possible to improve accuracy over time.

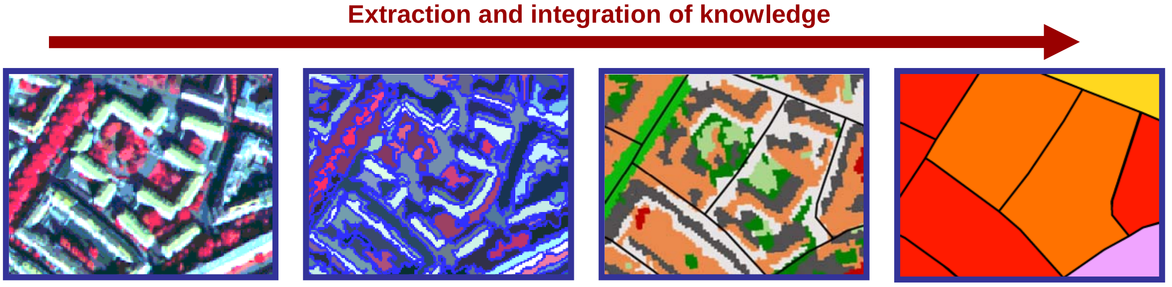
Several potential qualitative/visual and quantitative criteria for slum identification were discussed. Qualitative indicators include: Haphazard, high density building pattern; durability of housing/material for roofing (corrugated tin, plastic sheeting/tarps, cloth/grass); proximity to natural and technological hazards; structure, size and condition of road network; proximity to public services (health, education, open space, public transport). For automated approaches quantitative indicators and methods for generating required data will be needed. Measures that may be useful for slum mapping include: Proportions of land cover (% area covered by structures, % area of open spaces, % of vegetation); Spatial metrics (lacunarity, textural contrast, variability of building size & orientation); morphology of building heights (derived from shadows or lidar); characteristic scale (relative size of housing units, relative size of road networks, Plot Ratio, Floor Area Ratio).

Box 1: Object oriented approaches to image analysis *(by Prof.Dr.Christiane Weber, University Louis Pasteur, France)*

The development of very high resolution (VHR) satellites has decreased the value of traditional pixel-based image processing approaches. The general aim of such analysis, to recognize and extract specific landscape patterns from satellite data, is difficult for urban applications of high resolution data. To locate, analyse or interpret the complex structures of an urban landscape from high resolution remote sensing imagery it is necessary to extract the patterns through sets of pixels based on spectral variation within areas of homogenous land cover classes. One of the main difficulties is the spectral and spatial heterogeneity of urban landscapes. Urban land uses are composed of a variety of land covers. These will also be arranged in various proportions and patterns according the nature of the development.

VHR data provides new opportunities to comprehend and map urban areas due to their spatial resolution (pixel size). But this produces complications in image processing as many urban objects (e.g. houses) are larger than the pixel size. To be identified on the satellite image, an object must thus be recreated with the appropriate set of pixels. The difficulty here is to "shape reality" i.e. to extract out of the satellite image the correct set of pixels to build up the corresponding image objects, houses, roads, or even slums.

Extraction and integration of knowledge



Object-oriented processing logic is linked to this idea that the appropriate processing units are no longer single pixels but image objects. The sets of pixels, or segments, to be extracted are based on the assumption that image objects give more relevant information than individual pixels and that they must be defined using more information than spectral characteristics alone. OOA introduces the possibility to define criteria for image objects at various pre-defined scales using spectral reflectance characteristics, plus a variety of other measures: within and between object texture or morphological indexes, object shape, context relationships (like contrast), spatial relationships (adjacency, contiguity, density, etc.) and ancillary spatial data (roads networks, administrative units, etc) consisting of both thematic and continuous data values. An OOA relies on the definition of sets of knowledge rules for the above characteristics to describe each segment. The management of, and reasoning on spatial relations is essential when a scene object cannot be discriminated with its proper characteristics.

An OOA approximates human image interpretation by introducing knowledge and experience in image processing through formal languages (artificial intelligence, support vector machine, neural network or other logics) that improve the object extraction and classification process. They create possibilities to introduce technical know-how in the reasoning procedure that are closely tied to the practice of human interpretation process.

Box 2: Lacunarity *(by Dr. Mauro Baros-Filho, UFPE, Brazil)*

The term 'lacunarity' was introduced by Mandelbrot (1982) to describe the characteristics of fractals of the same dimension with different textures. Lacunarity is a measure of the distribution of empty spaces (lacunas) within an image and is therefore closely related to image texture analysis. Whereas image texture refers to the frequency of tonal change in an image, lacunarity is a measure of the density, packing, dispersion, and permeability of a texture across several scales.

There are many algorithms to calculate lacunarity. One of the most applied is the gliding-box algorithm proposed by Allain and Cloitre (1991). According to this algorithm, a sliding box or kernel of size *r* slides over the image, registering the box mass *S*, that is, the number of pixels with similar grey levels inside the box at each stop of the sliding process. Then, the size of the box is enlarged, and the procedure is repeated for each new box size, until eventually the box size equals the image extent. The figures bellow show an example of the convolution process of this algorithm performed on a grayscale image using 2 different box sizes (Barros Filho, 2006).

A frequency distribution of box masses $n(S,r)$ is then created. This frequency distribution is converted to a probability distribution $Q(S,r)$ by dividing each frequency value by the total number of gliding boxes of a given size $N(r)$. Finally, the moments $Z(1)$ and $Z(2)$ are calculated from these values:

$$Z(1) = \Sigma\, S\, Q(S,r) \qquad (1)$$

$$Z(2) = \Sigma\, S^2\, Q(S,r) \qquad (2)$$

The lacunarity $L(r)$ of a given box size r is calculated as:

$$L(r) = Z(2) / [Z(1)]^2 \qquad (3)$$

In general, a low lacunarity value indicates homogeneity of a texture, while high lacunarity indicates heterogeneity. The higher the lacunarity, the bigger will be the variation of pixels distribution in an image. In other words, high lacunarity means that pixels with similar gray levels are grouped in a wide variety of sizes of islands, surrounded by a widely variant emptiness.

The experiments carried out to date indicate a strong correlation between morphological conditions, as measured by lacunarity, and the quality of urban environments. The approach may provide a useful tool to distinguish between planned and unplanned urban developments, and is particularly promising when the dealing with well established and consolidated settlements. The technique is however not well suited to emerging slum areas where densities are comparatively low.

Box 3: Field data collection and community based approaches *(by Pratima Joshi, Shelter Associates and Richard Sliuzas, ITC)*

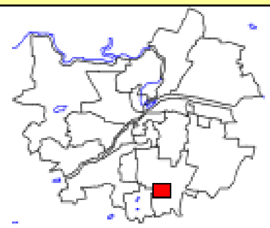
Remote sensing experts use field survey data to assess the quality of the data that they derive by image interpretation and classification processes. Without a measure of their accuracy the value of satellite derived data for policy development and decision making is substantially reduced as most users need an understanding of its uncertainty in order to decide whether and how it will be used.

An increasing number of community based organisations and NGOs are also making use of VHR images for slum surveys. One good example is the work of the NGO, Shelter Associates (SA) from Pune, India. For SA, VHR images are one of the most important tools for poverty mapping at the city level. They are used to project micro-level poverty mapping techniques and insights to include slums into mainstream city planning. Satellite images are complement and strengthen results derived from micro level planning, but NOT a substitute. For example VHR images have been used to: re-assess migration trends into cities thereby compelling governments to legitimize the status of migrants; start city planning, where road widening, flood protection, development of new infrastructure would affect slum settlements; bust existing myths by providing objective evidence to show that individual slums do not continuously increase in size.

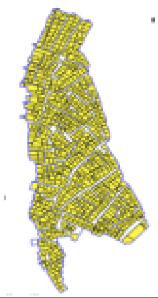
Working in close collaboration with residents of slum communities SA uses VHR images from Google Earth to digitise slum boundaries and attach fact sheets containing data that has been compiled by quick surveys in slums to register key information about the households, their dwellings and the site characteristics. Their Pune slum census covered over 100,000 households in over 200 slum pockets scattered throughout the city. Settlements were mapped by professional agencies using plane table methods to produce large-scale slum maps showing plot and building boundaries, while residents were engaged in the household surveys, gaining knowledge and skills on data collection and a better understanding of their community's problems, its opportunities and the planning process.

Chaitraban
Area:- Upper Indira Nagar.
Survey No:- 633
Address:- 633, In Front Of State Bank Colony, Upper Indira Nagar.
Survey Date:- May 2007

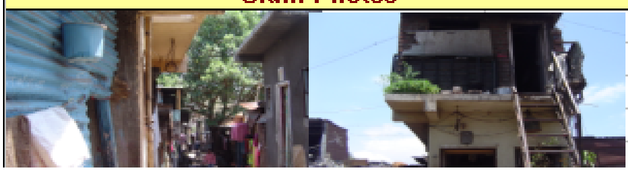
Location On The Pune Map



Map Of Slum



Slum Photos

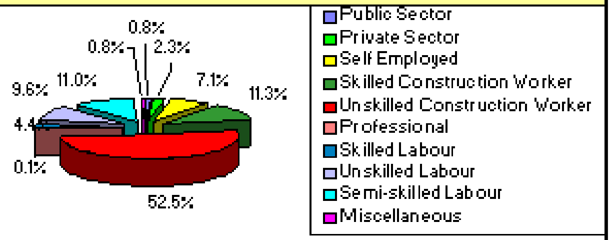


Slum Information

Household Anaylsis Based On 2000 Survey

Administrative Ward	Sahakar Nagar Ward
Ration Ward	Ambil Odha
Year Of Establishment	1975
Area Covered By Slum	13000 m^2
Number Of Structures	812
Estimated Population	3753
Location	Upper Indira Nagar

Livelihood



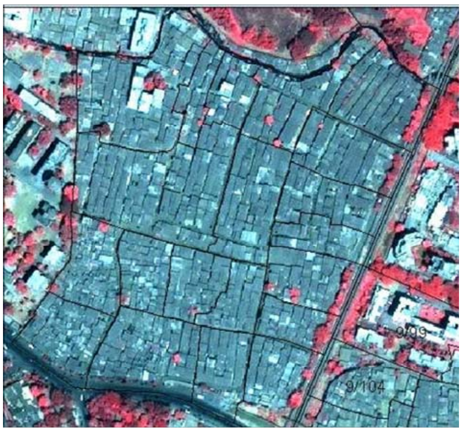
Housing Conditions

Kutcha	25%
Semi-Pucca	29%
Pucca	45%

Box 3 (continued):

The spatial and socio-economic data is entered into a GIS database and spatially analyzed for direct use by the communities, to prepare upgrading plans and to negotiate with local government authorities on policy and developmental issues. The process therefore contributes to community empowerment by enabling them to be fuller partners in settlement upgrading and in the subsequent management of their community.

The same approach within the Municipal Corporation of Sangli Miraj Kupwad, has led to the initiation of a holistic approach to improve all slum pockets. SA and communities are engaged with the local administration and elected members for drawing up an action plan for slum improvement. As a result of these community based approaches many slums have been mapped and plans for their improvement have been produced in a cost effective manner.



(see http://shelter-associates.org/ for details of these and other activities).

Several issues related to methods and data sources will require more attention. Tools/methods are in general available but not well established. The linkage between Earth Observation (EO) data and statistical data is especially important. A variety of methods for up-scaling and down-scaling data are available, including statistical, geo-statistical approaches and spectral un-mixing. The most appropriate will need to be identified via systematic research. Other aspects that require further analysis are the optimal resolution and EO product combinations for various scale levels and the cost comparison of EO versus ground survey methods.

Institutional issues

Organizations and bodies from 4 major groups (public sector, market sector, civil society and universities and research institutes) have an interest in this issue. Within the public sector it will be important to focus at the local government level in addition to the central level (e.g. National Statistical Office, National Mapping Agency, Public Works, Housing, cadastral survey). Slum mapping is probably not in itself a priority but has to be linked to other ongoing local activities such as taxation, engineering services, planning and upgrading programmes for water and sanitation. For civil society 'empowerment' through engagement is important; both data and technology should also be in their hands.
Universities & Research Institutes need to provide the latest methods & techniques that would otherwise not be available at the local level. The market sector is important both as a VHR data supplier but also for supplementary data on urban water supply systems, etc. Several new sources of VHR data have become available over recent years (see Box 4) and it is likely that the trend toward increasing spatial and spectral resolution will continue. Considerable scope exists for cooperation between research and the private sector for new product development.

The key element of strategies for procurement of VHR data is a partnership approach that can facilitate cost effective data and knowledge development and exchange. Reciprocity and transparency but also confidentiality (some data may not be sharable due to privacy concerns) are key issues to consider in creating and operationalising partnerships.

A major priority is to get slum mapping on the agenda of various key events, bodies, organizations. e.g. international research networks (see some possibilities in the table below). Some of the immediate follow up activities required are discussed below.

Table: Examples of networks and bodies potentially interested in slum mapping

Acronym	Name	Date of major event
EARSeL	European Association of Remote Sensing Laboratories	June 2008 (annual meeting and various working groups)
GISDECO	GIS for Developing Countries	Bi-annual (June 2008 joint meeting with EARSeL)
AARSE	African Association of Remote Sensing of the Environment	October 2008
AARS	Asian Association of Remote Sensing	Annual meeting ACRS November 2008
SELPER	Sociedad Latinoamerican de Percepción Remota y Sistemas de Información Espacial	Anual meeting September 2008
ISPRS	International Society of Photogrammetry and Remote Sensing	July 2008 (Congress every 4 years and annual working groups)
IHDP	International Human Dimensions Programme on Global Environmental Change	Open meeting Bonn, April 2009
JRC	Joint Research Centre - Institute for the Protection and Security of the Citizen	Research centres and networks funded by European Commission.
WUF	World Urban Forum	Bi-annual meeting organized by UN-HABITAT, November 2008
UCLG	United Cities and Local Governments	Regular meetings
ICLEI	International Council for Local Environmental Initiatives	World conference every 3 years.
Metropolis	World Association of the Major Metropolises	Annual conference. November 2008
GSDI	Global Spatial Data Infrastructure	Annual Conference June 2009

Box 4: Overview of current and planned civilian earth observation satellites

Earth observation satellites: current (white) & planned (grey)
d.d. 09-05-2008

Satellite System	year of launch	country	resolution in m.& nr of bands pan	ms	SAR	swath (km)	revisit/pointing	stereo
Civil/Optical/high resolution:								
Cartosat-2 (IRS P7)	2007	India	<1			10	4 days (1 day)	
Cartosat 2A	2008	India	<1			9.6	4 days	
EROS B	2006	Israel+USA	0.7			13.5	yes	al/ac
EROS C	2009	Israel+USA	0.7	2.8		13.5	15 days/yes	al/ac
GeoEye-1 (Orbview-5)	2008	USA	0.41	1.64 (4)		15.2	<3 days / yes	
GeoEye-2	2011	USA	0.25	1 (4)				
Ikonos 2	1999	USA	1	4 (4)		13	3 days/yes	al/ac
KOMPSAT 2	2006	Korea/Israel	1	4(4)		15		
Pleiades (2x)	2008/2009	France	0.7	2,8 (4)		20-120	26 days	al60/ac60
Resurs DK1	2006	Russia	1	2.5 (3)		28	yes	
Quickbird 2	2001	USA	0.61	2.44 (4)		16.5	yes	al/ac
WorldView-1	2007	USA	0.5			17.6	1.7-5.9 days/yes	al
WorldView-2	2009	USA	0.5	1.8 (8)			1 day / yes	
Civil/Radar:								
Cosmo-Skymed (4x)	june2007 (1st of 4)	Italy			1-2 (X-band)	10 - 200	< 0.5 day	
TerraSAR-X	2007	Germany			1-15m (X-band)	10-100	2.5 days	
TECSAR	2008	Israel			<1m (X-band)		36 days	

See http://www.npoc.nl/EN-version/satelliteinfo/satellitetabel.html for full details.

Follow up activities and responsibilities.

The meeting agreed to an **action program**, with a draft design on where to be within an initial **timeframe** of **2 years**, as well as to define **objectives**, clarify involvement (**who**), the location (**where**) and **financial** issues (who pays).

Main objective

The main task initially is to see whether VHR images can be used to identify slum areas and estimate slum populations in a small number of test cities (drawn from list of 35 cities provided by GUO: see Appendix C). A problem could be the availability of good images. Cities will be selected on the basis of a number of criteria. There will need to be local partners/universities/governments that are willing to cooperate. It will be important to include some small and medium sized cities (at least 2) and a 'spectrum' of city types (for example a recent analysis identified 4 different types of cities on the basis of GUO's slum statistics: Type A: very low levels of shelter deprivations; Type B: Low levels of water connections and overcrowding; Type C: Generally poor shelter conditions, especially in sanitation; Type D: Very poor shelter conditions typically found in countries in political crises). Finally, ancillary census or survey data will be needed for validation, and good cooperation between local agencies and actors will be important. Cities in which remote sensing applications have already begun will be given priority.

For the selected cities data need to be exchanged between research teams. The main focus will be the establishment of standardized methods. While for initial work to be presented at the 2008 World Urban Forum (WUF) each group will build on the data that they already have, standardization will become more important as research progresses, and it will also be important to assess accuracy levels.

Agreement 1:
Team 1 (Richard Sliuzas, Gora Mboup, Thomas Kemper, Alex de Sherbinin and Pratima Joshi) has the task to review GUO's list of cities and select a small number of test cities. Criteria for the selection: no. of inhabitants, location, data availability, regional coverage. Selection of one small test city (if possible for presentation during WUF4) and other case cities is to by made as soon as possible, preferably by mid July 2008.

Indicators, methods and accuracy levels

The discussion on indicators, methods and accuracy levels needs to be finalised. The suggestions for possible indicators (e.g. of shape, contrast, lacunarity, vegetation, orientation of buildings, % of ground cover as well as indices such as NDVI) requires a critical evaluation leading to a set of clearly defined indicators related to VHR images. Other open questions are the (spatial) resolution, criteria for indicator selection, the reliability of estimates of the number of dwellers and the role of local knowledge. Ground truth data on slum population will be needed for calibration; community groups and existing data sources should be used for this. It was agreed that for a start a 20% error margin is acceptable.

The initial focus will combine visual methods and automatic processing. The start will be land cover mapping and an up-scaling to land cover composites including slums. Although robust methods of up-scaling/down-scaling are not yet operational recommendation can be made on how to proceed.

Agreement 2:
Team 2 (Alfred Stein, Gora Mboup, and Sadhana Jain) to develop guidelines for indicators, accuracy levels and methods for validation. The first deadline (by end October 2008) will be to establish quality indicators.

Funding and Coordination

An important issue is that donors are not really interested in slum mapping but in slum improvement. Thus we need to combine the mapping and monitoring with ongoing improvement programmes and projects. We should pick cities where such upgrading programs are ongoing. Various suggestions were made for seeking funding: Use the opportunity provided by WUF; Check if Netherlands Government still interested in Kisumu, Kenya.

The support of UN Habitat is needed in the process of fundraising. The final EGM report should be presented to UN-HABITAT's senior managers as soon as it is practical to do so. A web based presentation of our initiative is recommended
(Note: CIESIN has hosted a wiki on Global Slum Mapping http://www.ciesin.columbia.edu/confluence/display/slummap/Global+Slum+Mapping).

Agreement 3:
The coordination team (Richard Sliuzas, Gora Mboup, Jan Turkstra, Thomas Kemper, Christine Weber, Reinaldo Pérez Machado, Sadhana Jain) will look into funding issues. Thomas will look into the possibility at JRC to set-up a data exchange centre.

Appendices

A: Programme and Details of Participants
B: Definitions of slum indicators
C: Candidate cities discussed during expert meeting

Appendix A: Programme and details of participants

Wed 21 May 08:30-10:30 Room 3-008	Session 1 Opening Chair: Richard Sliuzas Rapporteur: Alex de Sherbinin	
Time	Speaker	Topic
8:30	Arrival and registration of participants	
8:50	Richard Sliuzas, ITC Alex de Sherbinin, CIESIN, Columbia University, USA	Welcome and general purpose of the EGM
9:00	Prof Dr. Martien Molenaar, Rector ITC	Official welcome to ITC
9:10	Ron Spreekmeester	Word of welcome from representative VROM (Netherlands' Ministry of Housing, Spatial Planning and the Environment)
9:20	Personal introductions	Quick round of the table for participants to briefly introduce themselves
9:30	Dr. Gora Mboup Chief of the Global Urban Observatory, UN-HABITAT Maharufa Hossain, GIS and LUO Coordinator, UN-HABITAT	Slums, shelter deprivation and spatial concentration
10:15	Discussion and clarification	
10:30	Coffee/tea break	
Wed 21 May 11:00 – 12:30	Session 2: Developments in urban remote sensing and the diversity of slum conditions Chair: Jan Turkstra *Rapporteur:* Kirsten Hackenbroch	
Time	Speaker	Topic
11:00	Christiane Weber University Louis Pasteur, France	From slums detection to slum definition
11:30	Richard Sliuzas ITC, Netherlands	Diversity of global slum conditions – is a universal spatial definition of slums feasible?
11:50	Alex de Sherbinin CIESIN, Columbia University USA	Urban Poverty Mapping: Data and Methods
12:10	Q&A and discussion	What key spatial variables for characterising slums can be obtained from remote sensing?
12:30	Lunch (Buffet) ITC Restaurant Annex	

Wed 21 May 13:40-14:30	Special Guest lecture in ITC auditorium Prof. Uptal Sharma Center for Environmental Planning and Technology (CEPT), School of Planning Ahmedabad, India	
	Title: Slum Development Strategies for Dharavi Slum in Mumbai, India	
Wed 21 May 14:30-16:00	Session 3 Advanced methods for urban image analysis Chair: Reinaldo Machado Rapporteur: Chris Small	
Time	Speaker	Topic
14:30	Thomas Kemper and Martino Pesaresi JRC Italy	Examples of robust and replicable feature extraction for the study of built-up surface, using VHR data
14:50	Mauro Barros Filho University Recife, Brazil	Slums detection through lacunarity-based texture analysis of remote sensing images
15:10	Carsten Jürgens Ruhr University Bochum	A multi-scale remote sensing strategy for slum detection and continuous slum monitoring
15:30	Q&A and discussion	
15:45	Coffee/tea break	
16:15 – 18:00	Session 4: Statistical issues in urban poverty mapping Chair: Mauro Barros Filho Rapporteur: Monika Kuffer	
Time	Speaker	Topic
16:15	Alfred Stein ITC, Netherlands	Spatial statistics and their application in (urban) remote sensing
16:35	Chris Small Lamont-Doherty Earth Observatory Columbia University USA	Objectives, Strategies and Limitations of Remote Sensing for Slum Mapping
16:55	Peter Hofmann Leibniz University Hannover Germany	Detecting informal settlements using methods of object based image analysis
17:15	Q&A and discussion	
17:30	Richard Sliuzas and Alex de Sherbinin	Brief introduction to break out groups planned on Thursday afternoon

Thurs 22 May 09:00-10:30	Session 5: Methods and examples of slum mapping Chair: Christiane Weber Rapporteur: Huang Zhengdong	
Time	Speaker	Topic
9:00	Reinaldo Perez Machado University of Sao Paulo	Precarious settlements studies. Actual situation in São Paulo, Brazil
9:20	Iffat Huque CEGISBD, Bangladesh	Urban slum mapping in Bangladesh
9:40	Kirsten Hackenbroch Germany	Land use and cover mapping in informal settlements: the case of Dhaka, Bangladesh
10:00	Pratima Joshi Shelter Associates	GIS based poverty mapping for integrated development of slums
10:20	Q&A and discussion	
10:30	Coffee/tea break	
Thurs 22 May 11:00 – 12:30	Session 6: Methods and examples of slum mapping Chair: Alfred Stein Rapporteur: Maharufa Hossain	
Time	Speaker	Topic
11:00	Sadhana Jain IIRS India	Urban remote sensing for slum mapping in India
11:20	Monika Kuffer ITC, Netherlands	Measuring of spatial configuration of informal versus formal urban development using Spatial/Landscape Metrics
11:40	Huang Zhengdong and Zhan Qingming Wuhan University China	Mapping slums and urban villages in China
12:00	Jan Turkstra UN-HABITAT Libya	Visible and non-visible slums, Libya and Somalia
12:20	Q&A and discussion	
12:30	Lunch (Buffet) ITC Restaurant Annex	

Thurs 22 May 14:00-15:30	Session 7 Break Out Groups	
Time	Topics	
	Room: 3-008 Chair: Christiane Weber Rapporteur: Alex de Sherbinin A: What spatial criteria and indicators can be added to the currently applied slum definition and can they be universally applied?	Room: 2-008 Chair: Alfred Stein Rapporteur: Sadhana Jain B: Are there efficient methods for up-scaling data from one spatial level to another?
15:30	Coffee/tea break	
Thurs 22 May 16:00 – 17:30	Session 8: Break Out Groups	
Time	Topic	
	Room: 3-008 *Chair:* Mauro Barros Filho Rapporteur: Thomas Kemper C: How reliable does the spatial and statistical data on slums have to be for policy development and decision making? Can this be quantified and can the costs and benefits associated with the required level be assessed?	Room: 2-008 Chair: Richard Sliuzas Rapporteur: Pratima Joshi D: What institutional issues need to be addressed if local governments are to be able to be able to undertake slum mapping as a routine task? Can advanced technical approaches be combined with community based approaches?
Friday 23 May 09:00-12:30	Session 9: Break Out Groups Chair: Prof Martien Molenaar Rapporteur: Monika Kuffer	
Time	Speaker	Topic
9:00	Presentations of key findings and recommendations from break out groups A, B & C	Groups to report back in plenary 15 minutes and present proposals for amendments if desired.
10:30	Coffee/tea break	
11:00	Presentations of key findings and recommendations from break out group D.	Groups to report back in plenary 15 minutes and present proposals for amendments if desired.
11:30	Plenary discussion	Final round of discussion on conclusions and recommendations from the EGM to be brought forward at the World Urban Forum in Nanjing China, November 2008
12:20	Dr. Gora Mboup Dr. Richard Sliuzas Alex de Sherbinin Prof. Martien Molenaar	Closing of main programme

List of participants

Prof. Dr.Alfred Stein, ITC, Netherlands
Dr. Richard Sliuzas, ITC, Netherlands
Dip.Ing. Monika Kuffer, ITC, Netherlands
Dr. Norman Kerle, ITC, Netherlands
Dr. Gora Mboup, UN-HABITAT, Kenya
Ms. Maharufa Hossain, UN-HABITAT, Kenya
Dr. Jan Turkstra, UN-HABITAT, Kenya/Libya
Ms. Sadhana Jain, IIRS, India
Dr. Iffat Huque, CEGISBD, Bangladesh
Mr. Hao Pu, ITC (PhD student), Netherlands
Dr. Peter Hofmann, Leibniz University of Hannover, Germany
Dr. Mauro Normando Baaros Filho, ESUDA Dept. of Architecture and Urbanism, Brazil
Prof. Dr. Christiane Weber, University Louis Pasteur, France
Prof. Dr. Huang Zhengdong, School of Urban Studies, Wuhan University, China
Ms. Pratima Joshi, Shelter Associates, India
Prof. Dr. Reinaldo Pérez Machado, University of São Paulo, Brazil
Mr. Alexander de Sherbinin, CIESIN, Columbia University, USA
Dr. Chris Small, Lamont-Doherty Earth Observatory, Columbia University, USA
Dr. Thomas Kemper, European Commission - Joint Research Centre, Italy
Dip. Ing. Kirsten Hackenbroch, University of Dortmund, Germany
Prof. Dr. Carsten Jürgens, Ruhr-University Bochum, Germany

The presentations given at the meeting can be downloaded from:
http://www.ciesin.columbia.edu/confluence/display/slummap/Global+Slum+Mapping

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Appendix B: Definitions of slum indicators

Indicator 1: Durable structures

Habitat Agenda Goal: Provide security of tenure

Rationale:	Households which live in slums usually occupy non durable dwelling units that expose them to high morbidity and then mortality risks. Durable structures is part of the five key components of the agreed definition of slum[1]. Generally, a housing structure is considered durable when certain strong building materials are used for roof, walls and floor. Even though some houses may be built with materials classified as durable, the dwellers may still not enjoy adequate protection against weather and climate due to the overall state of a dwelling. Alternatively, a material may not look durable, in the modern sense, but is, in the traditional sense, when combined with skills of repair. Such cases are vernacular housing made of natural materials in villages, maintained by its residents annually.
Definition:	Proportion of households living in a housing unit considered as 'durable', i.e. built on a non-hazardous location and has a structure permanent and adequate enough to protect its inhabitants from the extremes of climatic conditions such as rain, heat, cold, humidity. The following locations should be considered as hazardous: Housing settled in geologically hazardous zones (landslide/earthquake and flood areas); Housing settled on garbage-mountains; Housing around high-industrial pollution areas; Housing around other high-risk zones, e.g. railroads, airports, energy transmission lines. The following durability factors should be considered when categorizing housing units: Quality of construction (e.g. materials used for wall, floor and roof); Compliance with local building codes, standards and bye-laws.
Methodology:	Data collection and sources: Data sources are mainly household surveys and censuses. Computation: The number of households living in a house considered as 'durable' should be divided by the number of households.
Gender:	Households headed by women tend to have lower incomes and are therefore more likely to lack durable dwellings to accommodate all the members. Divorced, separated or widowed women are more likely to head household with their children with limited resources for home

[1] UN-HABITAT, Expert Group Meeting on 'Defining Slums and Secure Tenure', Nairobi, November 2002

	improvement. In certain situation, they become homeless.
Comments and limitations :	Data on houses built on hazardous locations is difficult to collect and is not available for most countries. Therefore results for this indicator is mostly based on the permanency of structures, looking at the quality of materials used for dwellings. Durability of building materials is to a very large extent subject to local conditions as well as to local construction and maintenance traditions and skills. Which materials are considered durable under local conditions has to be determined by local experts. This is also true for the common problem that dwellings in the semi-urban outskirts of cities of developing countries often follow rural construction patterns by using materials, which can be considered non-durable under urban conditions. In addition, compliance with local regulations and the quality of the location form part of the definition. These two indicators cannot be easily observed as they require specific knowledge about the legal condition and the land use plan as well as skills to determine hazardous areas.
Level:	City, national urban

Indicator 2: Overcrowding

Habitat Agenda Goal: Provide security of tenure

Rationale:	This is a key indicator measuring the adequacy of the basic human need for shelter. Reduced space per person is often associated with certain categories of health risks and therefore considered as a key criteria to define the slum. Overcrowding is associated with a low number of square meters per person, high occupancy rates - number of persons sharing one room - and a high number of single room units. Examples of slums worldwide show that dwelling units are often overcrowded with five and more persons sharing a one-room unit used for cooking, sleeping, and other households activities. Several local definitions of slums include minimum thresholds concerning the size of the area, the number of structures in a settlement cluster, the number of households or people or the density of dwellings units in an area. Examples are the municipal slum definition of Kolkata with a minimum of 700 sq. m. occupied by huts, Bangkok with a minimum of 15 dwelling units per rai (1600 sq. m.) or the Indian Census definition with at least 300 people or 60 households living in a settlement cluster. This key indicator is part of the five key components of the agreed definition of slum[2].

[2] UN-HABITAT, Expert Group Meeting on ‘Defining Slums and Secure Tenure’, Nairobi, November 2002.

Definition:	Proportion of households with more than three persons per room. A house is considered to provide a sufficient living area for the household members if three or less people share the same room.
Methodology:	Data collection and sources: Data sources are mainly from censuses or household surveys. A room is defined as a space in a housing unit or other living quarters enclosed by walls reaching the floor to the ceiling or roof covering, or to a height of at least two meters, of an area large enough to hold a bed for an adult, that is at least four square meters. The total number of types of rooms therefore includes bedrooms, dining rooms, living rooms, studies, habitable attics, servants' room, kitchen and other separate spaces intended for dwelling purposes. Computation: The number of households with more than three persons per room should be divided by the number of households.
Gender:	Households headed by women tend to have lower incomes and are therefore more likely to lack enough rooms to accommodate all the members. Divorced, separated or widowed women are more likely to head household with their children with limited resources for home improvement. In certain situation they become homeless.
Comments and limitations :	Additional indicators of overcrowding can be used: average in-house living area per person or the number of households per area; the number of persons per bed or the number of children under five per room may also viable measures.
Level:	City, national urban

Indicator 4: Access to safe water

Habitat Agenda Goal: Promote access to basic services

Rationale:	Water is one of the great necessities of human life, which is taken for granted in the developed world. A supply of clean water is absolutely necessary for life and health, yet almost 2 billion people lack access to adequate water supply or can only obtain it at high prices. In many cities, households in informal settlements are rarely connected to the network and can only rely on water from vendors at up to 200 times the tap price. Improving access to safe water implies less burden on people, mostly women, to collect water from available sources. It also means reducing the global burden of water-related diseases and the improvement in the quality of life. This indicator monitors access to improved water sources based on the assumption that improved sources are likely to provide safe water. Unsafe water is the direct cause of

	many diseases in developing countries.
Definition:	Proportion of the population with sustainable access to an improved water source, urban, is the percentage of the urban population who use any of the following types of water supply for drinking: piped water, public tap, borehole or pump, protected well, protected spring or rainwater. The water should be affordable and at a sufficient quantity that is available without excessive physical effort and time. Improved water sources do not include vendor-provided waters, bottled water, tanker trucks or unprotected wells and springs.
Methodology:	This indicator requires definitions adapted to the local context for several elements: Affordable: water should not take an undue proportion of the household income, i.e. less than 10%; Sufficient quantity: water should be available at a quantity of at least 20 liters per person per day; Without excessive efforts and time: obtaining water for the households should not take an undue proportion of the household's time (less than one hour a day for the minimum sufficient quantity of at least 20 liters per person per day). Data collection and sources: Two data sources are common: administrative or infrastructure data available from public, parastatal or private companies in charge of water supply, that report on new and existing facilities, and data from household surveys, including DHS, MICS, and LSMS. Computation: The indicator is computed as the ratio is the number of urban population who use piped water, public tap, borehole or pump, protected well, protected spring or rainwater to the total urban population, expressed as a percentage.
Gender:	Women and men usually have different roles in water ad sanitation activities. Women are most often the users, providers and managers of household hygiene. If the water system breaks down, women are more likely to be affected than men because they have to use other means and travel in order to meet the household's water needs.
Comments and limitations :	When data from administrative sources are used, they generally refer to existing water sources, whether used or not. The judgment about whether a water source is safe is often subjective. Also, the existence of a water supply does not necessarily mean that it is safe or that local people use it. For these and other reasons, household survey data are generally better than administrative data, since survey data are based on actual use of sources by the surveyed population rather than the simple existence of the sources.

	While access is the most reasonable indicator for water supply, it still involves severe methodological and practical problems. Among them: the data are not routinely collected by “the sector” but by others outside the sector as part of more general surveys; and water quality is not systematically addressed.
Level:	City, national urban

Indicator 5: Access to improved sanitation
Habitat Agenda Goal: Promote access to basic services

Rationale:	Lack of sanitation is a major public health problem that causes disease, sickness and death. Highly infectious, excreta-related diseases such as cholera still affect whole communities in developing countries. Diarrhoea, which is spread easily in an environment of poor hygiene and inadequate sanitation, kills about 2.2 million people each year, most of them children under five. Inadequate sanitation, through its impact on health and environment, has considerable implications for economic development. People miss days at work due to sickness resulting from excreta-related diseases. Moreover, lack of excreta management poses a fundamental threat to global water resources. Good sanitation is important for urban and rural populations, but the risks are greater in slum areas where it is more difficult to avoid contact with waste.
Definition:	Proportion of the population with access to improved sanitation or percentage of the population with access to facilities that hygienically separate human excreta from human, animal and insect contact. Facilities such as sewers or septic tanks, poor-flush latrines and ventilated improved pit latrines are assumed to be improved, provided that they are not public. To be effective, facilities must be correctly constructed and properly maintained, and not shared by more than two households. This indicator requires definitions for several elements: Shared: the facilities should be shared by a maximum of two households; Sufficient capacity: the septic system should have a sufficient capacity in order not to be clogged. These definitions can be adapted to the local contexts.
Methodology:	Data collection and sources: Since the late 1990s, data have routinely been collected at national and sub-national levels in more than 100 countries using censuses and surveys by national governments, often with support from international development agencies. Two data sources are common: administrative or infrastructure data available from public, parastatal or private

	companies in charge of sanitation, and data from household surveys including Multiple Indicator Cluster Surveys (UNICEF), Demographic and Health Surveys and Living Standard Measurement Surveys. Before these population-based data were available, provider-based data were used. Computation: The indicator is computed as the ratio of the number of people in urban areas with access to improved excreta-disposal facilities to the total urban population, expressed as a percentage.
Gender:	Women and men usually have different roles in sanitation activities. Women are most often the guardians of household hygiene. If a sanitation system breaks down, women are more likely to be affected than men in order to meet the household's sanitation needs.
Comments and limitations :	When data are from administrative sources, they generally refer to existing sanitation facilities, whether used or not. Household survey data are therefore generally better than administrative data, since survey data are based on actual use of facilities by the surveyed population rather than the simple existence of the facilities. While access is the most reasonable indicator for sanitation facilities, it still involves severe methodological and practical problems. First, data are generally not routinely collected by “the sector” but by others outside the sector as part of more general surveys. Second, the quality of facilities is usually not systematically addressed.
Level:	City, national urban

Appendix C: Candidate cities discussed during expert meeting

MDG Regions	Country	City	Population
Northern Africa	Egypt	Alexandria	3,506,045
Northern Africa	Egypt	Shubra el Kheima	937,056
Northern Africa	Morocco	Rabat	1,616,313
Northern Africa	Morocco	Casablanca	3,357,453
Northern Africa	Sudan	Khartoum	2,741,515
Sub-Saharan Africa	Cote d'Ivoire	Abidjan	3,790,238
Sub-Saharan Africa	Ethiopia	Addis Ababa	2,644,942
Sub-Saharan Africa	Ghana	Accra	1,867,637
Sub-Saharan Africa	Nigeria	Lagos	8,664,892
Sub-Saharan Africa	Senegal	Dakar	2,077,826
LAC	Argentina	Buenos Aires	12,024,130
LAC	Brazil	Sao Paolo	17,962,440
LAC	Mexico	Guadalajara	3,697,166
LAC	Mexico	Mexico	18,066,397
LAC	Venezuela	Caracas	3,153,075
Eastern Asia	China	Shanghai	12,886,808
Eastern Asia	China	Leshan	1,136,983
Eastern Asia	China	Guangzhou	3,893,160
Eastern Asia	China	Hong Kong SAR	6,859,815
Eastern Asia	Republic of Korea	Pusan	3,829,513
South-central Asia	Bangladesh	Dhaka	12,518,695
South-central Asia	India	Kolkota	13,058,085
South-central Asia	India	Vijayawada	999,226
South-central Asia	India	Mumbai	16,085,750
South-central Asia	Uzbekistan	Tashkent	2,148,331
South-eastern Asia	Indonesia	Jakarta	11,018,168
South-eastern Asia	Myanmar	Yangon	4,393,156
South-eastern Asia	Philippines	Metro Manila	9,950,320
South-eastern Asia	Singapore	Singapore	4,018,110
South-eastern Asia	Viet Nam	Ho Chi Minh City	4,619,035
Western Asia	Jordan	Amman	1,147,507
Western Asia	Lebanon	Beirut	2,069,570
Western Asia	Saudi Arabia	Tabuk	469,797
Western Asia	Syria	Hama	399,175
Western Asia	Turkey	Istanbul	8,952,884

Partly sponsored by:
Netherlands Ministry of Spatial Planning, Housing and the Environment (VROM)

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