HIGH RESOLUTION GLOBAL LAND COVER/LAND USE MAPPING CURRENT STATUS AND UPCOMING TRENDS

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ABSTRACT

Land use, land cover and their dynamics are of high interest not only for geographic research but also of growing interest to many administrative, economic and environmental institutions. For four decades, Remote Sensing from satellite images has been a technology allowing the observation of regions even in remote parts of the world. Starting from the global meteorological and climatic dynamics, the observation of vegetation and more specific of food production became a field of great interest for research and environmental and economic applications. The paper highlights the methodological dichotomy between land use and land cover, the technological progress since the 1970s and recent applications on European and global levels.

The paper introduces different global land cover mapping and land cover monitoring data sets of public availability and reports on their significance of class division, spatial resolution and thematic focus if applicable. Recent results for high resolution global data sets are evaluated according to their methodological progress and their potential for further applications. Finally the upcoming trends in high resolution global mapping and monitoring are presented. The focus is not only on scientific progress but also on changing information demand because demands from different fields of application will help to generate the necessary funds for improvement of methods. The overall benefit will be a better knowledge of the actual dynamic of the world regarding food resources and environment.

INTRODUCTION

Since the first Earth Resource Satellite missions in the early 1970s, there have been attempts of obtaining global overviews of land use and land cover, vegetation, settlements and natural resources. While the first available satellite capacities could not easily provide a real global cover in short periods due to revisit limitations, today there are several high resolution satellite systems offering combined or multi date coverage around the world. The easy availability of image data now gives way to evaluate more precisely the limits and potentials of derivative products like land use mapping, land cover mapping or vegetation mapping.

There is a very strong demand for knowing and monitoring the land use on all scales. Remote sensing was seen as a solution to overcome the unbalanced updating of cartographic mapping (Konecny 2013). From local land parcels to regional or national land use dynamics, there is much interest not only for scientific but especially for environmental and economic reasons. The actual land use and the potential for land use development together with crucial questions of land ownership are the main reasons for investments and socio-economic decisions. There is a high demand for knowledge about land use and its dynamics, but the satellite images offer predominantly information on land cover. In the first global or continental remote sensing products of low and medium resolution, this dichotomy was not really obvious; the new potential of remote mapping was just amazing. With better image resolution and a greater differentiation in land use classes, the problem of ambiguities between land cover and land use arose. For instance, the land cover grassland may result from different land uses, like a meadow within the land use "agriculture", like a lawn within the land use "public recreation", like a soccer turf within the land use "sport field" or like a grass field within the land use "airport". Such problems can be tackled either by local validation or by automatic attempts of semantic and geometric interoperability.

METHODOLOGICAL CHALLENGE FROM LAND COVER TOWARDS LAND USE

Spatial patterns on the surface of the earth are of special socio-economic interest in terms of their actual use or the potential to change the actual use by different actors. The value of usable parts of the earth's surface is determined by natural properties of the land, by the access to land and often by the competition of human interests. Land offers potential for food production, cattle husbandry, settlement, economic production, circulation, recreation and extraction of earth resources. Therefore, the knowledge of the land use is an important parameter of decision for most human activities, especially with regard to a growing world population on a limited surface of the Earth. This also applies to the militant usurpations of foreign land as well as the actual globalisation of trade and exchange. Many stakeholders, regional planners and investors need to know the land use not only in their home region but also more or less worldwide.

The Gap

The principal gap between required land use and observed land cover appears in different parameter values. Generally spoken, the size of the gap grows with reduced pixel size and with increasing number of land use classes. In the initial ERTS-1 pixel size of 80 m x 80 m most natural or urban surfaces appeared rather interpolated and therefore appropriate to pixel based classification techniques of that time. Today's high resolution satellite data in the range of 10 m to 5 m are more difficult to classify due to many small differentiations, height differences, shadows and variations in illumination. In high resolution images there are less areas of homogeneous appearance than in image data of medium resolution.

The second reason for the gap between required land use and observed land cover is the number of land use classes. The CORINE Land Cover describes land cover and land use according to a nomenclature of 44 classes organised hierarchically in three levels. The first level comprises four classes, the second level 15 classes and finally the third level 44 classes.

Approaches to Bridge the Gap

There have been a series of different approaches tested during the last decades to refine automatic land cover classification by introducing algorithms for calibration, interpretation keys gained from field observation, libraries of spectral characteristics (reference signatures), knowledge based training parcels and object based class similarities.

LARGE AREA LAND COVER

To understand the different approaches it is interesting to look at large scale land cover mapping projects such as study areas covering whole countries or continents where remote sensing has to be performed without or with only reduced access to ground truth calibration or to ground based validation.

Historic Prototype: LACIE

From 1974 until 1977, the United States Department of Agriculture (USDA), NASA and NOAA conducted the first phase of the Large Area Crop Inventory Experiment (LACIE). The experiment was designed to develop a monitoring method targeted on wheat production in important regions throughout the world (U.S., Canada, USSR, and Brazil). The technological basis was the image data received since 1972 by the Earth Resource Technology Satellite (ERTS), later renamed as LANDSAT-1. The project proved successfully the usefulness of multispectral image data to extract timely crop information, mostly for wheat (Erb & Moore, 1979).

In retrospect, this project has been driven predominantly by political targets. It has also been successful because it concentrated at first on a single-class classification of multispectral data. So it became possible for the United States to predict the wheat harvest for large regions in Russia several weeks prior to harvest within a relatively small error margin. The background is that yield predictions mostly rely on the determination of crop extend and acreage and additionally on crop condition exposed to timely and geometric variables of temperature and precipitation. This explains why the researchers from the LACIE project used additional meteorological data to refine their results (NASA 1978).

Pan-European approach of CORINE

In 1985, the European Commission initiated the project "Coordination of Information on Environment" (CORINE), a very ambitious programme to monitor a great number of environmental features and their spatial distribution and development. Finally, the first feature, which came into realisation, was in fact the land cover, because of the available methods by remote sensing from orbital platforms. Most of the other important environmental features could not be taken into account due to scientific and administrative discussions about definitions and unsolved observation techniques on a European scale. So when the first CORINE Land Cover (CLC) started, it was based on the reference year 1990 and on Landsat 7 image data. Initially the inventory was set up with a minimum mapping unit of 25 ha and 44 land cover classes. For the follow-up mapping, the minimum mapping unit was reduced for changes to 5 ha.

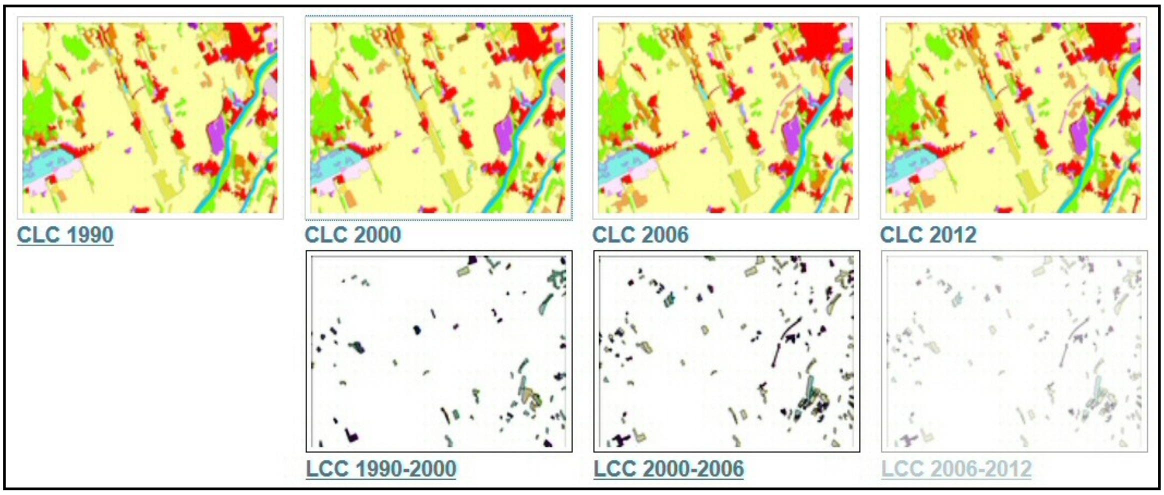

Figure 1: Monitoring stages of CORINE Land Cover (Copernicus 2014)

After the European Environment Agency (EEA) started to become operational 1994 in Copenhagen, tasks within the Directorate General Environment became assigned step by step to EEA, including the CLC 2000 update. Since 2012, the CLC time series became embedded in the structural context of the Copernicus programme. As far as member states are using national digital landscape models, updated with satellite image data, the CLC updates are no longer performed separately, but derived from these landscape models.

Figure 2: CORINE Land Cover 2006 main classes (Copernicus 2014)

LUCAS – the European Sample Monitoring Approach

Since 2001, there have been surveys approximately every three years throughout the European member states. In 2015, there will be another 270.000 points observed in a sample survey according to land cover classes, actual land use and soil conditions, ecological features including a photo documentation of about 1.5 million terrain witness photos per survey year. Based on a stratified sampling strategy on a 2 km by 2 km grid base, the data base of EUROSTAT offers a unique fund of land use/land cover information. Fig. 3 shows an overview of the main land cover classes depicting the 2012 survey results.

The right part of the figure shows an online extract from the terrain photos, one of the sample point itself and additional views in the four cardinal directions. Over the last 15 years, the LUCAS database has been a unique source of information on the spatial development of land cover change throughout Europe, a big data set showing the relation between land cover and land use and an on-site view collection which could provide a valuable calibration source for further refinement of remote sensing classification.

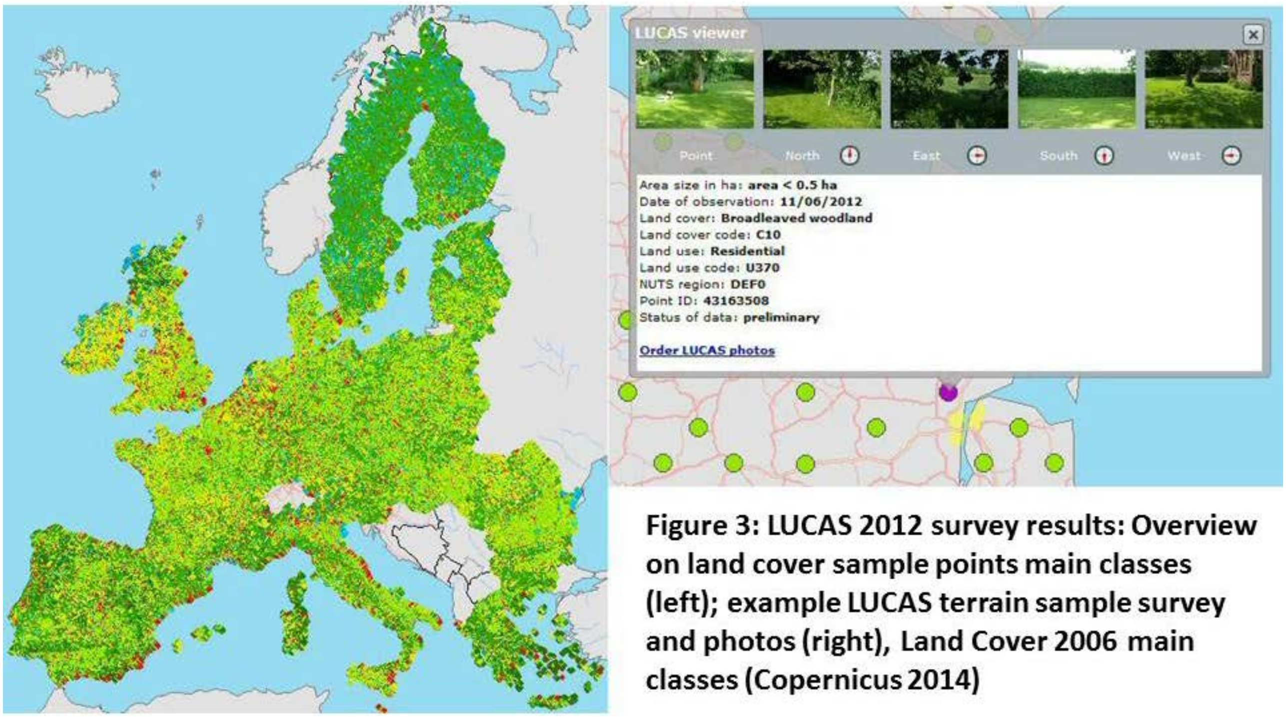

Figure 3: LUCAS 2012 survey results: Overview on land cover sample points main classes (left); example LUCAS terrain sample survey and photos (right), Land Cover 2006 main classes (Copernicus 2014)

GLOBAL APPROACHES

The early approaches for a global coverage were often limited by capacity constraints of the few satellites and by frequent cloud cover in many parts of the world. Therefore, the first global satellite maps often needed more than five years to achieve a complete coverage. More recently several satellite constellations are providing image data with GSD between 30 m and 5 m at short repeat cycles.

Copernicus Global

In 1988, the European Commission, together with the European Space Agency (ESA), initiated a joint programme called Global Monitoring of Environment and Security, better known under its acronym GMES. Under this umbrella a great number of initiatives, projects and service elements were developed. Some examples out of this programme have been the service elements of "Global Monitoring for Food Security" (GMFS) with regional components directed towards Africa (Brockmann et al. 2011, Komp & Haub 2012, Haub et al. 2013). Under the Frame Programme FP7 of the European Commission within the GMES initiative, the Fast Track Service Land was initiated. A bundle of Geoland 2 projects were started, like the Area Frame Sampling Africa. Parallel to those R&D projects the European Commission also initiated direct global monitoring themes, predominantly focussing on biophysical parameters like climate and vegetation. The following figure shows a snapshot from the dynamic development of the seasonal vegetation cover as observed by the PROBA V satellite from May/June 2014, originally with a coarse ground resolution between 100 m (nadir) and 350 m.

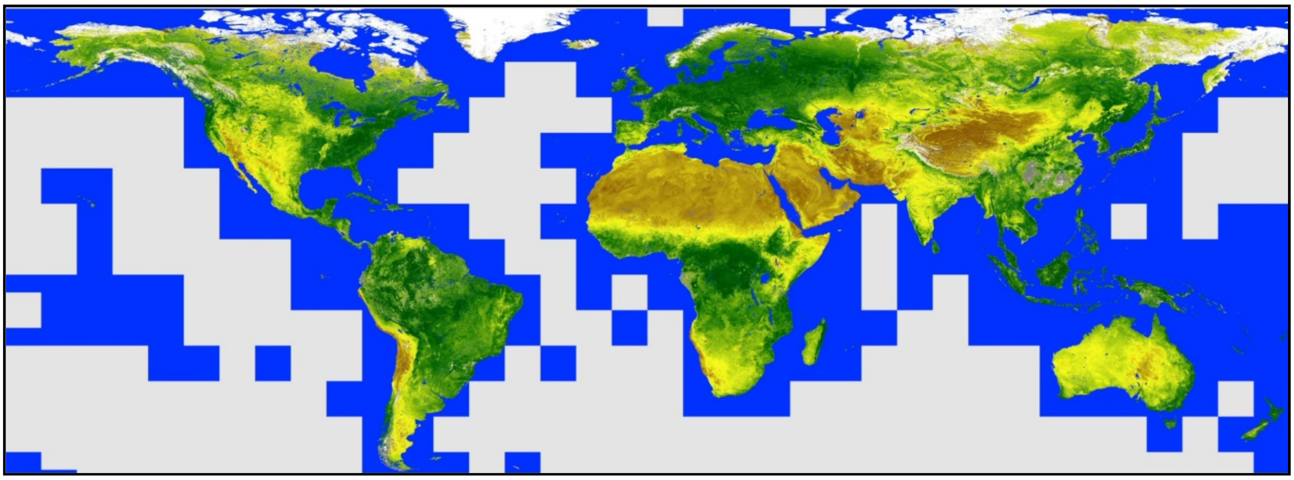

Figure 3: Global Land Cover of Vegetation of 2014 May/June (Copernicus 2014-2)

Another attempt was the Global Land Cover project initiated by the Joint Research Centre (JRC) of the European Commission starting under the frame of a project entitled as Global Environment Information System (GEIS). The task was to "provide information on changes in the world's vegetation cover for EU policy in the area of environment, development and external affairs" (Bartholomé 2002). The vegetation instrument on board of the SPOT 4 satellite offered a quick but coarse coverage. The cooperation of about 30 research groups developed for the GLC 2000 product a common legend using the LCCS terminology concerted between JRC and FAO.

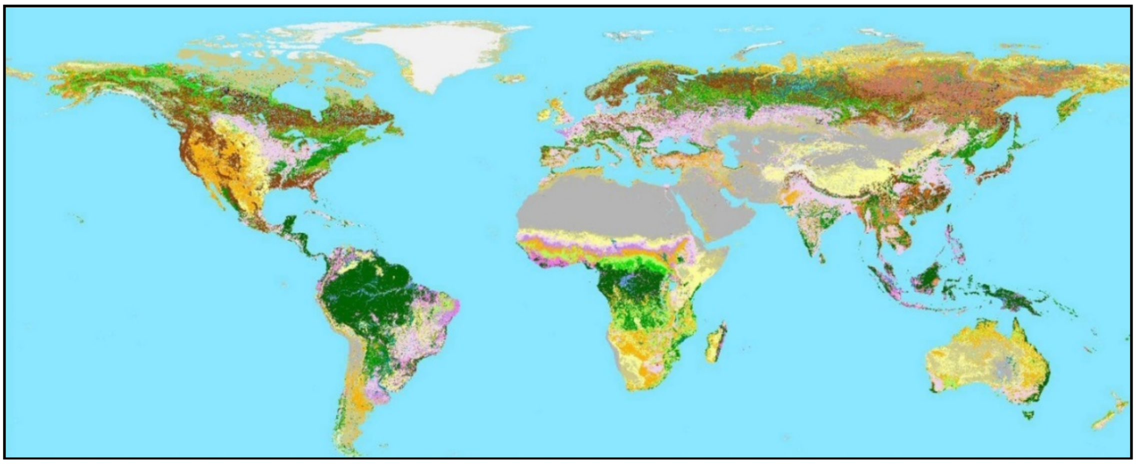

Figure 4: Global Land Cover2000 Product (Bartholomé 2002)

At the same time, similar attempts were conducted by the Food and Agriculture Organisation (FAO) of the United Nations. The new product is called "Global Land Cover – SHARE" (GLC-SHARE) and has been launched in a beta release in March 2014. The database utilizes the ISO standard "Land Cover Classification System" (LCCS) to harmonize various land cover databases from land cover products all over the world. The improved LCCS served to derive the "Land Cover Meta Language" (LCML), which is able to specify any land cover type around the world according to detailedness and scale. By using LCML, the researchers could create eleven land cover classes according to the System of Environmental Economic Accounting (SEEA).

Fig. 6 shows the global extend of ten of these classes with major proportion. The eleventh class comprises all artificial surfaces with only 0,6 % of the world's land area including inland water bodies.

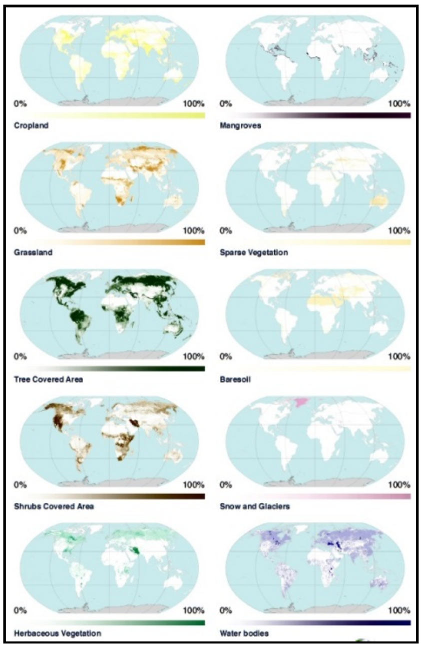

Figure 5: GLC SHARE Land Cover Data Base – single classes (Latham 2014)

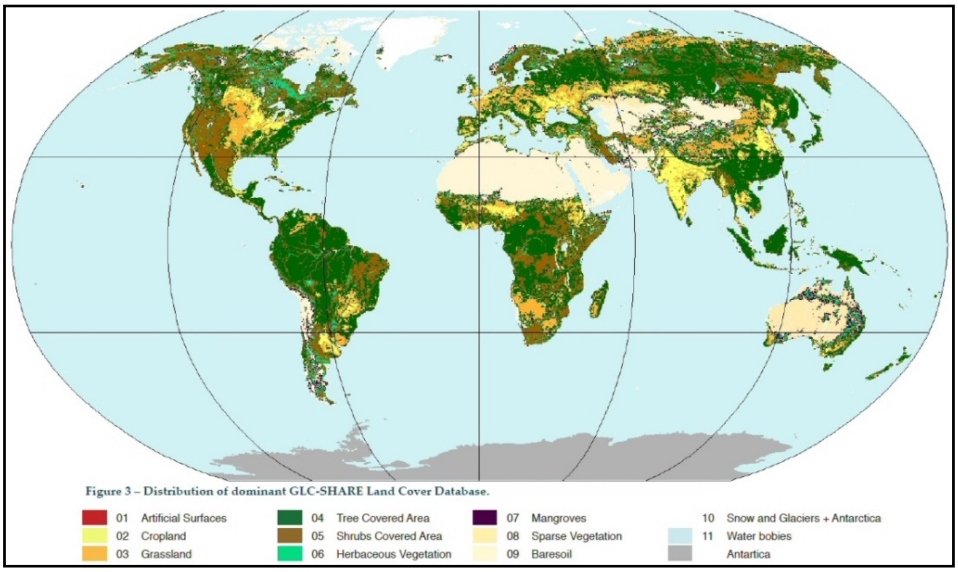

Figure 6: GLC SHARE Land Cover Data Base Map (Latham 2014)

The database is geometrically compiled within a pixel resolution of 30 arc-second, corresponding to ~1 km x ~1 km. The area south of latitude 60° S was not included in the data base. While Northern America, Europe, the Eastern half of Africa, Russia, China, some Southern Asian states and Australia were covered by high resolution data sets, Southern America, the Western half of Africa, the Arabian Peninsula, India and the Indonesian Archipelago were only covered by global data sets of coarse resolution.

Around 1000 stratified random sampling sites were used to perform a quality validation, of which the result is shown in Table 1. The overall class accuracy has been computed with 80,2 %. FAO is expecting that the reliability will increase with updates using improved databases.

Table 1: CLC-SHARE 2014 Quality Assessment
(own compilation from Latham 2014)

GLC-SHARE Land Cover types	Label	Global fraction	User’s accuracy	Producer’s accuracy
Artificial Surfaces	01	0,6 %	70,0 %	100,0 %
Cropland	02	12,6 %	94,9 %	88,8 %
Grassland	03	13,0 %	75,4 %	65,6 %
Tree covered Areas	04	27,7 %	94,9 %	91,8 %
Shrub Covered Areas	05	9,5 %	50,0 %	67,9 %
Herbaceous vegetation	06	1,3 %	56,0 %	53,8 %
Mangroves	07	0,1 %	80,0 %	100,0 %
Sparse vegetation	08	7,7 %	50,0 %	44,3 %
Baresoil	09	15,2 %	57,3 %	89,6%
Snow and glaciers	10	9,7 %	96,3 &	72,2 %
Water bodies	11	2,6 %	100,0 %	66,7 %
Total		100,0 %		

GLC Global Land 30

Between 2010 and 2013, the Chinese National Geomatics Center (NASG) prepared two global land cover maps of high resolution of 30 meters for the reference years 2000 and 2010 from freely available Landsat scenes. This has been launched as a national 30 m GLC mapping project and was listed as a GEO sub-task SB-02 C1 (Chen 2014).

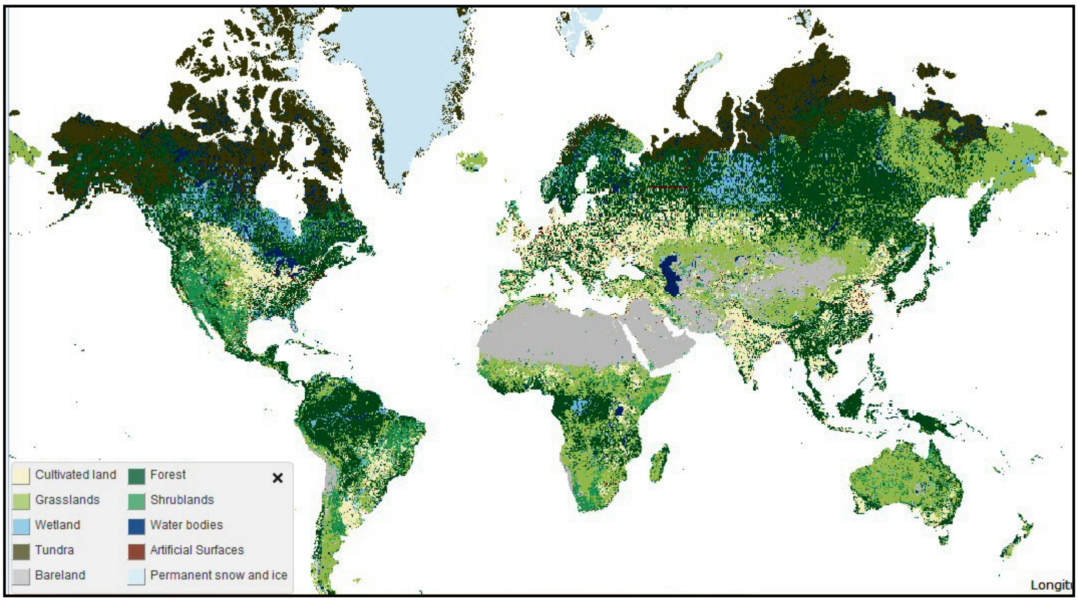

Figure 7: GLC Global Land 30 result for 2010 (Chen 2014)

To obtain a dataset for the reference year 2000, the National Geomatics Center of China in Beijing processed 10270 Landsat TM scenes. For the update 2010 though they could already use 2640 scenes from the Chinese HJ-1 satellite together with 9907 Landsat TM scenes. For four years around 500 scientists worked on the geo-coding and thematic processing of these data and developed a bundle of sampling techniques, classification and change detection procedures, e.g. the spectral gradient difference (SGD) based approach for land cover change detection (Chen 2013). The GLC 30 product comprises 11 land cover classes (see Fig. 8).

For the scientific user community it is very important that the complete data base for both reference years including sample areas and reference data like CORINE are available as a web service: www.globallandcover.com/GLC30Download/index.aspx. About 139 map sheets have been independently validated in sample areas by five international research groups, confirming a disagreement generally lower than 5 %.

Needs for Validation

All the explained land cover products basically have to face the same problem: The lower the number of well-known ground samples is, the more the automatic classification approaches have to extrapolate land cover characteristics into other regions, but with the consequences of raising risks of misclassification. On the other hand world coverage will hardly be completed without a certain margin of uncertainty related with time saving automation.

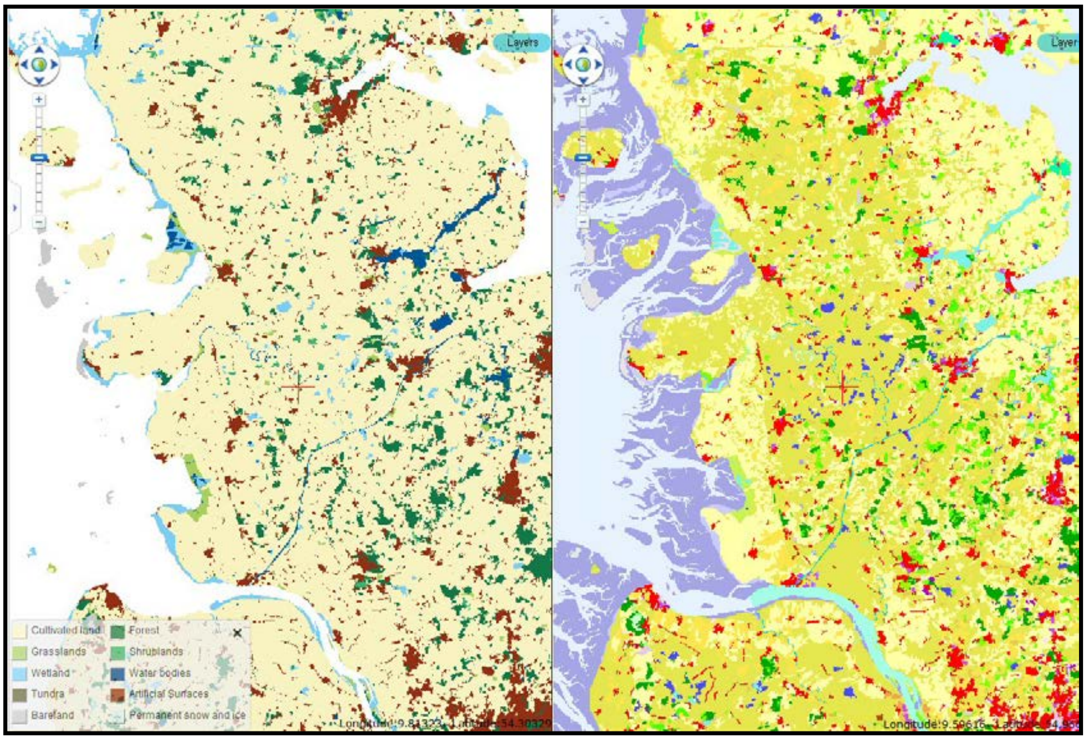

Figure 8: Validation example of GLC Global Land 30 (2010) against CORINE (CLC) for Schleswig-Holstein in Northern Germany (Chen 2014; www.globallandcover.com/GLC30Download/index.aspx)

Fig. 9 shows the comparative view of an extract from the GLC 30 and the corresponding CLC 2006 of a small part of Northern Germany between the city of Hamburg in the lower right corner and the German-Danish border of about 16.500 km², just separating the North Sea (left) from the Baltic Sea (right). Artificial surfaces, water bodies and forest show a very good concordance. But there is a well-known land cover differentiation of a strip of 40 km width and 120 km length parallel to the Western coast of predominantly grassland (CLC code 231), which is missing in the GLC 30 results. At least in this area, this will result to an underestimation of grassland cover to the benefit of the cultivated land ratio. Some other differences in the tidal flats along the North Sea coast are not of importance because in the global view these tidal amphibious lands are in the range of mangrove coasts extensions which also are not subject of GLC 30.

This example may underline the potentials for further improvements of the reference database, which will be performed certainly in the next update of GLC 30, as was already announced in Chen 2014.

MONITORING LAND COVER / LAND USE CHANGES

Methodological Advances in DeCOVER

In the frame of project for space-based services for German land cover, the DLR co-funded the development of approaches to overcome the gap between land cover and land use. The project DeCOVER focussed on the existing international and national land cover models like CORINE land cover, ATKIS Basis-DLM and DLM-DE with the aim to also support in future the setup of the European land service components within the Copernicus land serving components. Methodologically, there were different services to be addressed: the automatic detection and classification of land cover changes, the agricultural monitoring, the environmental monitoring and the crucial question of overcoming the partial discrepancies between the different existing national and international land cover models.

This special research needs to be explained in detail. Satellite based land cover data are supposed to have an area fully covered by a number of land cover classes, without overlaps and without any unclassified gaps between adjacent areas. Contrary to this, the ATKIS Basis DLM model provides information on land cover and land use, normally with several information layers (cadastre, legal requirements, land use, built-up structures, public limitations on real estate use, economic zoning, etc). The project has improved approaches of semantic and geometric interoperability to derive object classes from different cadastre comparable based on a common vocabulary (Christ & Lessing 2012, DeCOVER 2013).

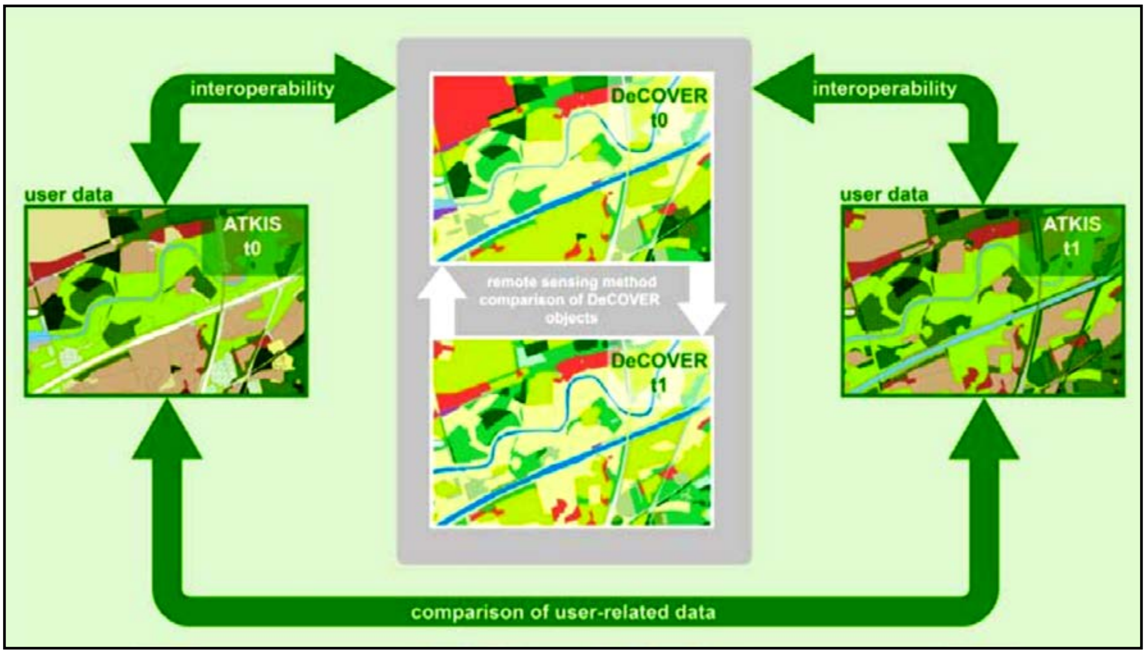

Figure 9: Knowledge based semantic and geometric interoperability (DeCOVER 2013)

The method allows for many suitable classes a semantic translation and for some classes even a geometric translation between the remote sensing derived land cover and the administrative and legal land use. These are for now R&D results in the frame of knowledge based regional context. To develop this method into a reliable service element there is still the need for more experience based case applications. Especially the local and regional knowledge bases according to the same standards will be a bottleneck for fast global spread of satellite based monitoring of high resolution. Perhaps the 15 years of recurrent LUCAS surveys will help to extend the knowledge base of land use and land cover at least in Europe.

These recent developments of methodological advances combined with repeatedly updated sample surveys give a very good perspective to improve the possibilities for global land cover / land use monitoring based on worldwide high-resolution satellite data.

Upcoming Trends in Global Monitoring

Several trends that can be observed lately will support further advances in high-resolution global land cover products. One important core issue is the continuation of high-resolution satellite programmes, even as a combination of satellite resources from different providers. Therefore, it is very promising that there is not only the Landsat continuity but also the upcoming Sentinel series, the RapidEye constellation, Spot 7, ResourceSat-2 from India and the Chinese HJ-1 that have enlarged the observation capacity already. Further follow-up satellites are under construction and planned. A second support field comes from various projects and international initiatives: Originally started as a project, there has been for several years one initiative working actively to promote and improve global earth observation, the “Global Observation of Forest Cover – Global Observation of Land Dynamics” (GOFC_GOLD) initiative. The Committee on Earth Observation Satellites (CEOS), the Group of Earth Observation (GEO), the United Nations (often through FAO) and many regional or national governmental institutions are pushing earth observation into a confluence of methodological and technical progress (Mora 2014).

Fortunately, there is other support, sometimes not in the focus of the scientific communities, but with growing and driving force. This support comes from an emerging group of users of global land cover information, not only from the public, but also from the private sector. The first global information of coarse resolution has created rising interest for information of better geometric and temporal resolution. The traditional user group has different administrative interests, like disaster mitigation, support to regional planning and zoning, monitoring of water resource regions, desertification, climate, biodiversity, ecosystem conservation and vegetation characteristics and change (cf. Mora 2014). Additionally, there is a special demand among the governmental user group to support earth observation in relation to developing countries and less-favoured regions (Komp 2010, Voelker 2011). The ongoing globalization of all social and economic relations has created a third important support group: the private sector, meaning the society as a whole. Besides the scientific interest of all earth-related disciplines, there is increasing interest in free access to global land cover information from private persons for travel, foreign investments, social engagement of NGOs and various economic activities. Initially, the main sectors that are profiting are the agriculture, forestry, mineral resources extraction and the energy sector, because all of them depend on knowing the spatial pattern in actual and accurate characteristics. The third group often benefits significantly from land cover information and will then be ready to finance projects that go beyond the free access information and generate information that is more specific. Such growing demand driven by globalisation will provide funding for scientific progress in earth observation, even in times of declining budget resources.

Those driving trends will be the basis for the scientific-technical trends in high-resolution global land cover mapping. Upcoming changes are visible in user oriented differentiation of monitoring cycles, monitoring scales and monitoring subjects. There are regions like the upper Amazonas forest or the north Siberian tundra where large scale mapping will happen only on demand in the absence of governmental programmes. On the other hand there will be extended online access to all geographic data. It is a very promising example that the Chinese GLC30 data base already offers an online validation tool which may serve in future to broaden the sources for local input of knowledge ("crowd sourcing validation"). Furthermore, the number of people travelling for private or work related reasons will increase further and require more specific information on their destination via online access. This will certainly bring new forms to display land cover mapping in user-adapted peculiarity.

CONCLUSION

Since the first satellite images were available, global land cover mapping data have been the key source for researchers, governments and private users. The paper demonstrated the scientific developments and technological progress since the Large Area Crop Inventory Experiment where the United States predicted the Soviet wheat yield. Furthermore, this paper discussed different land cover data sets to highlight the regional and global developments. In terms of high resolution, accuracy and actuality the Chinese Global Land Cover change detection data set presently appears to have the highest standard The GLC30 product fascinates with its information content and the web based functionalities, but also shows potential for local improvement.

The demand for ongoing global land cover observation is expressed by different user communities. Upcoming trends are more continuity of data with higher resolution, harmonization and standardization of mapping procedures, but also emerging user demands and new user communities related to web services. Finally, these prospects will broaden the user community who sees the Societal Benefit Areas (SBA) of earth observation. This will be the common mandate for all researchers and experts involved to support the advancement of earth observation. Their engagement in earth observation and high-resolution land cover monitoring will contribute to a responsible and sustainable development of our planet Earth.

REFERENCES

Bartholomé, E. et al, 2002. GLC 2000 Global Land Cover mapping for the year 2000. European Commission, DG Joint Research Centre, EUR 20524 EN, pp. 62.

Brockmann, J., Haub, C., Komp, K., 2011. Global Monitoring for Food Security Stage 3 (GMFS 3). *Photogrammetrie Fernerkundung Geoinformation*, 2011(3), pp. 194-195.

Christ, I., Lessing, R., 2012. Semantische und geometrische Aspekte der Interoperabilität. *DGPF-Tagungsband 21*, pp 18-25.

Chen, J., Wu, H. Li, S., Liao, A., He, C., Peng, S., 2013. Temporal logic and operation relations based knowledge representation for land cover change web services. *ISPRS Journal of Photogrammetry and Remote Sensing*. Vol. 83, Sept. 2013, pp 140-150.

Chen, J., 2014. GLC – GlobalLand30. GEO-X Plenary – Ministerial Side Event "Towards international Collaboration on Global Land Cover Products and Services". 14.01.2014, Genève, Conference Paper.

Copernicus 2014. Copernicus Land Monitoring Services – www.land.copernicus.eu/pan-european/corine-land-cover (04.03.2015).

DeCOVER, 2013. DeCOVER 2 – Space based services for German land cover, 12 p. www.decover.info (10.07.2013).

Erb, R. B., Moore, B. H., 1979. The Large Area Crop Inventory Experiment /LACIE/ - A summary of three years experience. *Canadian Symposium on Remote Sensing, 5th, Victoria, British Columbia, Canada, August 28-31, 1978, Proceedings. (A79-36486 15-43)* Ottawa, pp. 542-554.

EUROSTAT 2015: LUCAS online viewer. http://ec.europa.eu/eurostat/statistical-atlas/gis/viewer/?my Config=LUCAS-2012.xml (02.03.2015).

Haub, C. et al., 2008. Crop Mapping Services for the Sudanese Government in Frame of the ESA Global Service Element "Global Monitoring for Food Security". *Photogrammetrie Fernerkundung Geoinformation*, 2008(5), pp. 409-419.

Haub, C., Gilliams, S., 2011. Food Security: Crop Monitoring from the Sky. *Geospatial World*, 2011 (3), pp. 42-45.

Haub, C., Kleinewillinghöfer, L., Brockmann, J., Komp, K., Gilliams, S., 2013. Monitoring Services for Food Security – Successful Transfer of Technology to the Sudanese Government. *Photogrammetrie - Fernerkundung - Geoinformation* (Impact Factor: 0.43). 10/2013; 2013(5):459-472. DOI: 10.1127/1432-8364/2013/0192.

Komp, K., Haub, C., Dienst, H., 2010. Anwendungspotenziale der Erdfernerkundung für Entwicklungsländer – Erkenntnisse aus dem Technologietransfer – politische und gesellschaftliche Bedingungen für den Einsatz der Fernerkundung in Entwicklungsländern. Expert opinion commissioned by TAB – Office of Technology Assessment at the German Bundestag, Münster, 2010, 57 p.

Komp, K., Haub, C., 2012. Global Monitoring for Food Security and Sustainable Land Management – Recent Advances of Remote Sensing Applications to African and Siberian Show Cases. *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci*., XXXIX-B8, 265-270, ISPRS Congress Melbourne 2012.

Komp, K., Haub, C., Voelker, A., 2013. Tracing global warming by agricultural monitoring using multiscale approaches of remote sensing. Progress report from the German-Siberian research project "SASCHA". *Conference: Geo-Siberia 2013, 17 pp.*

Komp, K., 2014. Remote Sensing for Development in Africa – Technological and Political Perspectives based on Three Decades of Experience. *34th EARSeL Symposium: European Remote Sensing – New Opportunities for Science and Practice*, Warsaw, June 2014. Abstract Book, ISBN: 978-83-63245-57-3, Warsaw 2014, p. 142.

Konecny, G., 2013. The International Society for Photogrammetry and Remote Sensing (ISPRS) study on the status of mapping in the world. *Global Geospatial Information*. International workshop of the Siberian State Academy of Geodesy and ISPRS in Novosibirsk, Proceedings, pp. 4 – 24.

Latham, J., Cumani, R., Rosati, I., Bloise, M. 2014. Global Land Cover SHARE (GLC-SHARE) database Beta-Release Version 1.0. FAO, Rome.

Mora, B., Tsendbazar, N.-E., Herold, M., Arino, O., 2014. Global land cover mapping: current status and future trends. *Land use and land over mapping in Europe: practices & trends, Remote Sensing and Digital Image Processing 18*, DOI 10.1007/978-94-007-7969-3_2. Dordrecht 2014, pp 11 – 30.

NASA, 1978. LACIE – Phase I and phase II accuracy assessment final report. Houston, 186 pp.

Voelker, A., Mueterthies, A., Hoelzel, N., 2011. Implementation of a monitoring system for land cover changes in the Western Siberian corn-belt – A remote sensing approach from the SASCHA project. In: *Environment and Natural Resource Management*, Tyumen 2011. p. 233.

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