ITC NEWS

SPECIAL FEATURE
FOOD SECURITY

MICRO INSURANCE

GIMA JUBILEE

GREETINGS FROM

GROUNDWATER DAMAGE
KUWAIT

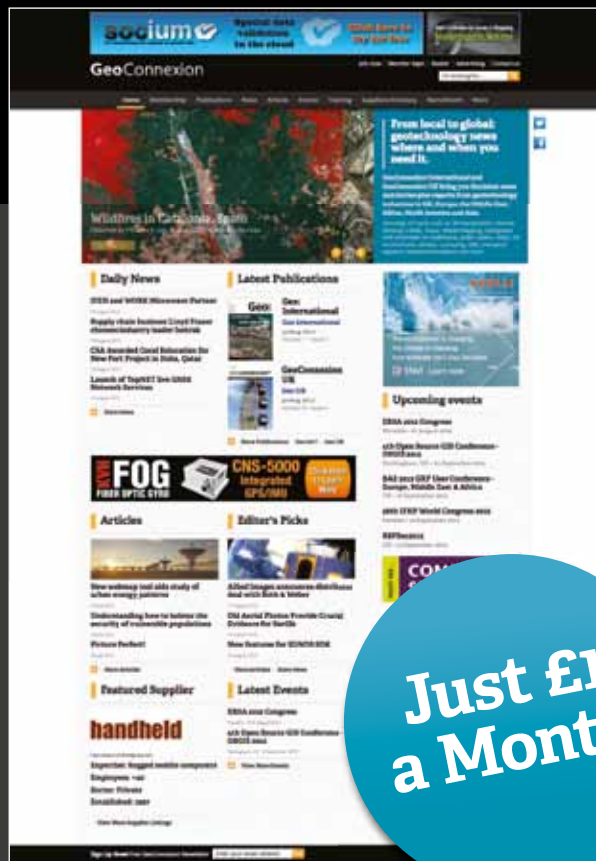# New website, latest offers, start saving...

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cover

The downside risk of farming in combination with lack of access to capital means that productivity increases are difficult to achieve. These represent serious challenges for both food security and overall poverty reduction.

INTRODUCTION

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Attentive readers of the ITC News know that the third issue of the year features the Academic Opening Ceremony bringing together academics in their gowns and new students in colourful national dress. Professor Veldkamp highlighted the new agenda of the government for assistance, commerce and investment as well as blended learning. The Schermerhorn lecture was given by Barbara J Ryan of GEO. You can read the full report on page 3.

When you are interested what the new agenda will comprise, the Special Feature of this issue is something you should not miss. One of the five new focal points of interest in the field of Dutch Education for developing countries is Food Security. The articles of the special feature show diverse activities within this knowledge field among staff, students and alumni of the Faculty. A tailor-made training course on the impact of climate change on food security (page10), students sharing their experiences on crop-intensity mapping (page 12), an alumna writing about mapping and yield estimation in the Mekong Delta (page 14), Micro insurance (page13), a collaborative research project focusing on improved monitoring of agriculture(SIGMA FP7) or GEONETCast for Water & Food security project (pages 8 and17) are just a couple of the activities mentioned in this special feature.

At the 10 years Jubilee Day of the Geographical Information Management and Applications (GIMA) programme (page 22) Mr Ed Parsons, the Geospatial Technologist of Google, shared the current trends in Geoinformatics according to Google. During the same event Dr Connie Blok retired after more than twenty years working at ITC (page 24). Within the Netherlands she played an important role in fostering knowledge exchange between academic and professional cartographers.

As mobility is a hot item among young alumni, alumnus Yohannes Yihdego tells his story about his research and his life after ITC (page 27). All in all a lot of new stories to read in this issue of ITC News. I hope you will enjoy it as much as I enjoyed making this issue.

Virtually yours,　　　Jorien Terlouw
Editor

MAIN FEATURES

Opening Academic Programme 2013-2014

Janneke van den Elshout   j.g.m.vandenelshout@utwente.nl

T**he** opening of the academic programme of the faculty for Geo-Information Sciences and Earth Observation (ITC) of the University of Twente was on Thursday 26 september. As is tradition, the celebrations took place in the Grote Kerk church on the Oude Markt in Enschede. The audience was mainly made up of students dressed in traditional - often colourful - outfits, professors in their black robes and ITC relations. The large chandeliers, the organ music as people flocked in and the sun shining through the stained-glass windows of the church gave the ceremony a particularly warm glow.

The faculty dean, Professor Tom Veldkamp, opened the ceremony and discussed some points of attention from the perspective of the Ministry of Foreign Affairs. April 2013 heralded the start of a new agenda for assistance, commerce and investments. These include, for example, five new focal points of interest in the field of Dutch education for developing countries: water, food security, safety and legal order, women's rights, and sexual and reproductive health and rights. Attention was also paid to sustainable results, in which the use of innovation, sharing knowledge, leadership and learning are important. Lastly, the dean discussed *Blended learning*, which combines various points of departure of ITC and UT, such as a focus on lectures, self-study and studying online on the one hand and the three mainstays of the UT (research, organisation and design) on the other.

Student at the rostrum
Okta Prastowo Raharjo from Indonesia, chair of the *Student Association Board*, related a personal story of his experiences at ITC and urged new students to demonstrate, among other things, their motivation and commitment, but also to make new friends. Prastowo Raharjo referred to the close harmony with which people collaborate with one another within Faculty ITC, a place where you are constantly meeting people of many different

Professor Tom Veldkamp, opened the ceremony

The academic cortege in front of the Grote kerk, Enschede

nationalities. He went on to thank the municipality of Enschede and its citizens: "Thank you, Enschede, for your amazing hospitality", as well as the ITC partners and the Dutch government.

Prize-giving ceremony

Veldkamp subsequently presented the ITC Research Award. This prize, awarded for the best scientific article by an ITC PhD candidate during the past year, went to Chandra Prasad Ghimire of Nepal. The title of the research is: "*The effects of sustained forest use on hillslope soil hydraulic conductivity in the Middle Mountains of Central Nepal*". The article was published in the Journal of Ecohydrology. Chandra Ghimire researches the common hypothesis which states that planting pine trees improves soil drainage. His field of study is located in Central Nepal. Chandra rejects this hypothesis with convincing scientific arguments. The local press has taken up the story and it seems that his conclusion is shared by the local farming community. The cheque for €1,000 was accepted in Enschede by co-supervisor, Maciek Lubczynski. The winner, Chandra Ghimire, is in Dehradun, India, where he is presenting his research to a broader audience at the Asia Pacific Workshop on Forest Hydrology, the theme of which is "Water and Forests – Beyond traditional forest hydrology".

First lecture

After a musical interlude, it was time for the Schemerhorn lecture. Willem Schemerhorn (1894 – 1977) founded the Faculty of Geo-Information Science and Earth Observation. This lecture, which is also the first lecture for new students, was given by Barbara J. Ryan, director of GEO (Group on Earth Observations) in Geneva, Switzerland. In her lecture, Ryan discussed the GEO organisation and her own vision. GEO's vision is to create a future in which decisions and activities on behalf of mankind are supported by sustainable earth observations and information. With 90 countries involved and 67 partners, they are capable of issuing, via earth observations, statements on: agriculture, biodiversity, climate, natural disasters, eco-systems, energy, health, water, and the weather. There are still a number of new challenges that

will form the basis of making the right decisions. Ryan demonstrated, with the help of colourful illustrations and graphs, the information that earth observation has supplied within the various sub-areas.

The afternoon concluded with a get-together for networking ■

Okta Prastowo Raharjo from Indonesia, chair of the Student Association Board

The audience was mainly made up of students dressed in traditional - often colourful - outfits, professors in their black robes and ITC relations

The award was accepted by co-supervisor Maciek Lubczynski

The Schermerhorn lecture was given by Barbara Ryan, director of GEO

Urban Futures.
Multiple visions, paths and constructions?

Javier Martinez   j.martinez@utwente.nl
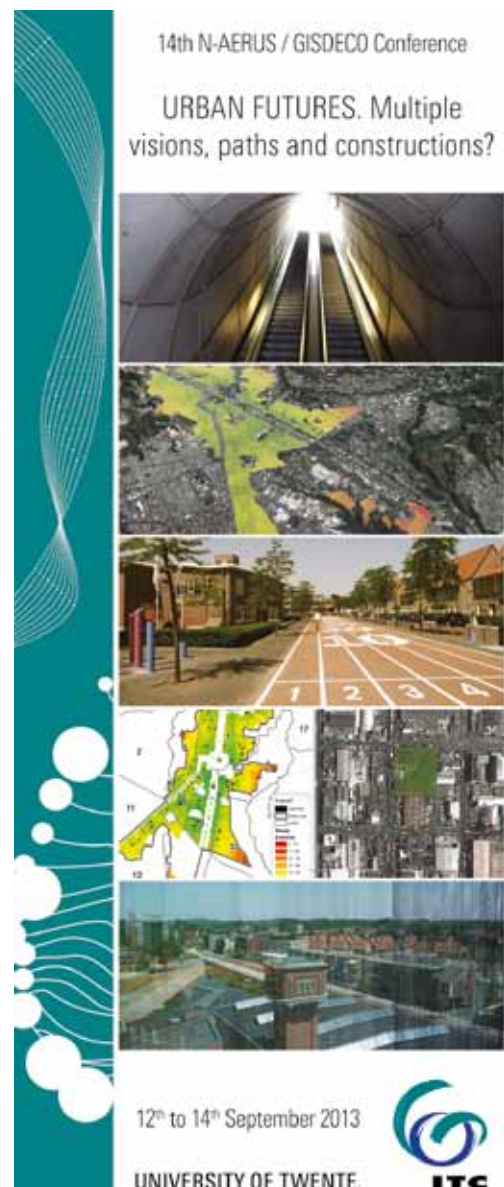
Richard Sliuzas   r.sliuzas@utwente.nl

From 12-14 September 2013, the Faculty ITC (University of Twente) hosted the 14th N-AERUS / 7th GISDECO joint conference. Forty-five papers were presented around the theme "Urban Futures: Multiple visions, paths and constructions?" In the conference call, we stated that having a prospective vision in the current climate of economic crisis - and under scenarios of greater social and political inequality - represents a challenge for city management due to the difficulty of imagining a prosperous future over the longer term.

The conference started with the premise that current urbanization trends and choices made by policymakers may lead to multiple futures affecting global development and, moreover, to understand these uncertain processes, we need cross and multidisciplinary perspectives. No single discipline can fully comprehend and tackle the complexity of urbanization, nor support policymakers in designing and preparing for better envisioned futures.
To transcend the divide between different research paradigms, we encouraged participation from different strands of academic discourse on urbanization issues. This was also reflected by the two keynote speakers. Maria J. Coetzee (Commission for Scientific and Industrial Research, South Africa) presented a quite technical perspective on "The role of evidence-based modelling and planning support systems in support of urban and regional policy development in South Africa". Navdeep Mathur (Indian Institute for Management, Ahmedabad, India) discussed a critical political science view in his presentation "Planning Like A State: Urban Governance by (Dis) Empowerment".

Four sub-themes were addressed: spatial information and urbanizing futures; crises and futures; planning, policy and futures; and "tales from the future" on innovative approaches both in methodological terms and theoretical perspectives. In an hour-long plenary session, the main issues to emerge from each sub-theme were discussed by Richard Sliuzas together with panel members: Maria J. Cotzee, Navdeep Mathur, Yola Georgiadou (Professor of Geoinformation and Governance) and Andres Morales (PhD candidate, University of Twente). The conference presentations covered a wide range of topics and included a mix of theoretical and practical examples through case studies from around the world. Three key issues to emerge from the debates relate to:
i) the process of urbanization itself –the spatial-temporal dynamics of a diverse range of actors, issues and processes that transcend various scales and give rise to complex forms and behaviours that challenge our abilities in measurement, description, comprehension, modelling and planning;
ii) data issues – the need to go beyond the physical dimension

Faculty ITC (University of Twente) hosted the 14th N-AERUS / 7th GISDECO joint conference

Site visit to the award winning new neighbourhood development in Roombeek

that is increasingly provided for via geographic information technologies (aerospace and ground based, professional and citizen sensors) and seeking better integration with social, environmental and economic dimension; iii) the issue of governance – from issues of how data is governed, to how to ensure equitable and effective stakeholder participation, and of how diverse stakeholder values and tacit knowledge can be included in urban futures. The urban futures debate is especially pertinent at this time: not only is the world increasingly being urbanized, most countries are also witnessing increasing inequality and inequity. The urban scientific community needs to not only develop sound concepts and frameworks upon which knowledge development and understanding can be based, but also needs to be willing to look at issues through different lenses and from different vantage points in order to do justice to the trade-offs and effects that urbanization inevitably entails ■

THIS CONFERENCE was the first time that the N-AERUS and the GISDECO network communities met. This provided for an opportunity to put different research paradigms and strategies into dialogue. N-AERUS is a pluridisciplinary network comprised of more than 400 researchers and experts with the objective to mobilize and develop the European institutional and individual research and training capacities on urban issues in the south. The GISDECO network was founded in 1991 as a platform for exchange between research and practice on the application of GIS for rural and urban planning in developing countries.

Food Security

Since April 2013 the Dutch government has a new agenda for assistance, commerce and investment in place. One of the five new focal points of interest in the field of Dutch Education for developing countries is Food Security. Within the Faculty ITC many staff members are working on education and/or research or have projects in the field of food security.

In this **Special Feature** you can read about the different aspects the Faculty is working on within this knowledge field.

Global Food Security

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As any compilation of newspaper items shows, our world cannot take food production for granted. An example: the 2010 summer drought in southern Russia led to a 37% reduction in the country's grain production and a global price increase of 80% within 6 months.

Food production will remain subject to uncertainties and the unpredictability of the weather and changing climate. Also, we cannot have a food-secure world if we continue to compound the inherent risks with poor policies due to a lack of reliable and timely information. Remote sensing products provide early warning following anomalies caused by drought (see map A).

To improve agricultural monitoring systems, GEOGLAM, the GEO Global Agricultural Monitoring initiative was initially launched by the Group of Twenty (G20) Agriculture Ministers. This took place in June 2011, in Paris. The initiative was addressing that:
• By 2050, global agricultural productivity will need to increase by at least 70% to guarantee food production for future generations;
• Agricultural production will need to be based on sustainable land management practices;
• Uncontrolled food price volatility must be addressed.

The G20 Ministerial Declaration states that as part of GEOSS, GEOGLAM "will strengthen global agricultural monitoring by improving the use of remote sensing tools for crop production projections and weather forecasting". By providing coordi-nated earth observations from satellites and integrating them with ground-based and other in-situ measurements, the initiative will contribute to generating reliable, accurate, timely and sustained crop monitoring information and yield forecasts.
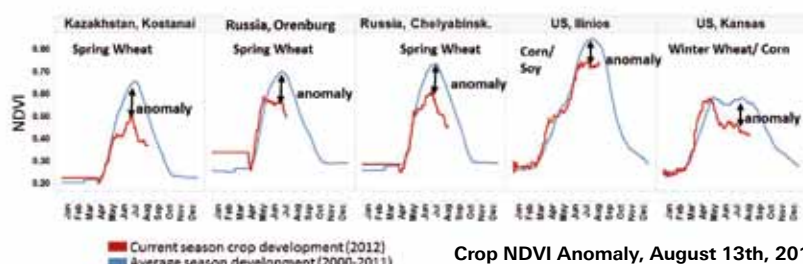

Our world cannot take food production for granted

Crop Condition Global Outlook: Building International Consensus
Assessment of Crop Conditions in Northern Hemisphere - input to AMIS

Map A: To improve agricultural monitoring systems the GEOGLAM initiative was initially launched by the Group of Twenty (G20) Agriculture Ministers

Crop NDVI Anomaly, August 13th, 2012

The Global Earth Observation system of systems

ITC and the SIGMA FP7 Project

To support GEOGLAM, the EU-FP7 has decided to fund SIGMA, a collaborative research project focusing on improved monitoring of agriculture.

At present, earth observation-based (global) crop monitoring systems focus mostly on short-term agricultural forecasts, thereby neglecting longer term environmental effects. However, it is well known that unsustainable cultivation practices may lead to a degradation of the (broader) environment, resulting in lower agricultural productivity.

As such, agricultural monitoring systems need to be complemented with methods to also assess environmental impacts of changes in crop land and shifting cultivation practices. It is thereby important that this be addressed on a global level. SIGMA

presents a global partnership of expert institutes in agricultural monitoring, with strong involvement in the GEO and the Global Agricultural Geo-Monitoring (GEO-GLAM) initiative.

SIGMA aims to develop innovative methods, based upon the integration of in-situ and earth observation data. This will allow for the prediction of the impact of crop production on ecosystems and natural resources. The proposed project will address methods to:
- enable the sharing and integration of satellite and in-situ observations according to GEOSS Data CORE principles
- assess the impact of cropland areas and crop land changes on other ecosystems
- understand and assess shifts in cultivation practices and cropping systems to evaluate impacts on biodiversity and the environment

Furthermore, dedicated capacity building activities are planned to increase national and international capacity to enable sustainable management of agriculture. Lastly, a strong coordinating mechanism will be put in place, through the project partners. Strongly linking SIGMA and the G20 Global Agricultural Geo-Monitoring Initiative (GEOGLAM) will assure transparency and alignment of the SIGMA activities.

Part of the project is Technology Transfer and Capacity Development. The used and/or created knowledge base will be efficiently packaged for a wider audience at country and regional levels. These training components will be implemented jointly by the FAO and ITC, and engage centres of excellence at regional and national levels ∎

How Climate Change Impacts Food Security: Rice in Indonesia

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As the world's fourth most populous country, food security in Indonesia is a persistent challenge. Climate change will have large impacts on the agricultural sector. We must understand such impacts before we can plan mitigation strategies.

In January 2013, staff of Badan Meteor-ologi, Klimatologi dan Geofisika (BMKG), the Indonesian Agency of Meteorology, Climatology and Geophysics, came to the Faculty of Geo-Information Science and Earth Observation (ITC). In a four-week tailor-made training course entitled "Climate Change and Food Security in Indonesia" the participants gained a lot of new insights. This training course was sponsored by NUFFIC and it enabled the Indonesians to design sound mitigation measures.
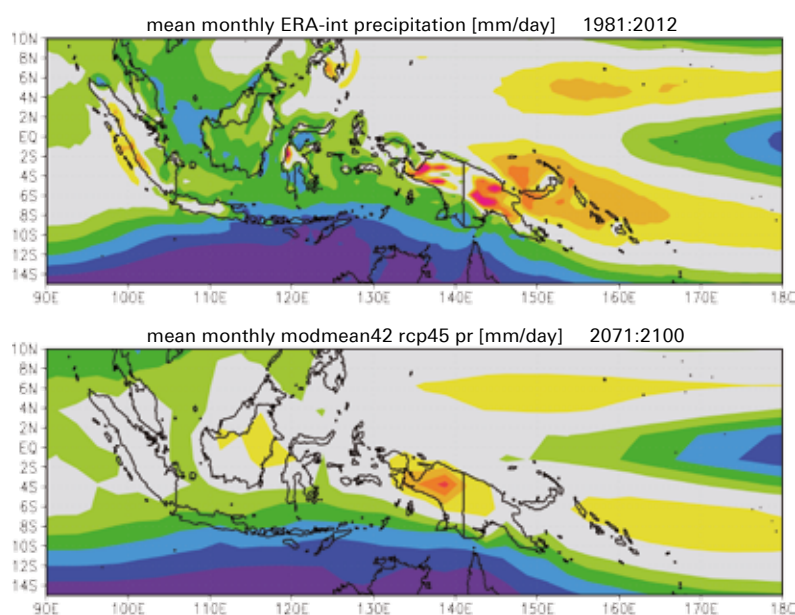
Agricultural production models need climate information as input. If no detailed climate change predictions are available, coarse-scale climate change scenarios must be down-scaled into more local information. One issue is that general climate models cannot generate sufficient accuracy which takes into account the complex Indonesian topography. The many islands and local sea- land- and air interactions are the source of the problem. During the tailor-made training course, special attention was given to the question "How can meteorological observations and

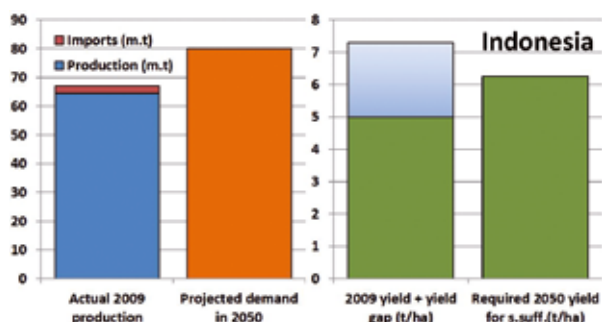statistical tools be used to develop local climate change scenarios?"

These climate scenarios were then fed into a crop model (AquaCrop) to simulate rice yields. Varying temperatures and rainfall characteristics, following the localized climate scenarios for 2050, showed clear

impacts on both absolute yields and on the yield variability. Specifically, changes in the start and length of the rainy and dry seasons were studied, categorized by location, planting date, and crop grown.
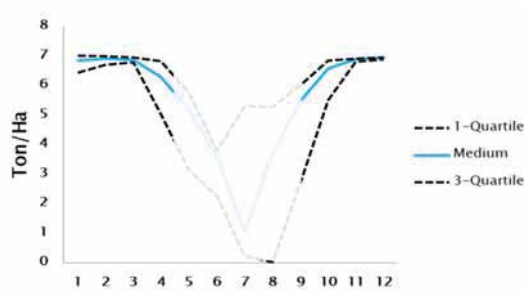
During the course, lively discussions took place between staff and participants. They concluded that high quality, long-term observations of meteorological conditions and past agricultural production statistics are necessary inputs for prediction models. The Indonesian meteorologists went home with new skills to translate global climate scenarios into local and future agricultural predictions ◼

The climate scenarios are then fed into a crop-model (AquaCrop) to simulate rice yields.

Left: Indonesia's required rice production in metric tonnes, based on population growth data. **Right:** the potential versus the required yield increments for rice self-sufficiency in tonnes per hectare (Laborte, de Bie, Smaling, Moya, Boling, and van Ittersum, 2012)

Impact on rice yield and yield variability (risk) when planted from January to December, as estimated after introducing a change in the onset of the rainy season

Learning over the internet: how can satellite images be used for crop monitoring?

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Time lapse series of satellite images provide important information on how well crops are growing. This allows harvest shortfalls to be predicted several weeks to a few months in advance. Given the extensive coverage of these images, large regions can be screened. Knowledge about the analysis of such images is required for effective monitoring and prediction.

A new e-learning course, developed for FAO and coordinated by the European Commission's Joint Research Centre, should make this knowledge available to food security analysts around the world. The Department of Natural Resources of ITC has made a substantial contribution to this course, which is expected to come online in 2014.

A food crisis?

Drought, flooding, and erratic rainfall all negatively impact plant growth. For example, a delay at the start of the growing season may require farmers to change crop types. When crops are blooming, they are very sensitive to dry spells. Comparing vegetation and weather patterns with those from previous years, thus, provide information on the performance of crops. Linking this to agricultural statistics from recent harvests can subsequently provide an estimate of the expected crop yield. If the estimate yield is low, and market prices for food products are high, there is a risk of a food crisis. This will need to be checked with the conditions on the ground. Having early knowledge about potential crises can help governments and other organizations to closely monitor the situation and prepare various response options.

Course content

The main objective of the course is to understand the meaning, usefulness, and the limitations of satellite-derived information for food security assessments. Regarding the sources of information, the focus is on rainfall estimates and vegetation indices. People who take the course learn, for example, how rainfall and NDVI (normalized differenced vegetation index) anomaly maps are made, and how these can help in localizing dry spells and vegetation stress at different times during the crop season. Calculating anomalies allows for the comparison of the rainfall and vegetation of the current season to long term averages, or specific reference years. The course specifies, moreover, how such information could be used to make yield predictions, and how the satellite-derived information can best be communicated to a larger audience in crop monitoring bulletins ◼

Screenshot of start of lesson 3(of the nine lessons) of the FAO E-learning course on crop monitoring.

Crop-Intensity Mapping Experience

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The mapping and monitoring of crops is of great importance to developing and maintaining food security policy. This is especially necessary in order to keep pace with the increasing needs of a growing world population. With the world's population estimated to reach 9.2 billion by 2050, food production will indeed need to increase by 70% above current production levels. Timely and accurate information on the crops, locations and the quantities grown is required. Without this, food security cannot be planned or controlled.

How does one get to know which crops are grown, at which locations and in which quantities? MSc students in the Natural Resources Management programme were challenged by their lecturer to create crop maps for Ghana, utilizing data-integration techniques and various software.
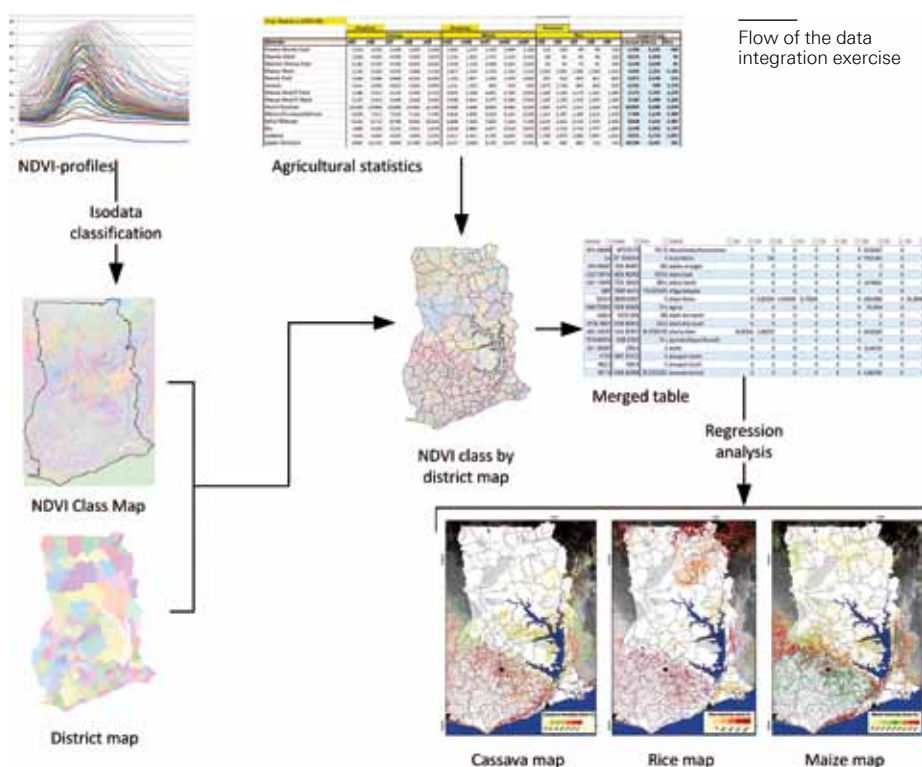
The Ministry of Agriculture in Ghana records the area of crops grown over time in each of Ghana's districts. The location of the crop fields, however, is not recorded. Therefore, additional data is required to produce crop maps that use the agricultural statistics. A rather inventive data-integration method, proposed by Kees de Bie, our lecturer, has been applied to acquire and prepare additional data and to successfully disaggregate the agricultural statistics into crop intensity maps. This method involves the use of hyper-temporal NDVI imagery and multiple linear regression analysis. NDVI stands for Normalized Difference Vegetation Index which strongly links with photosynthesis and the amount of healthy vegetation on the Earth's surface.

Each crop has its own phenological cycle, hence its own green canopy development pattern. This pattern may be used as a unique identifier. Hyper-temporal NDVI imagery is very suited to capturing green canopy development. NDVI profiles can be created for each pixel over time. These NDVI profiles can be clustered into unique NDVI classes, by which the study area over time can be classified. When applying basic RS, GIS and statistical analysis techniques, it becomes possible to create the required crop intensity maps. The flowchart shows a brief overview of the exercise.

The quality and accuracy of the resulting maps has not been established. This is outside of the exercise's scope. The idea of the experience was to demonstrate the purpose and use of data-integration techniques and to allow students to have a firsthand learning experience. It also serves to emphasize the fact that one needs to think outside the ordinary to extract the required unknown from the available data. We experienced first-hand that *"There is no lack of data, only a lack of information"* ∎

M.Sc. students were challenged to create crop maps for Ghana, utilizing data-integration techniques and various software.

Flow of the data integration exercise

Microinsurance and on-farm risk management preferences; the case of Ethiopian smallholder farmers

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For small-scale farmers in developing countries, especially for those living at subsistence levels of agricultural production, the downside risk of farming often prevents them from investing in technologies to increase the return on investment.

The downside risk of farming in combination with lack of access to capital means that productivity increases are difficult to achieve. These represent serious challenges for both food security and overall poverty reduction. In the last few years, credit has become more accessible to farmers. However, the risks in agriculture, and the consequent fear among farmers of being unable to repay the credit, prevents farmers from taking it up to increase investments in agriculture.

One mechanism to deal with agriculture risk is agriculture microinsurance. While several studies focus on supply and demand for agriculture microinsurance, few studies have considered its impact on on-farm risk management. In addition, little is known about the influence of different agriculture microinsurance product designs on impact. Therefore a study by the newly-established Laboratory for Social Interactions and Economic Behaviour (LSEB) hosted at the Faculty of Geo-Information Science and Earth Observation (ITC) of the University of Twente is investigating the impact of hypothetical average area-yield index insurance. The question being addressed by Karlijn Morsink and Tagel Gidey is: What is the impact of average area-yield index insurance on on-farm risk management preferences?

Through framed field experiments, the study investigates the effect of area-yield index insurance. The insurance covers the cost of inputs for fertilizer, improved seed and the hire of oxen which are part of the overall on-farm risk management of small-scale farmers in Tigray, Ethiopia. The on-farm risk management options being investigated are the drought-related risk and return for varying crops, investments in fertilizer, improved seed and the hire of oxen. The study combines focus groups, questionnaires and semi-structured interviews. The experiments are conducted on a sample of 220 randomly-selected farmers. Previous on-farm risk management behaviour, including loan behaviour, is first reconstructed, after which farmers are asked to explain, through a game, their farming plans for the upcoming season. Over several rounds of *games*, the insurance treatments are introduced and farmers are asked again to create their plan, after having paid the insurance premium.

We control for other household expenditures and investments in other economic activities, risk preferences, time preferences and typical farmer characteristics.

Our preliminary results show, firstly, that farmers create very precise annual farming plans and that a considerable proportion of the smallholders already take up microcredit. Secondly, the insurances have a positive effect on the uptake of microcredit and a significant and substantive effect on improvements in on-farm risk management ◼

Photos Karlijn Morsink

Mapping and yield estimation for rice in the Mekong – a thesis that faced 3 problems

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Significant work has been done in the past in the field of agricultural research utilizing remote sensing technology. Yet, up until now, very little existed which emphasized the development of a remote sensing based method to estimate actual crop yield and production. This changed in a recent PhD study. Various types of satellite data were combined with field observations to run crop simulation models. An early warning estimation method for rice in the Mekong Delta, Vietnam has now been created.

Our immediate ambition was to create the awareness that before any monitoring could be attempted, required facts about the rice cropping systems of the Mekong needed to be firmly in place. We began our search for maps and data, which led to the first problem: the maps proved far too general and of insufficient quality. Besides, official agricultural statistics at the local level could not withstand the simplest validity checks.

A discussion emerged about whether the cloudy region radar would be able to differentiate practiced cropping systems. Imagery was available, but its temporal coverage was grossly insufficient. A solution was found through the use of SPOT-VGT NDVI imagery (available for free from VITO, Belgium). After a de-hazing/clouding routine and a data-implosion routine, a space-time stratification emerged. Thus, it was "ready" for the first fieldwork campaign.

Hundreds of farmers were interviewed. Crop calendars were collected, classified and matched to the earlier prepared strata.

The fit proved simply perfect. Validation data collected later confirmed that. The relative local homogeneity of the landscape and the temporal SPOT imagery proved to work well together in differentiating 26 rice-based cropping systems (figure 1).

A second fieldwork campaign was needed to collect series of crop measurements and ultimately the actual obtained yields over a complete growing season. To do this, we visited 58 sites representing various cropping systems. Leaf area index imagery from MODIS was downloaded and compared with the field observations. Then, the second problem emerged: the relation between both data sets was nearly "zero". Discussions with Prof Wout Verhoef followed, and we decided to retrieve the original MODIS data (8 individual bands) to explore another approach. We tried a Soil-Leaf-Canopy (SLC) model with an inversion approach to prepare Leaf Area Index (LAI) estimates for the rice in the Mekong Delta. The eight-day LAI-imagery that we derived was then translated into daily data for the test sites using an empirical
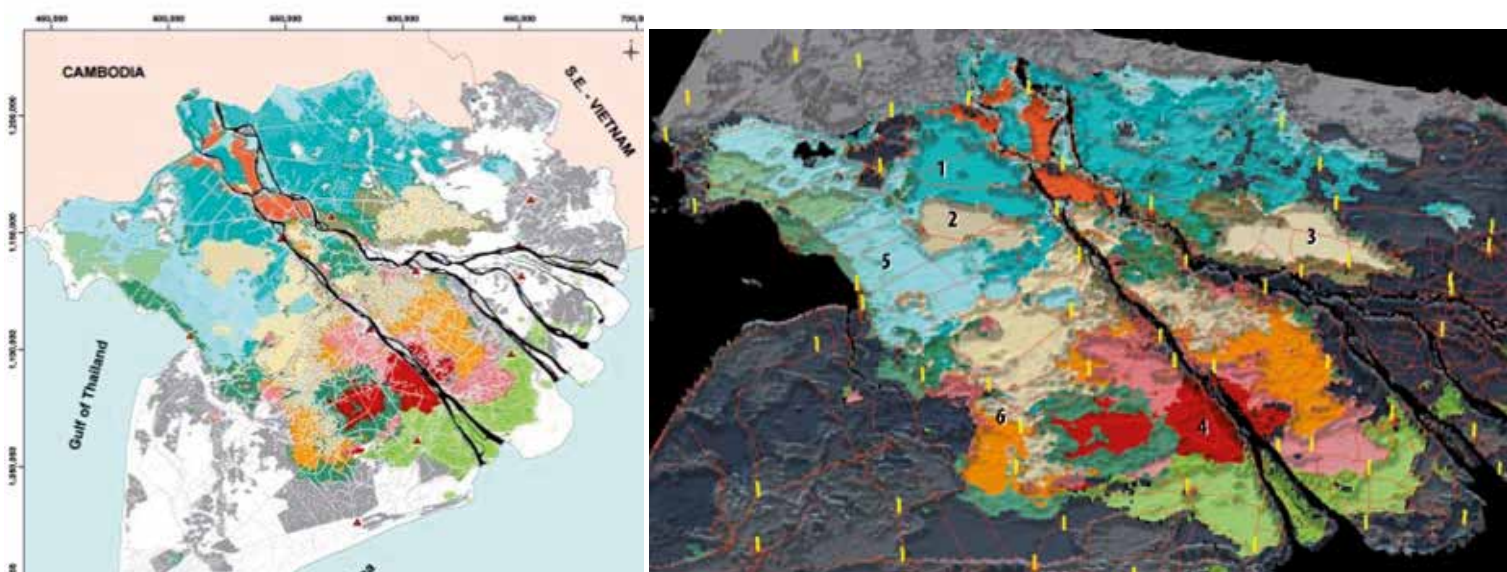

Figure 1 The relative local homogeneity of the landscape and the temporal SPOT imagery proved to work well together in differentiating 26 rice-based cropping systems (in the map, simplified to 10 classes)

We visited 58 sites representing various cropping systems

DR NGUYEN HA graduated earlier this year, obtaining her PhD degree from the Faculty of Geo-Information Science and Earth Observation (ITC). She graduated with her thesis, entitled "Earth observation for rice crop monitoring and yield estimation: application of satellite data and physically based models to the Mekong Delta." Full text: www.itc.nl/library/papers_2013/phd/nguyenha.pdf (Smaling, E.M.A. (Thesis Supervisor), Verhoef, W. (Thesis Supervisor) and de Bie, C.A.J.M. (assistant promotor)

temperature dependent equation. Outliers were automatically smoothed to "normal" during this process. After these two procedures, the remote sensing-derived LAI data correlated very well with the field measurements (see graph). This clearly proves that the readily available MODIS-based LAI estimates were not suitable for rice!

A lengthy process followed to address the last problem. We struggled with questions such as which crop growth simulation model to use, and how to force that model to make real-time adjustments to follow the MODIS-derived LAI data. After all, actual yield estimates were required: not potential or water-limited estimates. Plant nutrients, pests, diseases, saline and acid soils, and poor management all result in yield reductions and losses that should be covered by the sought method "in one go". The model should be capable of generating realistic estimates by the end of a growing season without any need for further adjustments.

The availability of ORYZA2000, an open-source rice crop growth model by the International Rice Research Institute (IRRI) in Los Baños, provided a great opportunity to take the step of coupling the RS data with the model. Series of complete "runs" were made for all sites, but the real battle concerned the fact that the rice varieties grown in the Mekong Delta differed from those used in the original ORYZA2000 model. At this point in time, it was impossible to return to the research stations and collect additional data to calibrate the used crop-specific parameters for three rice varieties. Thus, the "weakest link" of the research was identified! The results indicate a consistently higher simulated yield then was observed (see graph). Nevertheless, the explored method did prove its concept, andthe results were much better than expected: the final R-square for the 58 sites was 83%. This was sufficent to estimate rice yields with a much higher accuracy than ever before and, thus, to improve food security management ∎
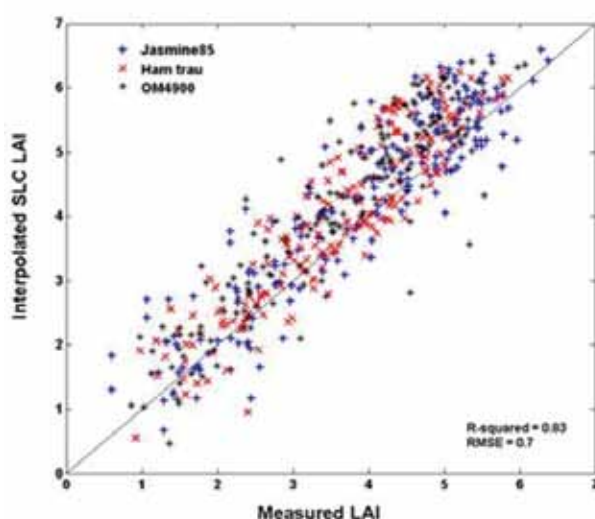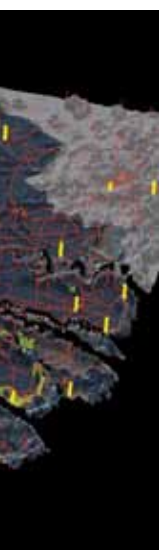
Figure 2 We tried a Soil-Leaf-Canopy (SLC) model with an inversion approach to prepare Leaf Area Index (LAI) estimates for the rice in the Mekong Delta
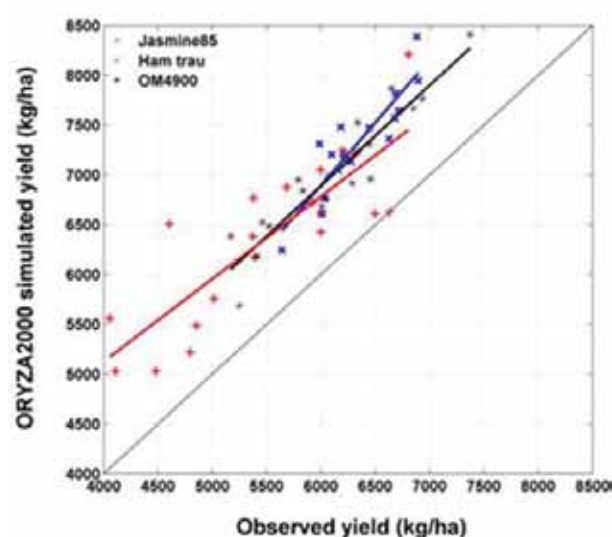
Figure 3 The results indicate a consistently higher simulated yield then was observed

Use of Space and Time to generate Crop-Intensity Maps

Kees de Bie   c.a.j.m.debie@utwente.nl

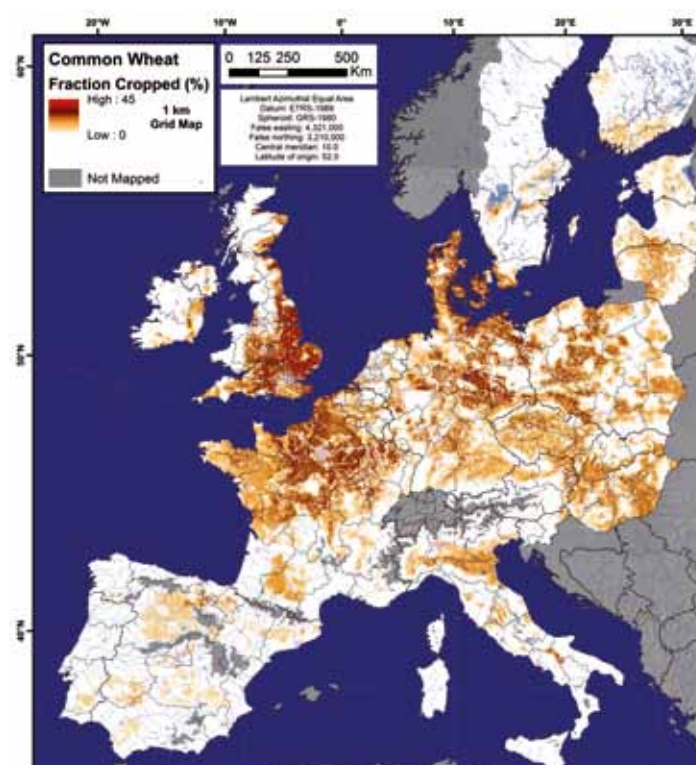Javier Gallego   javier.gallego@jrc.ec.europa.eu

Key information to addressing Food Security issues includes knowledge and products (maps) which concern "what is grown where, and how". The Faculty of Geo-Information Science and Earth Observation (ITC) has explored the use of data-integration techniques to generate that information or to improve upon existing methods of generation.

The method uses published statistics in combination with maps and field survey data and hyper-temporal SPOT-VGT or MODIS-data to represent the greenness of land in space over time. The use of this method delivered crop-intensity maps for various crops. These maps show the fraction of ground surface occupied by a particular crop (%) at 1km resolution. Validation tests showed that we were able to produce highly accurate maps.
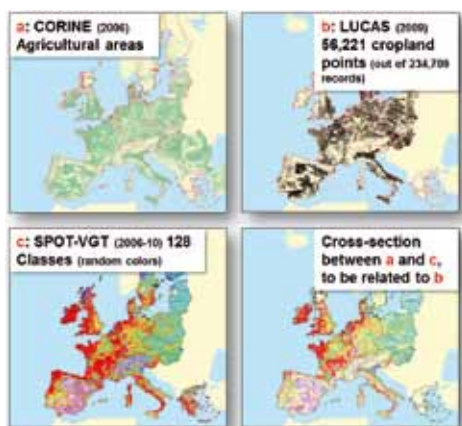
The International Food Production and Research Institute (IFPRI) has recently made excellent progress in crop mapping for sub-Saharan Africa. IFRIs Agro-MAPS information system shows crop-specific distribution on a 10km scale and their Spatial Production Allocation Model (SPAM) project has expanded this effort on a global level. At ITC, we are continuing along these lines and trying out the integration of various data types. Satellite data from different scanners, tabular data on crop statistics, and field observations and existing maps are organized and processed with advanced techniques. The remote-sensing images are reduced in size using unsupervised classification logic or fast fourier transforms. This has resulted in promising products.

Let us look at an example. In 2009, the EU launched the LUCAS project and collected about a quarter of a million point-based records on land cover. These data paved the way to generate detailed crop-intensity maps covering the territory of the EU in a systematic and uniform way. Such maps are required to improve, for example, crop monitoring projects or to have benchmarks for future land-use change specifications. They are also indispensable to optimize annual agricultural statistical surveys.

For the required upscaling process, the point data were cross-tabulated with two spatial products: the 2006 Corine land cover map and the results of hyper-temporal NDVI-imagery analysis. The latter was assumed to represent differences in land cover greenness spatially and over time; which correlates in-turn with variability in species phenology, cover density, and the crop calendars being followed. The cross-tabulation exercise of points and maps resulted in 36 crop-specific crop-intensity maps showing the percentage of ground cover that a crop occupies within a 1 x 1 km area. Validation of these maps showed that they are of excellent quality; the combined use of the Corine and hyper-temporal NDVI maps successfully complemented one another as regards spatial and temporal information. Till date, that knowledge is still insufficiently being used to generate the information required for a range of food security instruments ■

The cross-tabulation exercise of points and maps resulted in 36 crop-specific crop-intensity maps showing the percentage of ground cover that a crop occupies within a 1 x 1 km area

The LUCAS project collected about a quarter of a million point-based records on land cover

Add on to GNC4WFS project in Ethiopia

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For the GEONETCast for Water & Food security project in Ethiopia, near real-time satellite data received via GEONETCast are used in the food security early warning process. The different data sets i.e., rainfall, evapotranspiration, soil moisture, vegetation and cover, together with *in-situ station* weather observations and forecasts, are processed using ILWIS Open software technologies and especially GEONETCast data Toolboxes, developed at ITC for this purpose (figure).
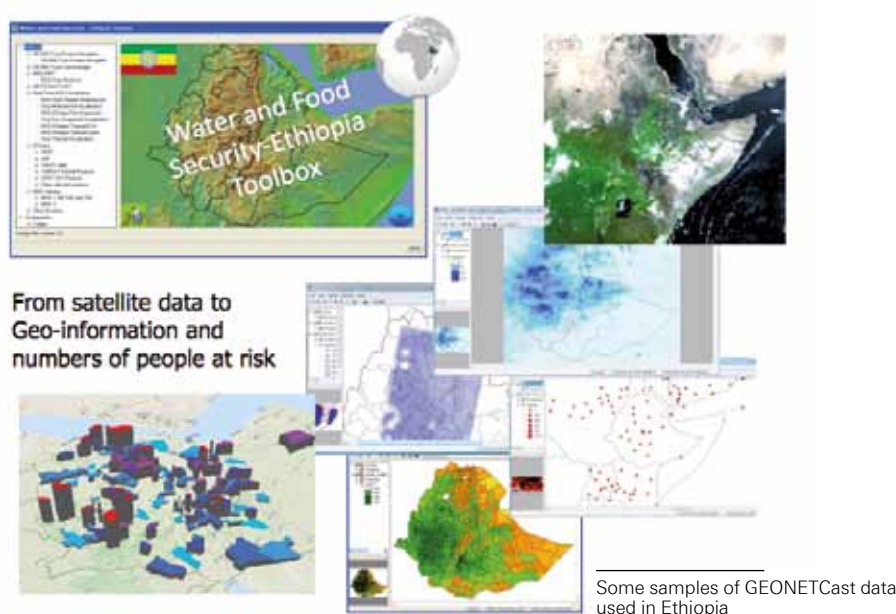
In the project, agricultural drought prediction and risk assessment are achieved using the proven WRSI or water requirement satisfaction index and YR or crop yield reduction concepts. The increased spatial and time resolution which can be achieved with the near real-time GEONET-cast data and technology is one of the main assets of the E-WFS Toolbox (Ethiopia – Water & Food Security Toolbox analysis system).

The information retrieved from earth observation and in-situ data are then directly assimilated into the Livelihood Early Assessment Program or LEAP tool used by the United Nations World Food Pro-gramme. This geospatial analysis tool was especially developed to determine the numbers of people affected by agricultural drought, food shortage and famine in Ethiopia. With the aid and timeliness of the GEONETCast data, this tool now allows for the provision of more accurate estimates of affected populations at risk in the districts, known locally as "woreda", in Ethiopia. Over 900 districts can be individually targeted by the process, permitting a more reliable and geospatially explicit analysis and decision making by the authorities, international agencies and players involved in food security. In the event of a confirmed drought alert and of rural people being affected by acute food shortage and possible famine, the Ethiopian government agencies, together with WFP, can initiate the relief process using mechanisms such as the PSNP (Production Safety Network), among others.

The GNC4WFS project in Ethiopia can be seen as a test bed and use case of earth observation and geospatial technology benefitting societal needs in a large country and region with recurrent food security risk ∎

Some samples of GEONETCast data used in Ethiopia

Income generation through harvesting frankincense
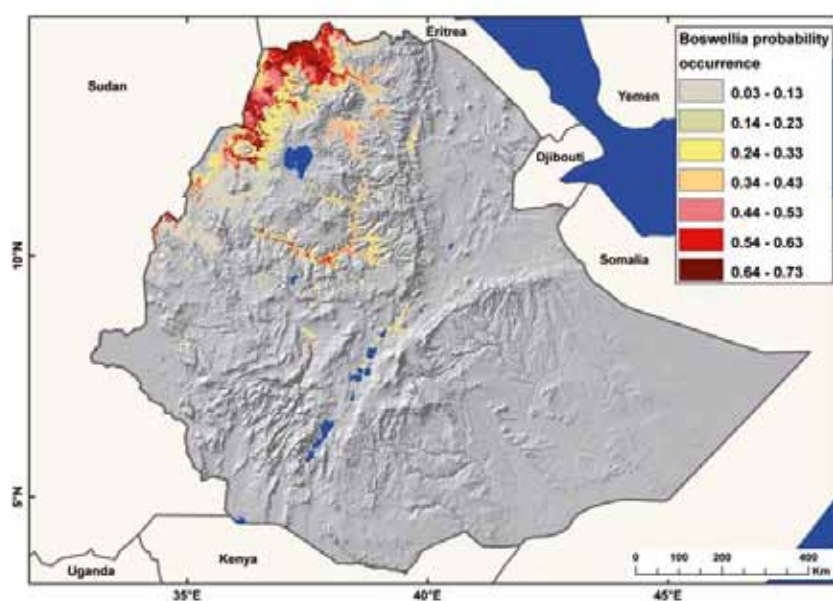
Atkilt Girmay   atkiltgirmagebrekidan@utwente.nl

The dry woodlands of Africa comprise 406 million hectares and are inhabited by 505 million people. They occur in regions that are predominantly inhabited by nomadic pastoralists. The vegetation in the drylands supplys the majority of the fodder requirements for the pastoralists' livestock.

In addition, the dry woodlands are a major source of traditional medicines for treating various human and animal diseases. The economic importance of dryland forests has only recently been recognized. Households earn a significant amount of income from the dryland forests for their livelihoods. The dryland forests also provide the local people with considerable employment opportunities. They contribute significantly to the economies of nations and to food security. The Faculty of Geo-Information Science and Earth Observation (ITC) for its FRaME project (The FRAnkincense, Myrrh and gum Arabic: sustainable use of dry woodland resources in Ethiopia) conducted research in Ethiopia to understand and map the distribution of the frankincense trees, scientifically known as *Boswellia papyrifera*. It is a deciduous tree species that produces the widely-traded aromatic olio-gum resin which is called frankincense or olibanum (see figure). The product is mainly used as incense for burning, for perfumery and in the preparation of several medicines. Moreover, the tree has several uses at the household level, as well as ecological functions. In Ethiopia and Eritrea, it is known to grow well in shallow soils and rocky areas. The production of this tree species fully orginates from natural population stands. Ethiopia is the second largest producer and exporter of natural gums and frankincense to the international market.

B. *papyrifera* has been reported as endangered and of ecological concern. Tree populations are declining at an alarming rate due to overtapping, insect pest attacks, and from the clearing and burning of undergrowth. B. *papyrifera* has a weak regeneration capacity. Despite its importance to Ethiopia and international mar-

Distribution of B. *papyrifera* in Ethiopia. The species has a high (probability of) occurrence in the north and north-western regions of Ethiopia

kets, there is very little information on the vitality, extent of the area and the locations of occurences of B. *papyrifera* tree-populations. Considering this, ITC, as part of its PhD programme, mapped the distribution of the tree species. Accordingly, in Ethiopia the distribution of B. *papyrifera* is estimated to cover 18,000 km^2 (see Map). In Ethiopia, the species is mainly found in dry woodland and wooded grassland located at altitudes (low and mid altitudes) between 950 to 1800 m.a.s.l.. The mapping or discrimination of B. *papyrifera* in Ethiopia has never been easy primarly because it mixes in with other species at sites, because it is deciduous in nature and because it is one of the species which loses its leaves earlier than any other species in the area ■

The frankincense tree, the frankincense, and frankincense burning

Schemes based on satellite data to insure Kenyan pastoralists

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Kees de Bie   c.a.j.m.debie@utwente.nl

Droughts induce livestock losses that severely affect Kenyan pastoralists. Satellite images provide an indication of vegetation conditions, and as such can provide input to new index-based insurance schemes that insure against drought-related risk. The Department of Natural Resources supports the International Livestock Research Institute (ILRI) to effectively use satellite time series for livestock insurance with the aim of obtaining long records of drought indices that can be easily updated.
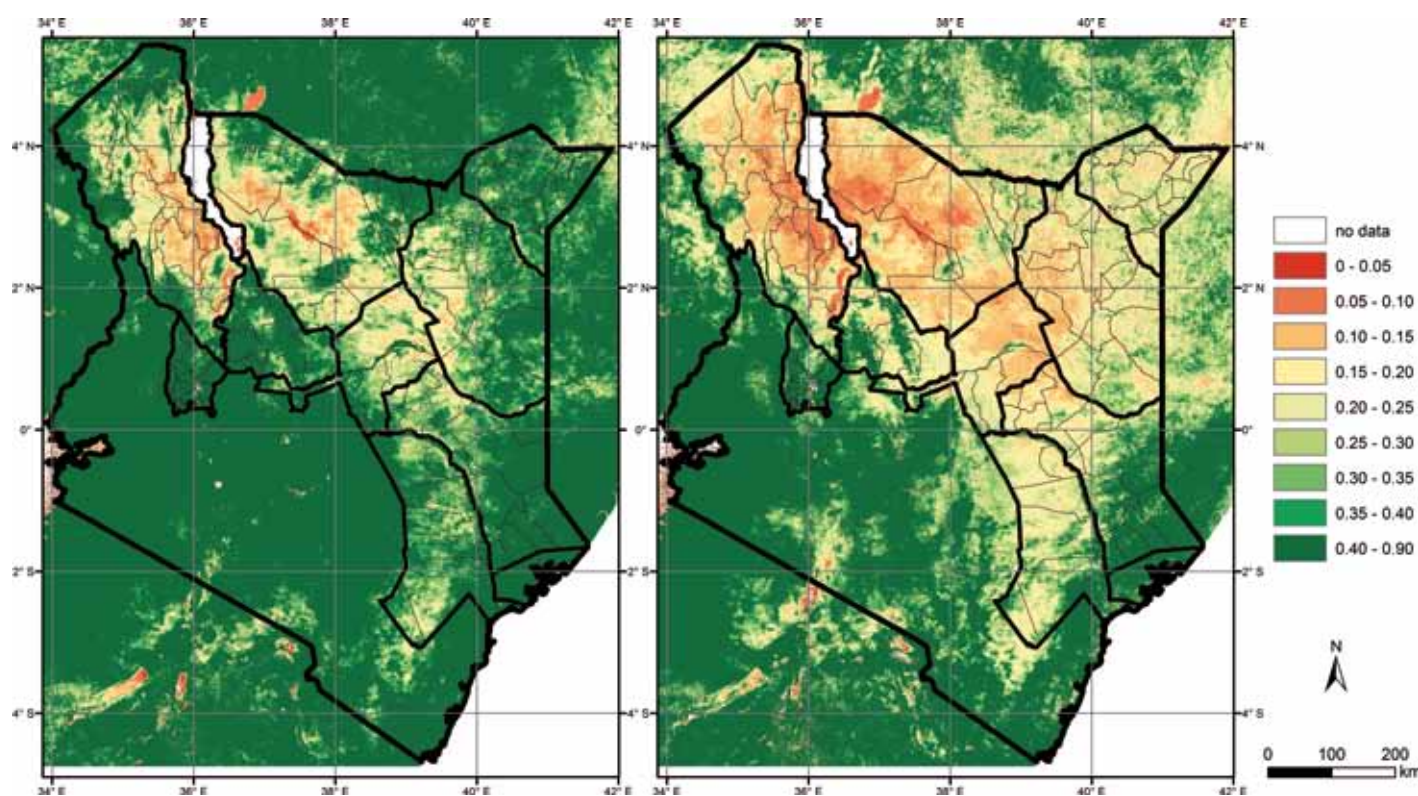
Drought in Kenya and insurance

Coping with drought is a major challenge for pastoralists in the arid and semi-arid regions of Kenya. During dry years, many animals die from the lack of sufficient feed and water, and from drought-related epidemic diseases. Insurance against the risk of livestock mortality may reduce the negative consequences of drought-induced livestock loss, and prevent families from falling into poverty. Traditional insurance requires expensive verification of losses by the insurer. A more cost-effective insurance approach is to base payouts on a transparent and objectively-measured variable, i.e., an index. Recently, index-based insurance has received considerable attention as it makes important contributions to agricultural growth and the reduction of poverty.

Index-based livestock insurance (IBLI)

Since 2011, ILRI and its partners in the public, private, and non-profit sectors have pursued a research agenda aimed at designing, developing and implementing index-based insurance to reduce the impact on pastoralists from drought-related livestock losses. This project is called IBLI (index-based livestock insurance). It has operated for four years in the Marsabit district (northern Kenya) with pastoralists purchasing insurance and receiving payouts. The project aims to cover 60 percent of Kenya's land surface by 2014. Since the start of IBLI, livestock mortality (and the related insurance premiums and payouts) has been estimated using a coarse-resolution time series of the normalized vegetation index (NDVI).

Example of an eMODIS NDVI image of 1-10 May (long rainy season) with relatively good forage availability (2010; left), and with poor forage availability (2011; right)

Water point in Burbisa, Marsabit *(photo courtesy of IBLI)*

Index requirements

One of the main limitations to index-based insurance is the possibility of households experiencing a loss, but no payment; or alternatively, not experiencing a loss, yet receiving a payment. This is referred to as "basis risk" and is caused by the imperfect relationship between the index and the incurred losses. For index-based insurance schemes to be effective, they require an index that:

- has a strong relationship with what is being insured (such as livestock or crop losses);
- is independently verifiable, i.e., based on well-described data sources and processing methods;
- can reliably be delivered into the future (at least for the duration of the insurance contract) and is available in near real-time, so that shortly after losses are incurred, payments can be made;
- is available for sufficiently long records to properly represent the climatic variability for estimating the probability of a payout, and thus accurately pricing the insurance product.

Long operational time series of NDVI

The support provided by the Faculty of Geo-Information Science and Earth Observation (ITC) to the IBLI project consisted of the comparison and intercalibration of

Insurance simulation games in Marsabit *(photo courtesy of IBLI)*

different sources of NDVI time series with the aim of obtaining a long operational record of division-level drought indices for Kenya. Recently, NASA produced a new 30-year (1981-2011) time series based on the Advanced Very High Resolution Radiometer (AVHRR) at 8km resolution. However, this dataset is not frequently updated. We identified the different options to successfully combine the AVHRR-derived division-level drought indices with other operational NDVI datasets based on data from MODIS and SPOT-VEGETATION. We showed that the availability of a longer

index series significantly impacts the calculated insurance premium. Besides ITC and ILRI, the European Commission's Joint Research Centre and Cornell University contributed to this study. A paper describing the details of the study has recently been submitted ∎

EVENTS

SEMA workshop "(Dis)connecting people and water"

Anne Wesselink   a.j.wesselink@utwente.nl

The NWO-Wotro funded SEMA project "Sensors, Empowerment, and Accountability" (2012-2016) is conducting cutting-edge research on the use of mobile phone and geoweb technologies for government accountability and citizen empowerment in Tanzania. Prof Yola Georgiadou, professor in Geo-information for Governance on the Faculty of Geo-Information Science and Earth Observation (ITC) of the University of Twente, is joint project leader.

Few research teams are active in this field and empirical evidence on the effectiveness of these technologies is scarce. At the same time, the hype around the potential of these technologies for empowerment and accountability is soaring and dozens of development practitioners and NGOs are implementing mobile messaging systems in the South. At the start of the second round of fieldwork, which took place in close collaboration with SNV Tanzania, these research teams met at ITC, together with development practitioners, to exchange their research findings and experiences.

The meeting was organised around three key questions:
1. Empowerment (S**EM**A): How do citizens gather water? How, when and why could reporting by mobile phone help them?
2. Accountability (SEM**A**): How do government agencies ensure water supply to citizens? How, when and why could reporting by mobile phone help them?
3. Sensors (**S**EMA): What should a messaging system look like in view of the above findings and other functionality considerations? Which domain concepts and their relationships should be identified for such a system to function properly?

We concluded by formulating five challenges for a hackathon which is due to take place in Dar es Salaam on 26-27 October 2013 ◼

The research teams met at ITC, together with development practitioners, to exchange their research findings and experiences

GIMA, 10 years celebration

Lyande Eelderink   l.eelderink@utwente.nl

Since 2003, Delft Technical University, Utrecht University, Wageningen University and the Faculty of Geo-Information Science and Earth Observation (ITC) of the University of Twente have been jointly teaching the GIMA MSc programme. In addition to offering the use of advanced GIS technologies, the Geographical Information Management and Applications (GIMA) programme covers the management of geoinformation and spatial data infrastructures in organizations and management styles.

The GIMA MSc programme may be followed on a full-time (2 years) or part-time basis (4 years), in a "blended learning programme" (a combination of distance learning and contact hours). Since GIMA is predominantly a distance-learning programme, extensive use is made of various ICT media. In addition, the programme requires several short periods of intensive classroom attendance.

GIMA Jubilee
On 2 September 2013, 10 years of existence for the GIMA MSc programme was celebrated at ITC.

The day started with an outdoor mapping event. Together with ITC staff members, former and current GIMA students mapped points of interest in the city centre of Enschede. These points of interest were shared on the web.

After a networking lunch; Professor Ottens, emeritus professor of the University of Utrecht, opened the celebration by sketching for people the early days of the GIMA programme. After a presentation on the GIMA statistics over the past 10 years by the current GIMA chair, Professor Menno-Jan Kraak, a presentation on the "Develop-

ments in GIScience and implications on education" was given by Professor Weibel of the University of Zürich.

Two former GIMA students, Marije Louwsma and Rob de Wolff, shared their GIMA experiences with us.

Last but not least Ed Parsons (Google) presented the current trends in geoinformatics according to Google.

The GIMA Jubilee Day was concluded with drinks in the Annex of the ITC Restaurant ∎

Professor Ottens, emeritus professor of the University of Utrecht, opened the celebration

GIMA experiences of alumni

Participants mapped points of interest in the city centre of Enschede

Ed Parsons of Google

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Education and Culture

Erasmus Mundus   MSc programme in Geo-information Science and Earth Observation for Environmental Modelling and Management

ANNOUNCEMENT

Programme Director retires during GIMA jubilee

Corné van Elzakker   c.vanelzakker@utwente.nl

In the spring of this year, Dr Connie Blok had a surprise in store for her colleagues in the Department of Geo-Information Processing of the Faculty ITC of the University of Twente. She informed us, as well as her students and colleagues in Geoinformatics, GIMA and the International Cartographic Association (ICA), that she would be taking early retirement. Because of her many remaining holidays, she actually left her workplace before we had become accustomed to the idea and we said farewell to her at an informal reception on 2 September 2013.

However, to the last, Connie remains the trustworthy and dedicated colleague she has always been: even though she is de facto retired now, she is still providing materials and transmitting her experiences to some of us and to some of her students, and she still coordinates and organizes the required input for the formal visitation (in October 2013) of the GIMA MSc programme, of which she was the Programme Director.

Connie Blok was originally drawn to education: she wanted to be a geography teacher and obtained all the qualifications for that. But after a short while, she became more interested in research and cartography and completed her Master studies in Geography with cartography as her main subject at Utrecht University. She started working in 1986 in the then Cartography Department of ITC and performed a variety of tasks for education, the management of education, and research and advisory services.

Within The Netherlands, but outside ITC, she also played an important role in fostering knowledge exchange between academic and professional cartographers. She was, for instance, editor of the Dutch cartographic journal, the *Kartografisch Tijdschrift,* which no longer exists.

In her research, she focused on methods and tools to visualize the dynamic aspects of geographic data and on the related user cognition. She obtained her PhD in 2005 with a dissertation entitled: *Dynamic visualization variables in animations to support the monitoring of spatial phenomena.* Not only inside (through education and supervision), but also outside ITC, she shared her knowledge about these aspects with many colleagues all over the world. This was done mainly through activities at ICA conferences and in ICA commissions where she was regarded as one of the leading authorities in the field of (the cognitive aspects of) dynamic geovisualization.

At the end of her career she had come full circle and returned to education, i.e. the management of education. She not only became GIMA's Programme Director, but, at the same time, Course Director of all Geoinformatics programmes at ITC. However, after doing this for a couple of years, she decided to enter a new and now more important stage of life in which she could (literally) be closer to, and spend more time with, her family. Connie really deserves to enjoy her retirement, but we will miss her for a long time to come ■

Dr Connie Blok

Visits

Visit from Land Information New Zealand

John Horn   j.a.horn@utwente.nl

On Friday 6 September, the Faculty of Geo-Information Science and Earth Observation (ITC) was delighted to welcome a delegation from Land Information New Zealand (LINZ) for discussions on modern issues in land mapping.

The delegation consisted of Mr Graeme Blick, chief Geodesist and Manager of the National Topographic Office, and Mrs Jan Pierce, Customer Services Group General Manager.

The visit was part of a wider European visit LINZ was making following the International Cartographic Conference in Dresden the preceding week.

After an initial welcome by Mrs Erna Leurink, ITC's Managing Director, and a brief overview of ITC's history and current activities by John Horn, the delegation had the opportunity to discuss matters of mutual interest with senior staff of the Earth Observation Science (EOS), Geo-information Processing (GIP) and Urban and Regional Planning and Geo-Information Management (PGM) departments.

Like many national agencies around the world, LINZ is keen to embrace modern technology to assist in its ongoing tasks, and is also seeking optimal training solutions for its staff in such technologies and practices.

It was no coincidence that the LINZ visit took place in this period, as one of its staff, Miss Charlotte Dawson, is currently completing her studies in Geoinformatics at ITC, and the visitors were interested to hear of her experiences during the programme of the work she had carried out in her final project.

Charlotte is in fact studying at ITC on a fellowship established by LINZ, in memory of two former colleagues and ITC alumni: Geoff Howard and Robin Pickering.

Since the earliest days of its existence, over 50 New Zealanders have studied at ITC, many of them from LINZ. Following this recent visit, ITC sincerely hopes that many more "Kiwis" will find their way to ITC in the future ■

John Horn, Charlotte Dawson (currently studying at ITC), Jan Pierce, Graeme Blick

Greetings from…

NAME:

Rohan Bennet

JOB DESCRIPTION:

Assistent professor of the

department of Urban and

Regional planning and

Geo-information management

ACTIVITIES:

A training session on the

Social Tenure Domain Model

in Malaysia

After spending a week with our wonderful ITC alumni and staff, and colleagues at the Vietnamese National University of Science in Hanoi, for the highly productive Nuffic refresher course: "One stop e-governmenwt for sustainable land administration", (coordinated by Dr Arbind Tuladhar), I am heading down to Kuala Lumpur, Malaysia to help deliver a training session on STDM (the Social Tenure Domain Model).

STDM is intended as a flexible open-source software tool for supporting land administration activities in local communities. ITC played a significant role in the development of the tool a few years back, and is now actively assisting in its dissemination along with UN-HABITAT, FIG (International Federation of Surveyors), the GLTN (Global Land Tool Network), and others.

The event will be held on 23September 2013 and purposefully coincides with the 5th International Workshop on LADM and ISG2013. The local branch of FIG's Young Surveyors Network, along with ITC alumni Prof Alias Abdul Rahman (University of Technology Malaysia), are responsible for the organization of the event. As expected, preparations are running very smoothly. Around 35 participants will attend from across Malaysia, with a representative from the Philippines also to be present. Organizations to be represented include: UTM; the Department of Survey and Mapping Malaysia (JUPEM); the Association of Authorised Surveyors Malaysia (PEJUTA); ITC; Delft Technical University; and Kadaster.

John Gitau (UN-Habitat) will introduce the philosophy underpinning the software. He will also demonstrate its functionality in a workshop. The participants will follow along on their own laptops using the freshly installed STDM software. They will also receive documentation to take home with them. Along with Dr Chrit Lemmen (Kadaster International) and Ms Eva-Maria Unger, I will assist the participants in completing the activities. We will also hold a discussion at the completion of the training session. The aim is to get feedback for further improvements to the software. We are expecting most participants to see the potential utility of the software in underrepresented contexts; however, given the highly developed nature of Malaysia's existing land information systems, it is likely that issues of scalability and compatibility issues will be raised. The current FIG president, Mr Teo CheeHai, a strong advocate of STDM and a Malaysian national, will close out the day with a presentation on the broader context of STDM and present all participants with certificates.

LIFE AFTER ITC

Remediation design for the groundwater damage in Kuwait due to the 1991 Iraqi invasion

Yohannes Yihdego Woldeyohannes   yihdego06723@alumni.itc.nl

Groundwater is a precious commodity everywhere in the world, particularly in countries like Kuwait, which is characterized by extremely arid conditions. Kuwait is among the oil producing nations. Additionally, Kuwait is the only nation with no surface water. The only secured freshwater resources are the fresh groundwater lenses that occur in the Al-Raudhatain and Umm Al-Aish depressions of northern Kuwait. The importance of these lenses as the country's only secured freshwater reserve, and its fragile stability, call for thorough management schemes for its utilization.

The Iraqi invasion of Kuwait in 1990 left an indelible mark on Kuwait's air, water and soil. The magnitude of the pollution problem in Kuwait due to this incident is unparalleled in the history of mankind. Consequently, no comparisons can be made and no conclusions can be derived from similar experiences elsewhere. The Gulf War of 1991 resulted in the detonation of 798 out of 914 operational oil wells in Kuwait. The total oil burnt due to oil wells being set on fire was about 240 x 106 m3. The byproducts of combustion were spread over an area of about 1,722km^2, representing about 10% of the total area of Kuwait. The total oil spilled as a result of the damaged wells was about 3.5 x 106 m^3. The spilled oil was collected in 300 oil lakes, spread out over an area of about 49 km^2. As a consequence of their close proximity to the oil fields, the fresh groundwater lenses have been directly affected by the damage caused from the destruction of oil wells during the Gulf War of 1991 and the sea water used to control and extinguish the oil fires. Snowy Mountains Engineering Corporation (SMEC) was awarded the assignment to assess remediation options which was funded by the United Nations Compensation Commission (UNCC).

The scope of the study encompasses data assessment, information review and modelling, and has been carried out to (i) assess the actual and likely impacts on groundwater, (ii) the extension of impacts in groundwater in the years since the invasion and subsequently, and (iii) to assess the design and effectiveness of remediation for the groundwater. The study also involved conducting laboratory tests to remediate the polluted groundwater as

Dr Yohannes Yihdego received an Australian National Award of the Year 2013 as one of the most influential African-Australians

DR YOHANNES YIHDEGO received an Australian National Award of the Year 2013 as one of the most influential African-Australians. Dr Yohannes Yihdego is one of the leading figures in the International Engineering Corporation (SMEC), where he is a senior Hydrogeologist/Modeller. SMEC has more than 70 offices across the globe. He has been working on many national and international high-level engineering projects in the fields of water, mining, infrastructure and energy in countries such as Australia, Mongolia, Saudi Arabia, Kuwait and Tanzania.

effectiveness and timeframes for clean-up. Simulations suggested that withdrawal of groundwater from approximately 40 extraction (and injection) wells in both Raudhatain and Umm Al-Aish at rates of 110-200 m3/day for 40 years would significantly reduce TDS and TPH concentrations in the aquifers. In addition, it was concluded that flushing of the vadose zone with additional water was required to shorten remediation timeframes, and to avoid pumping for in excess of 80 years. Alternative methods for treatment of groundwater have been assessed to provide water suitable for drinking and re-injection into the aquifers.

Remediation efforts for the Raudhatain and Umm Al-Aish areas consider removal of both hydrocarbons and salt derived from seawater. Pump & Treat (followed by re-injection of treated water) is the first option under consideration, including the use of aeration and activated carbon, followed by reverse osmosis. Natural or assisted bioremediation may also be a remediation alternative. The total estimated costs are approx. US$ 238 million. These cost estimates indicate a treatment process involving carbon adsorption to remove petroleum hydrocarbons, ofollowed by reverse osmosis to remove salt ◼

well as suggestions regarding the required on-site remediation techniques. My role was to review existing groundwater monitoring data, develop numerical modelling simulations of remediation options and to provide training for local staff to apply the model. This study was funded by the United Nation (UN) Compensation Commission. A 3-D numerical model has been developed to simulate the flow and transport of the hydrocarbon pollutants in the groundwater of the study area.

The study results suggest that the groundwater in the Umm Al-Aish area has been significantly affected by the hydrocarbon pollutants and it has been predicted that these pollutants will move towards the Al-Raudhatain area if no preventive and/or remedial measures are taken in the near future.

Dissolved hydrocarbon (TPH) was predicted to increase to a maximum concentration of 6 mg/L and to remain at high concentrations for 15-20 years. Simulations for TDS and TPH predicted groundwater plumes up to 1km in longitudinal extent, with plumes covering up to 860 ha of Umm Al-Aish and 1,170 ha of Raudhatain, after 20 years. Nearly 25% of the fresh water bodies were predicted to be contaminated within the first 20 years after the oil spills.

Based on the findings of the study, a number of steps were suggested in order to reduce the risk of further groundwater deterioration in that area. Remediation scenarios were reviewed and pump-and-treat options were simulated to assess

"Once again, I would like to thank you all for your marvelous support you provided us to complete our study adequately and personally to reach at this level with full of success stories, because the courses we participated in allowed us to acquire solid understanding on the subject matter mainly in the numerical modelling and become very competitive across the globe."

ITC