ITC FACULTY OF GEO-INFORMATION SCIENCE
AND EARTH OBSERVATION

SPACE FOR GLOBAL DEVELOPMENT
ITC'S 2021 RESEARCH STRATEGY EVALUATION

READY FOR SHAPING THE FUTURE

UNIVERSITY OF TWENTE. | ITC

COLOPHON

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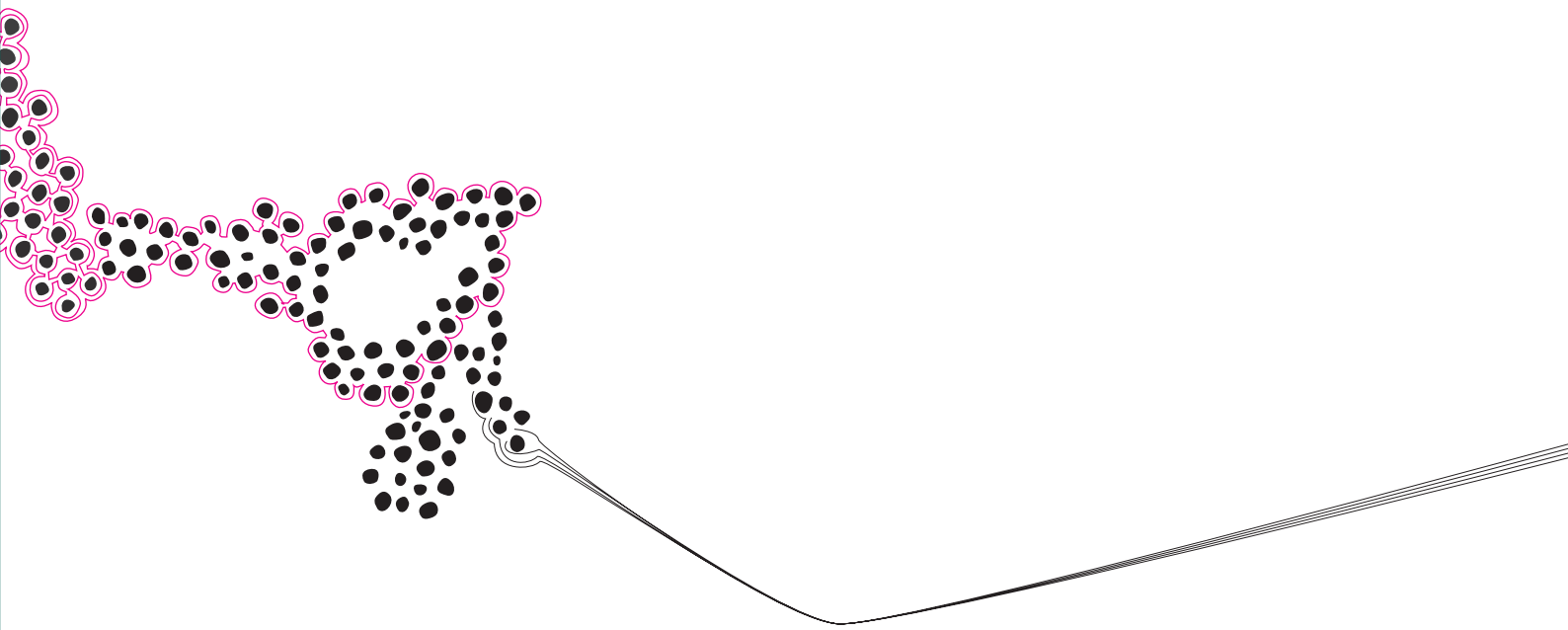
ABSTRACT

This document presents the self-reflection of the research strategy of the faculty of Geo-Information Science and Earth Observation (ITC) of the University of Twente. It has as its background the Strategy Evaluation Protocol (SEP) 2021-2027. The first four chapters contain a summary of achievements over the last seven years. Chapter 5 provides our vision of the way towards the future. Our message is that the faculty is ready and well-positioned to address future challenges in geo-information science and Earth observation.



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1 INTRODUCTION

We, ITC, are the Faculty of Geo-Information Science and Earth Observation of the University of Twente. Our academic activities focus on understanding and helping to solve real-world problems using geospatial data, methods, and tools. We develop capacity mainly in the majority world, where our activities lead to positive societal impact and contribute to a more sustainable world.

ITC started as the International Training Centre for Aerial Survey in 1950. ITC was established by the national government to assist in developing skills and knowledge for rebuilding *3rd world countries* after the second world war. In 1968, additional emphasis was given to the importance of Earth sciences, with a change of name to the International Institute for Aerial Survey and Earth Sciences. Recognizing the rapid development of satellite-based information, ITC became the International Institute for Aerospace Survey and Earth Sciences in 1985, and the International Institute for Geo-information Science and Earth Sciences in 2002 to acknowledge developments in the field of Geo-Information Science. With this technical background, the integration with the University of Twente in 2010 was a natural one. ITC became a faculty of the university and adopted its current name *Faculty of Geo-Information Science and Earth Observation (ITC).*

ITC offers a plethora of academic, educational, and research activities, while maintaining its international reputation and unique capacity development mandate. The research, education, and institutional strengthening[ii] processes each have their own merits and interaction (Figure 1).

Within ITC, research, education, and institutional strengthening activities are led by six scientific departments, each focusing on a different research theme. Two departments are technology-oriented (Earth Observation Science - EOS and Geo-Information Processing - GIP), while four are application domain-oriented (Earth Systems Analysis - ESA, Urban and Regional Planning and Geo-Information Management - PGM, Natural Resources - NRS and, Water Resources - WRS). All departments have a common focus on use of geo-information and EO data, methods, and tools. Faculty level research support consists of the portfolio holder for research, the research coordinator, the research support coordinator, and a management assistant. Since 2010, research themes have been organized around the individual departments, where professors (and since 2018 senior associate professors) have the *ius promovendi.* Whilst each scientific department has its own research theme, areas of complementary expertise have developed over time, with the benefit of strengthening our research program and identifying new multidisciplinary topics. Consequently, our faculty has grown in international recognition and impact. We are convinced that our faculty will continue to address societally relevant challenges that improve people's well-being and increase the sustainability of our planet.

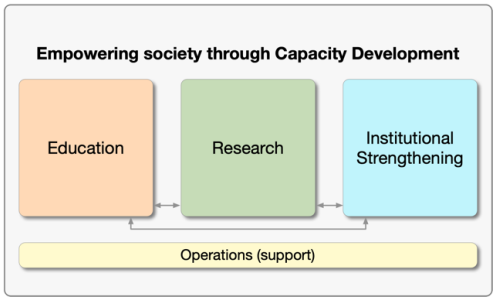


Figure 1 ITC's academic structure.

Reading guide
Chapters 2, 3 and 4 reflect upon our achievements between 2014 and 2020. Chapter 5 presents our ambitions. Important in this respect is that the research aim and vision were substantially revised in 2020 and aligned with developments around us and our expertise.

2 MISSION, STRATEGIC AIMS, AND STRATEGY OF THE PAST SIX YEARS

2.1 THE STRATEGIC AIMS AND STRATEGY OF THE PAST SIX YEARS

Following the previous SEP research assessment, our aim from 2014–2020 has been to enhance our standing as an internationally recognized knowledge hub in the spatial domain, renowned for its collaborative educational and research activities, particularly in the majority world. Our vision during this period was that current global challenges all relate to sustainable development. Local development issues are often attributed to wicked problems such as climate and global change while, in reality, they are caused by a multitude of local and regional interactions within the complex human environmental system. It requires a spatially explicit approach to unravel this local and regional complexity and that is why ITC worked on *Space for Global Development*. Under this motto, we aimed to serve society by providing and developing relevant geospatial data, methods, and tools to facilitate sustainable development. This can be effective only when we base our activities on the societal demands and needs of the majority world. We incorporated the needs and demands of (potential) users in majority world countries in our research and institutional strengthening projects, and we embodied a set of core values - *focused on society, driven by synergy, entrepreneurship, and an international nature.* These core values have formed the basis for our strategy for the last seven years with its four main research aims.

1 Become a pro-active player in international agenda setting. To become a pro-active player in international agenda setting, we focused our network more on specific organizations that fit our vision. To maintain and strengthen our profile, we have continued our cutting-edge research, disseminated our results through academic publications at the highest level, become more visible in public media and have increased our internet and social media presence. We have supported staff and students to attend and organize scientific conferences and international events such as the World Urban Forum and encouraged their participation in policy networks.

2 Start research-based start-up companies. Our alumni are key members of our community. We consider our alumni to be proud ambassadors and preferred partners in many projects. We have given our alumni network a central place in achieving our mission and goals; our support and collaboration with alumni directly contribute to our four core values listed above. For instance, we have stimulated and supported the development of spin-off companies in particular in the majority world, by offering network facilities and partnerships.

3 Further diversify funding sources and act international. We consider diversification of funding sources essential for a sound financial situation. Before merging with the UT, funding was largely provided by the Netherlands Development Program, whereas potential funding opportunities existed with the Dutch Ministry of Education, Culture and Science and (inter)national research programs. Our aim was to become less dependent upon a single source of funding for our research activities. This diversification is reflected in the source of funding for all areas of research: projects in general, PhD studies, postdoc projects, staff composition and research visitors. The strategy to diversify funding has been to increase our focus on H2020 and NWO projects, while keeping an open view towards national scholarships. In Chapters 4 and 5 we will come back to this. We further aimed to increase funding through individual grants.

4 Fill knowledge gaps and align with other valid policy guidelines. In the reporting period, we have identified knowledge gaps where the use and application of geo-information and EO data, methods and tools is pivotal for problem solving. These are cutting-edge challenges at different scales (local, regional, global) with a global impact: disaster management, food security, geo-health, governance, smart cities, and water management. These challenges require innovative, multidisciplinary approaches where the use of geo-information can make the difference. They make good use of rapidly developing technology such as big geodata, open science, and citizen science in the geospatial domain. Our rationale was that geospatial research for capacity development can sustainably contribute to the long-term resilience of people, our planet, and profit. To address the knowledge gaps, our strategy was to actively recruit new professors as research theme leaders by defining new research directions for positions that became vacant because of retirements, such as urban infrastructure and food security. In addition, we aimed to establish part-time chairs with highly visible national and international institutes and to align with policy agendas. We further aimed at identifying Tenure Track (TT) positions in line with known knowledge gaps. Our annual and domain plans were the main instruments to evaluate our progress in aligning our human resource policy with these knowledge fields and in adapting our strategies to achieve our main goals. Domain plans were updated frequently, in line with strategic discussions that were held in the scientific departments and the Academic Board.

In 2014, our program was aligned with the three Dutch government priorities outlined in the policy note *A World to Gain:* alleviating poverty, having sustainable and inclusive growth across the globe, and supporting successful business for Dutch companies abroad. In 2017, it was aligned with the 2030 Agenda for Sustainable Development embodied in the United Nations Sustainable Development Goals (SDGs) [iii]. Discussing our position, we found that our strengths are particularly relevant to SDG 2 (Zero hunger), based upon our research on natural resources; SDG 6 (Clean water and sanitation), based upon our research on water resources; SDG 11 (Sustainable cities and communities), based upon research on deprived urban settlements; SDG13 (Climate action), based upon research on hazards and risks; and SDG 15 (Life on land), based upon our ecological research – see Annex B. We also aligned our research with several specific agendas of the United Nations [iv,v,vi], the European Commission[vii], and the agendas of national[viii] and international [ix,x] space agencies. Because of our location in Twente and the Netherlands, we aligned with regional issues on, for instance, drought in Overijssel, and we continued our involvement with the Kadaster in Apeldoorn and with the region of Zwolle. We will come back to these aspects in Chapters 4 and 5.

2.2 PHD POLICY AND TRAINING

PhD candidates are pivotal to our research. Traditionally, many join our research program with a scholarship, such as from the Chinese Scholarship Council (CSC) or from Nuffic, or external/own funding. Since ITC integrated with the University of Twente, more emphasis has been given to appoint PhD candidates to contribute to research projects, funded by 1st, 2nd, and 3rd money streams. We have aligned PhD topics with our research themes, offered the necessary training in generic and research project-specific expertise and skills, offered staff training to supervise PhD candidates and encouraged student-led activities that enhance the intellectual and scientific aspects of student life.

Our PhD program is coordinated by the Twente Graduate School (TGS)[xi], which includes training and education of PhD candidates. Meanwhile, we have maintained our membership of the National Research School SENSE[xii] as it provides additional training opportunities and a useful network and discussion platform with related research institutes.

We further established our PhD ITC Community (pITCom) in 2017 with the aim to organize research activities and social events in line with interests among the PhD candidates.

2.3 OPEN SCIENCE

In the past six years, our open science activities largely focused on open access publishing, pushing towards open data and code, while in the years to come, we will focus on the wider range of open science principles (Chapter 5). Our goal in open access publishing has been to achieve direct links between our research and the needs of science and society. We concentrated on a) having data from operational EO missions freely available; b) using data to create fit-for-purpose solutions; and/or c) to make data available in a privatized, or business-model format. Our ambition has been to establish research practices that are as transparent and open as possible to increase the credibility and accountability of our research and to accelerate scientific discovery. In 2016, we sharpened our Research Data Management (RDM) strategy and developed a step-by-step protocol following standards of the NWO to archive research data. Agreements with the Data Archiving and Networked Services (DANS)[xiii] were realized and DANS Easy[xiv] became the default trusted data repository at our faculty. Since 2018 this protocol is applicable to all staff and PhD candidates.

To further increase awareness and adjust our way of working, developments in Open Access (OA) were frequently discussed at the faculty level and with ITC researchers, for instance, at the well-attended session on Plan S[xv] which took place in 2019. Departments were asked to budget for OA publication fees and make use of funds provided by ITC and UT to further promote OA publication. Chapter 5 will highlight our aims to further make progress in Open Science.

2.4 ACADEMIC CULTURE

Our strategy in the past six years was to shape an inclusive, collaborative, and ethically aware academic culture around our research, where institutional strengthening and participatory approaches are an integral part of our way of working. The involvement of local partners and stakeholders in our research activities, and our alignment of research with education are key to this ambition.

Strategies to create an inclusive and collaborative academic culture consist of developing grant proposals with local partners and stakeholders, and encouraging collaborations and joint PhD supervision across disciplines, departments, faculties, and partners organizations. They build on the complementarity of partners and researchers, like for example, joint doctorate degrees with Macquarie University (Australia). Interaction with institutional strengthening serves as the main source of inspiration, being most important for having impact. Relations with education occur through the MSc supervision, and incorporating research findings into elective modules and updates of the educational program.

A specific strategy was to support obtaining individual grants. To do so, we established a grant proposal development procedure that covers approximately six months, with detailed steps. After an applicant launches an idea, a support team of ITC experts provides feedback on this idea in several feedback sessions, also involving an external expert.

The strategy to increase awareness of ethical and research integrity issues within our Geo-Community has institutional, human resource, and information dimensions. In 2019, the UT established its House of Integrity[xvii] integrating scientific, social, and business integrity. We have invested in a social and technical research support infrastructure for research ethics, integrity, and data policy, by appointing a research

support officer, creating awareness, and developing workflows and tools. We aim to pro-actively assist researchers at all academic levels and for all types of projects. To give it its necessary attention we organized faculty wide events and included research integrity components in PhD and MSc training[xv]. We also created a TT position in critical geodata studies and geodata ethics to further develop these scientific fields.

2.5 HUMAN RESOURCES

In human resources we considered diversity aspects like age, gender, ethnic, and cultural backgrounds in our progress towards a more balanced staff composition. We are specifically aiming to diversify our staff, by increasing both the number of young and female staff, and their presence in senior positions. Our strategy aimed at an adaptive recruitment aligned with the changing dynamics of our knowledge fields and academic culture. For this purpose, we strategically filled knowledge gaps and vacant positions using the TT system, the UT Twist initiative creating female TT positions and Educational chairs. We established our own TT program in 2008 that was aligned with the UT TT program in 2010, and is valid to date. Our program has invested in young talents by offering opportunities for personal profile strengthening, conference attendance, and high-level committee interactions with external domain experts. We also focused on talent development for all staff through the University Functioning (UFO[xviii]) system. Our strategies also included the organization of social, information, and scientific events that are particularly aimed at the multicultural integration of new and present staff.

2.6 INVESTMENTS

Given the source of our still significant base funding, we aimed our strategic activities mainly at countries in the majority world. Nevertheless, we strived to become less dependent upon base funding and we have made several major investments to strengthen our domain and knowledge field.

- We initiated the *Ingenuity* fund that invests in staff projects and student acquisition to generate more revenue. This fund should strengthen our financial position, for instance to support our move to the campus in 2022.

- We invested in our GeoScience lab to maintain and expand its facilities by upgrading the spectroscopy lab and modernizing the geochemistry, added a visualization lab to the pool of labs and we invested in field labs in, for example, Kenya. A more strategic position for the lab was defined, integrating different smaller labs, and a new head of laboratory position has been appointed.

- We became a member of the Digital Society Institute of the UT, which is particularly relevant to our big data and open science ambitions.

- We established a laboratory on big geodata (CRIB) supported by new staff.

- We created a position on the 4TU Resilience theme.

- We provided start-up packages (PhD candidate or Postdoc) for starting TT candidates and new chairs.

3 EVIDENCE

In this chapter, we present and explain the indicators of our research goals that we have set since the previous SEP research audit. Our indicators are summarized in Table E1, while in Annex A we provide a full list of indicators and our rationale for using them. Beyond the indicators in the six established categories, we like to highlight indicators focusing on future viability: development of PhD candidates, diversity of research projects, the number of cross-domain collaborations and the enhanced visibility of the ITC Ethics and Integrity portfolio. We present and explain the quantitative evidence of the input of research staff (Annex E, Table E2), Funding (Annex E, Table E3) and PhD candidates (Annex E, Table E4). We also include benchmarking our remote sensing based research with peer research organizations, as well as marks of recognition for research quality and societal relevance.

3.1 RESEARCH STAFF

Table E2 (Annex E) shows the input of research staff, in terms of their number and FTEs, while an overview of staff composition is given in Annex C. The FTEs are based upon the assumption that staff spend approximately 30% of their time on research, a ratio that was also used in previous evaluations, and was verified with our time registration system TAS. Our staff time allocated to research has remained relatively stable during this reporting period: the average time spent was equal to 169.4 FTE/yr. The number of PhD candidates employed by the faculty reached a stable number of around 50; the number of PhD candidates with a scholarship, however, has decreased from 141 on 01-01-2014 to 119 on 31-12-2020, a reduction that is partly due to the reduction of full scholarships provided by capacity developing organizations such as Nuffic. The number of externally funded PhD candidates remained stable at around 20, whereas the number of postdocs doubled from 17 to 34 (Table E2). Support remained steady at around 2.5% of total research staff. The highly fluctuating number of visiting fellows and academic visitors dipped in 2016 and 2017 for unknown reasons.

3.2 FUNDING

Table E3 (Annex E) shows the funding of our research program. We distinguish base funding, research grants, and contract research (i.e., research financed by external partners). Most of our research projects (Annex D) have both a societal and an educational component, related to our capacity development mandate. Base funding also includes promotion premiums and covers approximately 40% of the total research funding. Annual differences in funding are limited with the highest difference of 7% between 2017–2018. Research grant funding shows low fluctuation since 2015 with the highest percentage in 2018 (18.5%). Contract research contributes around 52% of the research funding; an exception is 2018 with only 35%. Over the period 2014–2020, personnel costs have increased from 85 to 94%, while the material costs reduced from 4 to 3%, partly reflecting the effects of open data. Between 01-01-2014 and 31-12-2020, our research program has attracted 28 projects, with a total budget equal to € 5,766k.

We have maintained our funding diversity from different sources. In addition to a strong contract project portfolio, we placed emphasis on research projects financed by H2020 and NWO. Our research program is strengthened by attracting externally funded PhD candidates with scholarships from national organizations like the China Scholarship Council.

3.3 PHD CANDIDATES

Table E4 (Annex E) shows the length of PhD research trajectories from enrolment until graduation. It also shows the number of discontinued studies. Most candidates defend their PhD thesis within six years, while many sandwich, and external PhDs require more time as they research part-time while combining the PhD research project with work in their home organization. Although this is in line with UT and national averages, there are arguments to improve the efficiency. For instance, the number of discontinued research studies is of a concern, but the time spent by candidates in the research program could be shortened, by further professionalizing supervision and implementing stricter monitoring of PhD candidates. In Chapter 5 we will come back to this. In the reporting period ITC has invested in its research program, by providing start-up packages for TT candidates, strengthening chairs with PhD candidates (or postdocs) and appointing PhD candidates between departments. Also, several departments have made strategic appointments of PhD candidates.

3.4 BIBLIOMETRICS OF OUR PUBLICATIONS

Table F1 (Annex F) shows an overview of our bibliometrics, based on the output stored in our research information system Pure. Our scientific output has increased substantially, measured by the number of publications[xix]. There has been a steady increase in the number of refereed articles, and a decrease in the number of published books and book chapter. The number of conference papers and professional publications show more fluctuation, the former being most likely coupled to conferences being organized in a particular year. The number of PhD theses increased until 2019. The sudden drop in 2020 may partly be related to the impact of Covid-19. High numbers for 2014 and 2018/2019 may also point to a cyclic pattern, where new candidates are attracted upon completion of finishing candidates, inevitably leading to another peak in two to four years' time from now.

A word cloud of the top 50 key phrases based on 2496 publications is shown in Figure 2. It puts remote sensing as central, including synthetic aperture, lidar and unmanned aerial vehicle (UAV) and is encircled by landslides, land, slums, and informal settlements.

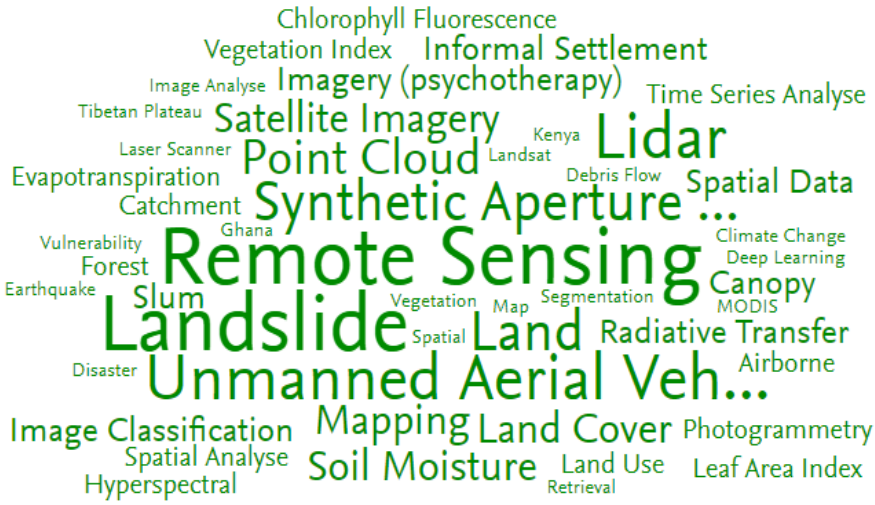


Figure 2. Wordcloud of 50 key phrases in ITC's 2014-2020 publications.

The bibliometrics further show that we publish as first authors and co-authors in top-journals Nature and more recently in The Lancet, and in well established journals in various domains. Co-authors come from around the globe (Figure 3). Our papers are cited widely, resulting in 467 quotes for a paper in the Journal of Environmental Botany, while we were involved in a 2020 paper that has already received 257 quotes. Hence, our research is recognized by our scientific peers.

3.5 BENCHMARKING

Benchmarking was done by analyzing the scientific output from Pure on the SDGs for the field of remote sensing. Table F2 (Annex F) shows the benchmarking against seven other research units: Wageningen University, University of Bonn, University of Reading KNUST (Ghana), University of Addis Ababa (Ethiopia), University of Wuhan (China), RMIT (Melbourne, Australia) and INPE (Brazil). These units were chosen for the following reasons; Wuhan University ranks first in the Shanghai rating of remote sensing; Wageningen University has points of contact in many domains; University of Bonn incorporates the Zentrum für Entwicklungsforschung (ZEF) with a comparable mission as our faculty; the University of Addis Ababa and KNUST are research units from countries in the majority world; University of Reading and RMIT are of similar sizes as the University of Twente and ITC, respectively; and INPE is a research institute in a rapidly developing country. A comparison with these research units shows important parallels and major differences that may be useful for identifying future changes. Some units have a – much – wider scope than our faculty.

From the overview we note differences in focal area. Wuhan University has a larger fraction of research on SDG 11 (Sustainable cities) and 7 (Energy); Wageningen University scores higher on SDG 13 (Climate), SDG 2 (Zero hunger) and SDG 14 (Life below water). Both KNUST and the University of Addis Ababa have a stronger focus on SDG 13 (Climate), whereas also both University of Bonn and the University of Reading produce more output on SDG 13 (Climate). Quantitatively, we feature less prominently in SDG 13, but several of our researchers have an international reputation in climate change research, as evidenced by their lead-authorships in the IPCC report. Overall, the field weighted citation index shows that our research scores relatively high on SDGs 11 and 13, and relatively low on SDG 2. A stronger emphasis on SDG 15 in the future would bring us more in line with research units in countries in the majority world, while a stronger emphasis on SDG 7 can lead to more similarity with Wuhan University with its higher ranking on the Shanghai list. The field weighted citation impact of our publications shows that we ranked first in the domain of Agricultural and Environmental Sciences, and third in the domains of Earth and Planetary Sciences, and Environmental Sciences, both after Wageningen University and the University of Reading.

3.6 RECOGNIZED INTERNATIONAL RESEARCH PARTNER

Being a recognized international research partner was established by analyzing the geographies of co-authored publications in Scopus. In 2014, 84.6% of our publications were co-authored with institutions in other countries. By 2020 this percentage increased to 94.0%. Most collaborations have been with research units in China and the Netherlands, as well as with two universities in Australia (see table I1, Annex G and Annex I). With the Analytic Tool Dimensions we created the following collaborations maps. These maps show that we have expanded our international collaboration network, most noticeably in a relatively large increase in collaborations in African and Latin American countries as compared to other regions. Compared with the benchmarking institutes, our percentage of international collaborations is high. In 'Agriculture and Biological Sciences', we have the highest percentage of international collaborations, while in 'Earth and Planetary Sciences' we are on the same level as Wageningen University & Research, University of Bonn, and Addis Ababa University.

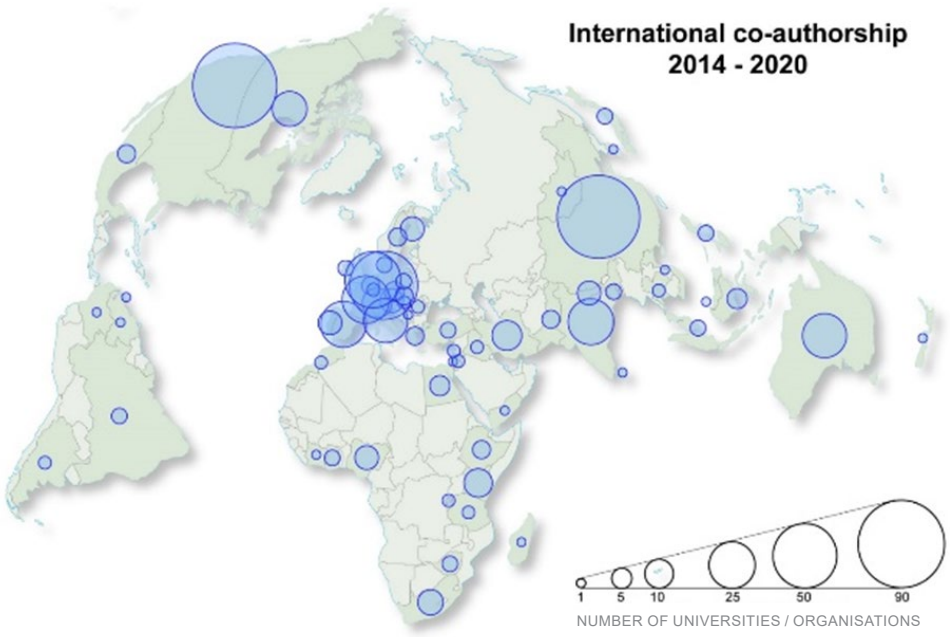


Figure 3. International spread of co-authors in ITC's 2014-2020 publications.

3.7 RELEVANCE OF OUR RESEARCH OUTPUT

Relevance of our research output was measured by how much private and public actors made use of, recognized, and applied our outputs. Annex H lists various applications directly supported by research of staff and PhD projects, highlighting the topicality and relevance of our research. For instance, geospatial approaches for crop and livestock insurance have been adopted in Ethiopia and Kenya. Local governments and intergovernmental agencies have benefited from the use of UAVs and geo-information technologies for diverse cadastral applications in both high- and low-income countries. Developed techniques of participatory modeling served to handle map toponyms in multi-lingual countries.

PhD research has also supported the development of new products, ranging from algorithms to extract roads from street level imagery to mobile phone apps with innovative location-based services that indicate the risk of getting a tick bite. PhD research results have also formed the basis for some of the services and products offered by international research organizations. Examples include global climate change vulnerability maps and approaches to include quality flags to crowdsourced geo-information.

Our research outputs are also finding a wide range of applications by international organizations. They have supported the activities of WHO (allocation of health facilities), FAO (WAPOR datasets), UN-HABITAT (spatial development framework), and ESA (science advisory groups) as well as the development of biodiversity policies. The seismic monitoring and Earth imaging network in Botswana, developed in an NWO project, has been bought by the Botswana government for full implementation in hazard monitoring in the country and is now embedded in the global seismological monitoring network. At the European level, we highlight projects

that provide climate services (CORE-CLIMAX) and others that support the protection of Natura2000 areas.

At the Dutch and local level, our research outcomes are used by the Dutch Kadaster and to drive the energy transition in Twente, and used by the wider public.

3.8 MARKS OF RECOGNITION

We have formulated marks of recognition to show the recognition and relevance of our scientific knowledge by academic and societal actors: being awarded a personal grant, invited for editorial responsibilities, invited as keynote speakers and lecturers at conferences and academic seminars as well as to participate in national and international policy activities, and being visible on the internet and in the media (see also Annex H and Annex I).

Academic. Three personal grant proposals have been granted: in 2017 an ERC advanced grant on biodiversity (See insert below), in 2018 a Veni grant in RS-based population mapping in unplanned settlements and in 2019 a Veni grant on responsible use of artificial intelligence in geospatial data. We have also been asked to participate in grant committees.

BIOSPACE - Monitoring Biodiversity from Space. In 2019, an ERC grant was awarded to the BIOSPACE project, led by Prof. Andrew Skidmore. Its overall aim is to monitor biodiversity by upscaling field observations and genomic information using satellite remote sensing. To synthesize global biodiversity on a fine granular scale, the first aim is to predict biodiversity over large areas using environmental DNA (eDNA) and hyperspectral and LiDAR satellite remote sensing. Secondly, the richness in ecological function is monitored by satellites. A third objective is to understand how the many available eDNA sequences interpolated by remote sensing for ecosystem function and taxonomy are affected by environmental gradients and anthropogenic pressure. The main impact of BIOSPACE will be demonstrating the synergy of new technologies for rapid monitoring of biodiversity.

We have been invited to take responsibility for many editorial activities of relevant journals and provide(d) the editor-in-chief for Spatial Statistics, Land Use Policy, Catena, and the International Journal of Applied Earth Observation and Geo-information and Agriculture Ecosystems and Environment.

Our researchers have been invited as keynote speakers to several scientific conferences, especially in the field of GIScience and Earth observation, e.g., at the ISPRS Geospatial week in Wuhan, China, and the 18th General Assembly and 29th International Cartographic Conference, ICA, Tokyo, as well as in our application domains: the 7th International Workshop on Catchment-Scale Hydrological Modeling and Data Assimilation (CAHMDA-VII), Xi'an, China, the 10th World Conference Ecosystem Services Partnership, Hannover, Germany and the utility of geo-informatics for disaster risk management in the 3rd Engineering Research and Development for Technology (ERDT) Congress in Manila, Philippines.

Many of our researchers have been invited to present their work at seminars at universities across the globe, or to conduct training, particularly in the majority world. Topics include advanced geospatial methods such as deep learning, point cloud analysis, drone technology, spatial accuracy, innovative cartographic mapping, natural hazard modeling and fit-for-purpose tools in land administration.

Policy. We consider being invited to national and international policy platforms and policy events as a recognition of the societal relevance of the scientific knowledge we have produced. Most policy events where we presented our work on e.g., mapping informal settlements and cadastral boundaries, cartographically visualizing, and measuring the sustainable development goals, assessing ecosystem services, or modeling disaster risks were organized by UN units, such as UN-Habitat, UN-GGIM, UN-IPBES, or UNISDR. In addition, several of our researchers contributed as lead authors to the most recent reports from the Intergovernmental Panel on Climate Change and Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. In addition to global policy network visibility, several of our researchers have contributed expertise at national events, such as the Dutch Kadaster, agricultural stakeholder meetings in Uganda or at the Greek National Centre.

Internet visibility. The most popular research related news items on itc.nl have shown high interest in environmental issues and mapping and modeling of socially relevant phenomena. Among these were local climate change adaptation, spotting elephants through satellite imagery, automated cadastral mapping, remote sensing lodged crops, 3D maps in support of disaster management, predicting landslides caused by earthquakes, mapping ticks, mapping access to resources and opportunities for sustainable development and mapping Covid-19 (see Table J1 in Annex I).

Media visibility. A relatively large proportion of news about ITC is published through traditional (radio, TV, newspaper) and online press. After an unexpected dip in 2018, the trend in the past two years has been increasing in the total number of news items, items in traditional media, and specific research related items. The number of research related items is relatively low compared to the total number of news items.

A general trend (Table J2 in Annex I) in the press and media landscape is that during the past years online news has become much more dominant. Popular research related articles in traditional and online media favor stories about animals and environmental conditions as evidenced by the Meltwater Media Analysis report (see J3 in Annex I for examples).

We have become increasingly active on social media in recent years, starting the use of Facebook and LinkedIn in 2011 and 2014, respectively. In the last quarter of 2019, Twitter and Instagram were added. These channels are an accessible way to connect with our students and stakeholders.

Unfortunately, data are unavailable on the reach of specific research topics between 2014 and 2020. Table J4 in Annex I shows the number of people potentially seeing our stories on the various platforms. These numbers are increasing every month. In addition, some individuals share their stories from their personal account.

In addition to ITC's corporate social media channels, there is a large alumni network at ITC. As of 2020, it consists of more than 24,000 people who follow ITC news, often through various channels (Table J5 in Annex I).

4 ACCOMPLISHMENTS ON RESEARCH QUALITY AND SOCIETAL RELEVANCE OF THE PAST SIX YEARS

In this section, we describe our accomplishments regarding our strategic aims and its strategies as well as on PhD policy and training, Open Science, Academic culture, and Human Resources. We include short narratives to highlight some of our pearls.

4.1 ACCOMPLISHMENTS ON OUR STRATEGIC AIMS AND THE STRATEGY OF THE PAST SIX YEARS

1 Become a pro-active player in international agenda setting. We have a strong involvement in various international, professional, and scientific organizations. We have substantially increased our involvement as a Participating Organization in GEO by delegating a staff member to the GEO Secretariat in Geneva to coordinate the Capacity Development Working Group and through the active involvement of several staff in the GEO Work Program, e.g., GEOGLAM, GEOBON, GEO LDN, AFRIGEO and Digital Earth Africa. Further, we have a strong involvement in the ISPRS by organizing the GeoSpatial week in 2019, while in the International Cartographic Association (ICA), we chaired one period and co-chaired a second period. We lead the journal Spatial Statistics, founding the journal in 2012 and organize and chair its bi-yearly international conferences. We will continue this in the future. In addition, we are an active member of the International Federation of Surveyors (FIG) where we were involved in organizing several meetings. Furthermore, a further expansion of connections and contributions to the flagship Digital Earth Africa is foreseen. We are involved in different boards and regularly participate in evaluations of international institutes. These concern the IPCC, CSSTEAP (Centre for Space Science and Technology Education in Asia and the Pacific), the advisory board of GLTN, and the review panel of UN-Habitat's Strategic Plan 2020-2025. There are connections to the European Space Agency and involvement (two memberships in Mission Advisory Boards) in upcoming satellite missions. We are connected to the UN e.g., FAO/WFP, in relation to agricultural water productivity, soils and water management. While having a strong international visibility, more efforts will have to be taken to increase this nationally.

2 Start research-based start-up companies. We have been actively involved in setting up spin-off companies (see Annex J) and supporting individual alumni initiatives to start those. The increased emphasis on creating spin-offs has resulted in 39 entrepreneurial enterprises, more than 50% of these are in Africa, spread over eight countries, with 33% in Kenya alone. Most of these companies are of a relatively small size (0 – 10 staff), whereas the larger ones like Natural Resources Planning (Bangladesh, 0 - 50), GeoCensos (Argentina, 50 – 200), LocateIT (Kenya, 10 – 50), Tovos Technology (China, 10 - 50) and IDA&RM (Mexico, 10 – 50) started before 2014. Several companies use the name ITC as a brand for project acquisition.

3 Further diversify funding sources and act international. Internally, ITC has invested in research by appointing six PhD candidates in 2014, with the aim of promoting integration between two departments, in 2016 by appointing 12 PhD candidates to each chair, and in 2019 by starting the *Ingenuity* program. The *Ingenuity* program serves to strengthen the financial position of the faculty, also with a view to move to the campus in 2022. This has recently been followed up with the *Ingenuity*-2 program. Apart from internal investments, there has been an increasing emphasis on attracting H2020 and Horizon Europe funding, funding from national

organizations like STW and NWO. Successful consultancy projects like the GEOCAP and STARS, and projects in conjunction with the World Bank, have increased funding diversification. A typical project for ITC is the EENSAT project, established together with Ethiopian universities. Its research concerns nine PhD positions to strengthen agriculture and water for food security and socio-economic development. This project is jointly financed by ITC and Nuffic.

The spin-off GeoNAREM: Solving human problems. GeoNAREM, Geo-information for Natural Resources and Environmental Management, is a multi-national initiative co-founded by four alumni. Conceived in the Netherlands, it is established in Ghana, Kenya, Tanzania, Papua New Guinea, and Rwanda. A major selling point is the diverse background of the team, offering expertise and experience in Forestry, Agriculture, Geography, Environment Management, Geology and GIS & Remote Sensing. The main aim of GeoNAREM is to apply GIS- and Remote sensing-based solutions in solving human problems. It bridges the gap between developing spatial tools and on-the ground application to solve real-life problems. GeoNAREM integrates remote sensing, GIS technology and natural resource management to find smart solutions for the sustainable use of the natural resources for a better livelihood.

4 Fill knowledge gaps and align to other valid policy guidelines. In the field of Geospatial Science and Technology, we contributed new knowledge and technologies on geospatial data acquisition, processing, monitoring, modeling, and analysis. Our achievements include adapting machine learning and deep learning methods to geospatial data and studies on heterogeneous data integration, the integration of novel data sources (UAVs and in *situ* sensors) with other geospatial datasets, advancing citizen science and crowdsourced geospatial data science, and designing GIS and analytical workflows that leverage distributed computing solutions.

We have created considerable knowledge in support of sustainable cities and communities (SDG 11) through numerous PhD theses, projects, as well as a personal Veni grant in the urban domain. Research outputs, making use of a variety of geospatial approaches, address the mapping of deprived/unplanned settlements (three theses, of which two *cum laude*), sustainable transport, spatial inequalities and quality of life, and disaster risk reduction in vulnerable communities.

Geo-Health has developed from incidental studies to an integrated domain. Research outputs involve new knowledge on neglected tropical diseases, geo-aspects of obesity, the planning of health units and clustering of contagious diseases. Recently, the appointment of a new professor (with an educational focus) and a TT candidate have started research activities in WASH (water, sanitation, and hygiene) and in developing methods for assessing health and disease risks in space and time, like Covid-19. Relations with remote sensing are anticipated.

In the field of Zero hunger (SDG2), local and cloud-based workflows have been developed to analyze high spatial resolution data in support of smallholder farming. In the EENSAT program for instance, we address the use of RS-based crop and cattle insurances.

Research that is fit for purpose. "As researchers, we often also fail to understand the local conditions…Over the past months [during Covid-19], we learned a lot in the interaction with local community leaders on what is needed and what not OR what can work and what not. The creation of data for any purpose, should not only be in terms of addressing the needs and conditions but also in understanding the implications of data. We should also understand why timely and accurate data on deprived urban areas are needed and comprehend the massive data gaps in any global datasets[xlvi]." https://www.itc.nl/research/research-themes/plus/PLUS%20Stories/plus-stories-2-kohli-kuffer/

(Quote: Kuffer and Kohli, 2020)

Regarding our focus on (clean) water (SDG6), we have contributed new knowledge and tools on flood prediction, groundwater recharge, drought monitoring and prediction, water quality monitoring, and climate studies. Produced knowledge on water management is dedicated to the availability of potable, i.e., clean, and safe water for all. Potable water is becoming increasingly scarce, which makes it a valuable resource to be managed wisely. Also, extreme weather causes excessive flooding which can often be prevented with targeted interventions, e.g., based on flood simulations.

Related to SDG13, our research achievements address the urgent need to integrate hazard assessment and disaster risk management into strategic planning and sustainable development. Worldwide the impact of disasters is rapidly growing. However, many countries and development agencies do not, so far, consider hazard and disaster risk in development planning, and lack sufficient strategies to plan, assess, prevent, or mitigate the effects of extreme events. This knowledge gap is being addressed, closely tied to the UT resilience theme and the 4TU resilience program, and will also be a major research direction for the future.

Regarding Life on land (SDG15), a major step forward is anticipated by the Biospace Project. In this project, modern EO technologies will be combined with field observations that will allow us to understand the diversity at the micro scale.

Our future strategy will concentrate efforts to more effectively utilize our multi-dimensional expertise to address complex global challenges.

In situ observation sites. ITC maintains several *in situ* Earth observation sites to support research and education. These sites are used to conduct research using both space-based and *in situ* sensors in relevant ITC research domains and application areas and they offer advanced Earth observation courses integrating satellite and *in situ* observations. Currently, ITC operates six sites, with three of them located in the Netherlands, one long-term monitoring site in Spain, one in Lake Naivasha in Kenya and a regional observation network on the Tibetan plateau. More information can be found on the ITC webpages[xlvii]. https://www.itc.nl/about-itc/organization/scientific-departments/water-resources/earth-observation-sites/speulderbos/

4.2 FOSTERING SOCIETAL RELEVANCE THROUGH STAKEHOLDER ENGAGEMENT

Many projects have an active stakeholder engagement. Stakeholders are located in all continents and in various societal domains, whereas the source of the involvement varies. Stakeholder involvement concerns several target groups.

The first group of stakeholders relates to projects granted by the EU, the Gates Foundation, and Dutch organizations like Nuffic and NWO – TTW or NWO-Wotro. Typical examples are local farmers in Indonesia, tropical smallholder farmers in Mali, Nigeria, Tanzania, Uganda and Bangladesh, and firefighter organizations in European countries. Major challenges are the automation of information collection, addressing scale levels that were impossible so far and transferability of knowledge between different areas and domains.

The second group of stakeholders concerns our traditional partners with whom we have established long-term relationships. In the Netherlands, for instance, the Dutch Kadaster and water resource management boards, while abroad governance

institutes, and the natural resource management in the Naivasha basin in Kenya. (Annex K).

The third group of stakeholders concerns industrial partners, like AKZO Nobel, Geodan and Cyclomedia. These companies have a main interest to implement and/or use the products generated from our research.

The fourth group of stakeholders concerns a growing interest in our research in the Overijssel and the Twente region, where we have achieved collaborations with spin-off companies, the police and fire brigades. Major challenges concern elevating the technological level, e.g., drones, to serve the needs identified.

The fifth group of stakeholders concerns incidental involvements of organizations that approach our research program with specific questions. An interesting example concerns older residents of high-deprivation areas who walk less than those of low-deprivation areas. Using GIS and walking interviews in combination, we measured neighborhood built environment characteristics that may encourage outdoor walking in high-deprivation areas.

Caroline Gevaert: Understanding social implications of new geospatial technologies
Improving living conditions in deprived areas is prominent on the Sustainable Development Goals. Prioritisation and design of measures to upgrade these areas requires detailed geospatial information, which is generally unavailable. A research project was carried out in Tanzania and Rwanda, focusing on the utilisation of Unmanned Aerial Vehicles (UAVs or drones) to solve this deficiency. The project overcame technical challenges regarding the adaptation of deep learning to the 2D and 3D data obtained by the UAVs and resulted in providing classified maps and digital terrain models. Simultaneously, the social impact of the use of this new technology in deprived communities was investigated. Research was conducted on how the data could be used by different stakeholders to support the upgrading project. It proved to be useful to communicate and prioritise interventions with the community as well as support the design of upgrading measures. Privacy concerns were also investigated by asking community members to indicate objects in the imagery that they considered to be sensitive. The UAV data proved to be very useful for the upgrading project and was still being used by the local government five years later.

We also see an increase in participatory, citizen science and volunteered geographic information, involving citizens. Examples are the exploration of how much information detail of UAV data in informal settlements was acceptable to the residents of the settlement, monitoring ecosystem services in Suriname, or the tick projects where citizens contribute to collect observations on the presence of ticks in certain locations in the Netherlands. A complete list of citizen science initiatives is provided in Table L1 in Annex L.

We have ample examples of foreseen societal impact but we will have to develop effective strategies to trace them.

4.3 PHD POLICY AND TRAINING

The strategy, established in 2010, to become less reliant on scholarship-funded PhD candidates, but to focus on employed PhD positions which has resulted in a wide diversity of PhD candidates from various origins and backgrounds and financed by different sources of funding. Between 2014 and 2020, 37.8 % of the PhD candidates

were funded by ITC. The percentage of employed PhD candidates increased to 42% of all recruited PhD candidates. Close to 10% are funded by STW/NWO or EU, while nearly 15% of PhD candidates come from China with a CSC scholarship.

To safeguard the quality of the PhD research, we have a graduate admission portal and admission procedure, designed to attract and select the best PhD candidates with their own scholarship/funding (see Annex M). This procedure includes careful screening of the candidate's background, covering aspects such as command of English, the quality and fit of the proposed research idea, and an online interview.

In the first half year, PhD candidates prepare and present their research plan during the qualifier defense. This is evaluated by a committee, consisting of the supervisors and a scientific expert from a different department, for soundness and feasibility of the research design. Candidates compile a personalized Training and Supervision Plan (TSP)[xxiii] which defines how supervision is executed in practice and what courses and academic activities will be followed. The training program consists of 15 ECTS on skill developing courses, and 15 ECTS on domain specific courses. Of the 30ECTS, 6.5 ECTS consist of mandatory courses such as Data Management and Research Integrity.

All PhD graduates who started on or after 1 January 2014, complete the 30 ECTS training. Exceptions apply to candidates who are exempted (though not from mandatory courses) due to obtaining substantial training and expertise prior to the PhD trajectory. These are, for instance, senior researchers who had considerable research experience but not yet a PhD degree. TGS offers courses on six learning tracks (see Annex M), and the mandatory courses are offered several times per year.

After the qualifier defense, annual interviews help to monitor the progress of the PhD candidates and adapt the TSP where applicable. The qualifier defense and annual interviews are documented in Hora Finita. Quality assurance also follows the TGS procedures when a candidate is admitted to the PhD defense: the TSP should be completed and the thesis should meet the PhD thesis requirements[xxiv]. TGS training quality is systematically evaluated, while TGS also conducts an exit evaluation after the PhD defense. The PhD thesis is evaluated by an independent committee consisting of 4-6 members where each committee member completes an assessment form. In the assessment period we had five *cum laude* graduations. One of these was shared between two departments. Two of the *cum laude* graduates are continuing their research line by both having attracted a Veni grant.

We have provided organizational support to encourage PhDs in their scientific and intellectual development. Several events have been organized by and for PhD ITC Community (pITCom), formally established in 2017, following suggestions in the previous research evaluation. pITCom was involved when collecting feedback on training needs by PhD candidates to an Academic Board meeting, it was involved in organizing the *Annual Science day* in 2018 on the SDGs, a scientific meeting in 2019 on advanced geospatial research methodologies and tools, the *PhD publication award* in 2018, 2019, and 2020, training courses in 2018 (LaTex) and 2019 (Python), and monthly online lunch meetings focused on learning from recent PhD graduates in 2020.

From a township to the Edge of Science: the story of Sibu Khuluse. Growing up in KwaMashu, a large township adjoining the city of Durban, South Africa, Sibusisiwe Khuluse was sent to live with her grandmother in a rural area when violent Apartheid-related protests erupted. She returned to the township to complete her schooling, and later obtained an undergraduatee degree in Statistics from the University of KwaZulu-Natal in Durban. Her efforts allowed her to continue studying on a part-time basis at the University of the Witwatersrand in Johannesburg. She successfully obtained a highly coveted Mandela-Rhodes scholarship enabling her to attend Harvard University for a full year. Upon her return she selected the University of Twente for her PhD studies. On July 21st, 2017, she defended her PhD thesis on Spatial Statistical Modelling of Urban Particulate Matter. The central insight of her PHD research was to improve the quality of the data by using disparate sources. She now uses her skills to carry out research with IBM and the IBM Research laboratory in Johannesburg.

4.4 OPEN SCIENCE

Opening our research data has led to 175 datasets in DANS Easy[xxv]: 80 of these datasets are open and 95 were published with restrictions meaning that interested parties need to contact the main author or the ITC research support coordinator to discuss how to access the files. Outside DANS, 14 datasets are stored in the 4TU data archive, eight of which have data in the Figshare repository, and four datasets in Zenodo. In 2014 ITC published 15.35% of its journal articles OA. In 2020 this number increased to 70.90%. Figure 4 shows the progression towards more and more open publications.

As a combination of ITC's OS strategy and changes in the scientific publishing landscape, ITC published more in gold OA journals: 28 articles in 2014 vs 137 articles in 2020. Publication in hybrid OA journals has also increased from five articles in 2014 to 92 articles in 2020. This increase is largely supported by the so-called OA deals between large scientific publishing firms and Dutch universities. As a result of this shift towards OA, the number of ITC publications under a paywall has been halved from 184 in 2014 to 92 in 2020.

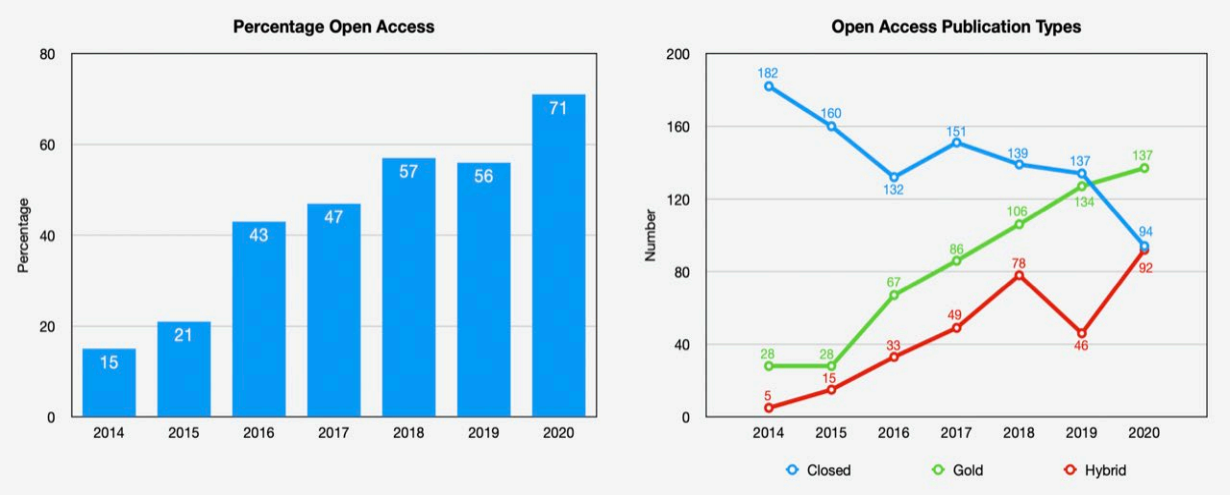


Figure 4. Development of OA publications as a percentage of the total number of publications (left) and the type of publication: Gold OA (green), Hybrid OA (red) and Closed (blue).

In 2017, the standardized procedure to document data management plans (DMP) became mandatory to PhD theses and NWO funded projects. Since 2017 (until the end of 2020) we have a total of 58 DMPs completed by PhD candidates (i.e., about 62%, however, with an increasing trend in the completion rate) and 21 DMPs from NWO funded projects.

This strategy also contributed to our capacity development mission: data and know-how became more accessible, thereby supporting further research on topics that are often linked to problems faced by the majority world.

4.5 ACADEMIC CULTURE

Our strategy on academic culture has promoted team-based research, without neglecting the strengths of individual disciplines. It has built bridges between different disciplines, and connected research themes within ITC and across faculties and institutes in the UT, thus recognizing the multiplicity of perspectives and identities. It has also created awareness of the ethical considerations of geospatial research and on research integrity. A recent survey on ITC values has demonstrated the appreciation of the academic culture at ITC. Our international working environment, in particular, was highly valued, both as what it represents, and as the way of working. We recognize the importance of diversity in talent, an openness to use and combine different approaches, and respect other's as well as differing opinions. This fosters a strong sense of community and trust among staff, students and alumni from diverse cultures and countries. ITC employees, students and alumni refer to terms like *multicultural, collaborative community thinking, international character, diversity in topics, academia with a soul, an international institute that openly caters students from all over the world, world of different cultures, and social and personal approach making feel people welcome and at 'home'.* Maintaining this character is essential for ITC's success in attracting and retaining talent and establishing a life-long learning culture. Nevertheless, further promoting collaborations across different disciplines and research groups may require adaptations in the institutional structure.

Collaborations between different departments, other UT faculties, and local partners in the majority countries have resulted into joint PhD supervision. For instance, in the past few years, we have acquired multiple research projects where at least two departments collaborated. Larger ones are the EU funded H2020 program ITS4Land on land rights registration, the faculty wide EENSAT program, the Earth Observation Africa Research and Development Facility, and the NWO project Microwaves for a New Era of Remote Sensing of Vegetation for Agricultural Monitoring (MINERVA).

We have initiated several activities to stimulate the awareness of ethical considerations and research integrity in our Geo-Community. In 2018, we established the ITC ethics committee (IEC) for the geospatial domain with the support of UT's ethics experts (see Annex N). It also spurred the design of an MSc elective on Space for Ethics.

Regarding research integrity, the UT launched the House of Integrity in 2020[xxvi], subscribing to the Netherlands Code of Conduct. Sitting staff were informed through the research integrity seminar in 2020, while new staff receive relevant information in the introduction meeting. In the years to come we will continue to create, together with our international partners, awareness on integrity, jointly identify potential scientific and social integrity dilemma's in our own domain and community and explore how to monitor and evaluate research integrity in practice.

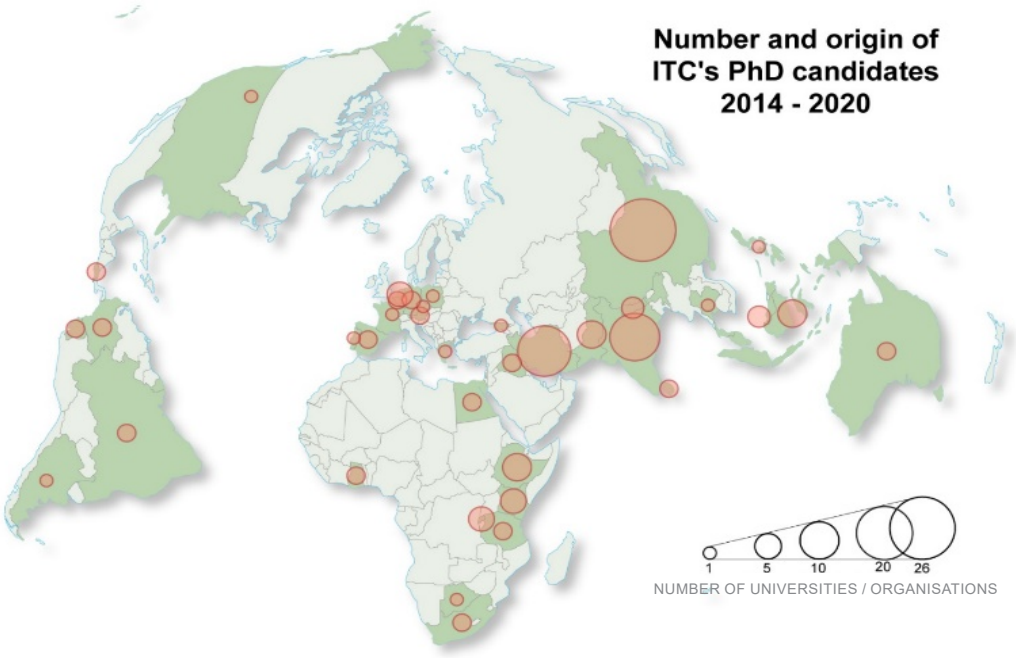


Figure 5. Number and origin of ITC's PhD candidates between 2014 and 2020.

4.6 HUMAN RESOURCES

Tables in Annex E and C (E2, G1-G3) contain an overview of the staff composition. This has been elaborated in Chapter 3. Aligning our human resource strategy with emerging knowledge fields and developments has resulted in part-time chairs connected to existing institutes, in particular the Kadaster, Royal Dutch Meteorology Institute, the Red Cross, and the Royal Netherlands Institute for Sea Research. The number of full professors has increased by five, accounting for successful completions of the TT process and retirements.

To keep up with technological development in the geospatial domain and provide the necessary support to research, we have recruited an UAV expert, an expert on big data and cloud computing, research support officers, and TT candidates on deep learning and hyperspectral remote sensing. Other hires and promotions have strengthened our knowledge fields in disaster risks and climate change, urban (infrastructure) planning, and natural resources, and the Geo-Health domain.

The number of female professors, associate professors, and assistant professors has increased; there is an increase in female assistant professors from 7 to 22, in female associate professors from 0, while the number of female professors has increased from 1 to 5. We also attracted more postdoc researchers through 2nd and 3rd stream funds. The higher share in the youngest age category is due to PhDs being younger, while the other age categories were fairly stable. We realize that attention needs to be paid to the lower number of female PhD candidates.

Regarding geographical background, we have at present staff from 41 different countries, where we notice a slight increase (+4%) of the staff and PhD candidates coming from Europe, in particular from the Netherlands and Germany (Figure 5).

Space for female talent in 2014 and 2017 ITC offered tenure track positions to female geo-science talent (UTWIST, IWIS). The selected researchers were given *carte blanche* to develop their research field within ITC. This open recruitment led to the emergence of a research line on geo-information for 'ecosystem services'. Three researchers from these talent programs found each other in their joint ambition to innovate this area. While based at different departments, they took the initiative to join forces in research, education, and capacity strengthening projects. This resulted in successfully funded research projects, a new elective course and e-learning material (building on research outcomes), joint publications, and increased visibility. While open recruitment makes research lines vulnerable as they lack embedding in the organization, this unique bottom-up development of a research line shows what space for talent development can enable.

There is also a slight increase in staff and PhD candidates from Africa and China, but a decrease of PhD candidates from India and the rest of Asia (together from 31 to 16%). Our diversity strategy (more younger staff, more female staff in higher positions) points thus to a satisfying trend. The TT program (see Annex O) is successful in the sense that by now four candidates have reached the professor level. It has also led to a cross-departmental research line on ecosystem services. From the 22 started candidates there are still 12 in the program. Drop outs from the TT track are due to leaving ITC (3) and to being unsuccessful in meeting the required level (7). This will be carefully examined in current initiatives of shaping individuals and teams. Talent development extends well beyond the TT system: since 2014, we recorded 29 academic promotions within the regular UFO system.

4.7 SWOT ANALYSIS

A SWOT analysis was conducted in October 2020 by the Academic Board[xxvii] and was further discussed with TT staff. The SWOT (Annex P) forms the basis of our strategic goals, and is summarized below.

Our strengths are a combination of a top-level position in our domain, being among the largest and most influential centers of expertise on geo-information and Earth observation, our unique global network of alumni and institutional partners, our diversity that covers the full chain of GIScience and Earth observation and fields of applications, and our focus on capacity development. Our main weaknesses are a sub-optimal integration of domains, a lack of a clear strategy to demonstrate societal impact, and that our visibility in the Netherlands is relatively low compared to our international visibility. We see opportunities in upcoming new programs such as the sector plans for Earth and Environmental Sciences to which we contributed substantially, the Dutch Research Agenda (NWA), Horizon Europe, (Inter)national policy alignments, and the EU Copernicus program. Our main threats are our politically motivated and thus sensitive base funding, and the perception that we are no longer unique in our geospatial and capacity development mission.

The SWOT resulted in three strategic pathways to fulfill our mission. These pathways anticipate scientific, societal, and institutional developments and outline ITC's future role in shaping those developments. They will be described in the next Chapter.

5 STRATEGY AND VIABILITY FOR THE NEXT SIX YEARS

Our mission[xxviii] in today's world is capacity development, where we apply, share, and facilitate the effective use of geo-information and Earth observation for tackling global wicked problems. Our purpose is to enable our partners around the world to track and trace the impact – and the shifting causes and frontiers – of today's global challenges. We are here to identify and understand vulnerability, and to use geospatial solutions for converting it into resilience, thereby contributing to the establishment of sustainable living environments anchored in an inclusive society. Our vision of *tomorrow's world* is that researchers, educators, and students collaborate across disciplinary and geographic divides with governmental and non-governmental organizations, institutes, businesses, and local populations to surmount today's complex global challenges and to contribute to sustainable, fair, digital societies. This new mission and vision are the result of aligning the earlier *Space for Global Development* mission and vision to UT's mission and vision Shaping 2030 and developments around us. Here, we outline our future strategy to fulfill this mission and vision. We present our strategic goals, organization, and resources to ensure our viability through continued scientific excellence and societal relevance.

5.1 STRATEGIC PATHWAYS

1. Develop and define a long-term research profile that links the Research Themes of the University of Twente with the main themes in our mission and vision. In our living environment and societies, global problems such as disaster risks, scarcity of resources, population growth, global health threats and geo-computational challenges are complex problems that require multi- and transdisciplinary, multi-scalar and multi-stakeholder approaches. We identified four main themes for ITC's long-term research profile where we can both pioneer and facilitate research to address global problems: Hazards, Risk & Resilience; Food Security & Biodiversity; Geo-Health; and Big Data/Governance, with emphasis on Geo-AI (Annex Q). The choice for these themes is informed by deepening our well established knowledge base in those fields, possibilities of cross-domain collaborations. This is much needed to address pressing global challenges, aligning with emerging societal and technological developments in our field and opportunities for creating synergies with our network and acquiring funding. Through our past strategy focusing on scientific contributions and highlights, societal relevance, grant acquisitions, human resource policy and infrastructural investments, we have planted seeds in fertile soils for further spur and growth of scientific and societal impact. For each theme, we will stimulate and facilitate bottom-up initiatives to jointly develop visible publications a year, including review and perspective papers and we will organize at least one research event per year, in 2021 related to celebrating 70 years ITC. Within the themes we will increase our research grant acquisition and visibility to attract PhD candidates (aiming at least at one graduation per year per staff with promotion rights), postdoc researchers and visiting scientists. Our target is to be a widely recognized knowledge hub, expert, and trusted partner for disaster resilience, geospatial technology for natural resources and geo-health issues, and responsible big data and AI in the geospatial domain. Synergy with other UT partners and the UT research strategy[xxix] will also be stimulated by our move towards the campus. A new location for the faculty and its student housing on the university campus will not only enhance the international character of the UT, but also spur collaboration with other faculties and within the supporting environment of the design lab and other available facilities. We will allocate a certain share of the strategic funding to ITC's profiling themes as well as to strategic collaborations with UT partners, e.g., on energy transition.

The aim is to be more visible in the Netherlands (and Europe) and more viable through increased European funding. We will use our worldwide experience and put this into practice in the Netherlands. We will build on experience such as our link with the SERVIR program that connects space to village and programs at NASA and USAid. Likewise, we aim to build a strategic partnership with the European Space Agency (ESA) to strengthen our European position and use of EO data, for instance through EO4Africa, where we co-create and co-invest with ESA, and with Dutch institutes like NSO, RIVM, PBL, KNMI and the Kadaster. We consider it important to continue the discussion on novel scientific partners in the Netherlands, Europe and beyond. Typically, a strategic focus will be on UN partners, NGOs like SDI, international organizations, and European organizations like JRC and ESA.

This strategy uses our *strengths* of being top in our geospatial domain and our unique interdisciplinary networks, to make the most of funding opportunities in the Dutch sector plans and Europe, and to strengthen UT collaborations to profile our research in the Netherlands. It addresses our weaknesses of sub-optimal coherence and the still relatively low visibility in the Netherlands compared to our international visibility, to mitigate the threats of reduced 3rd party funding and too many subdomains.

2. Develop procedures, platforms, and tools that continuously demonstrate the long-term economic and social value of our work, especially of our research-based capacity development. We want to quantify the economic and social value of our capacity development mandate, by working in integrated public-private partnerships (PPP) for spinoff-oriented research. We will build on past successes from the STARS, GEOCAP and EENSAT projects to develop interdisciplinary teams that work in strategic locations to address real-world challenges. For instance, the STARS project investigated ways to use remote sensing based monitoring to improve agricultural practices such as crop management decisions in Sub-Saharan Africa and South Asia. These may lead to follow-up projects especially if improved EO technologies become available.

We seek to identify and analyze best practices from its past performance to learn lessons and apply those to enhance our present and future impact. For instance, the evaluation of our long-term research activities and associated scientific and societal impacts in the area around Lake Naivasha (Annex K) can serve as a model to measure several impact indicators over a longer period[xxxxi]. The impact assessment took place at societal, organizational, and individual level. The involvement of stakeholder organizations around the Lake in the identification and definition of research questions, the dissemination of results, and the influence on the work of these organizations gave an especially good impression of the impact of the work that was achieved. Currently work is being done to further develop the methodology for impact monitoring and evaluation and the make the efforts and impact more explicit and more visible.

We recognize the need to maintain our mission and to stay ahead of the competition by being innovators. We consider long-term field hubs like big data, AI, cloud technology and our own Living Innovation Lab (LILa[xxxxii]) on the campus and Open Science (OS) to be strong drivers for this strategy for the years to come. We recognize the potential for tensions between OS and PPP agreements. We strive for more programmatic planning of our activities, e.g., through long-term projects and continuously working in a certain area, while being flexible enough to respond to changing dynamics in the world.

This strategy uses the strengths of our alumni and partner networks and our niche in capacity development, to make the most of the opportunities of involving them in research, co-creating developments and developing communities of practice. It

mitigates the threat of waning interest in funding "classical" capacity development activities. Our targets are to have established several long-term field hubs, communities of practice and new PPPs for long-term economic and social impact monitoring.

3. Refine our academic program along the lines of 'challenge-based' research, education, and innovation and tie this into the challenge-based approaches championed by the European Consortium of Innovative Universities (ECIU), of which our university is a member. We want to bring research challenges from stakeholders like our alumni into our education and research program. We see transdisciplinary and geo-citizen science approaches as a way to achieve this and have therefore invested in a long-term Geo-Citizen scientist position. We will continue to work together with ministries and intergovernmental organizations like GEO to address full value chain issues and further develop our geo-citizen science and participatory approaches. An illustrative example is our study on air quality in the Netherlands, initiated by the civil initiative Aireas, where we linked questions from user groups to medical professionals, industry, MSc education and PhD research[xxxiii].

Linking research and education is a vital part of our vision and of achieving our goals in society. We are further concentrating our efforts to strengthen the ties between our research themes and the thesis research carried out by our master's students and using research outputs in our educational curricula. Joint research with partners and in partnerships is also adding strength and impact, e.g., Digital Earth Africa, UN-Habitat, and the Red Cross.

This strategy uses our *strengths* of being top in our domain and our unique networks, to make the most of the *opportunities* we see in the *sector plan*, other programs and in our interdisciplinary networks. It addresses our *weakness* of lack of coherence in our research program and mitigates the *threat* of the perceived tension between research and institutional strengthening objectives.

5.2 VIABILITY

The **three strategic pathways** are strongly aligned with our viability. They support our academic viability through a continued development of four scientifically and socially relevant research themes, where we have or will build critical mass as domain leaders and/or influential actors. The pathways also strengthen our financial viability by diversifying our portfolio of projects, ranging from shorter-term blue-sky research to longer-term research programs and facilitated by our in-house research support services. This portfolio will include valorization of research at higher technology readiness levels and will need a clear policy for collaboration with industry. The three pathways also enhance our viability in terms of remaining at the forefront of our domain. This focus on four themes enables us to target our resources for more visibility and influence in policy and agenda setting arenas in the Netherlands and elsewhere. We will strengthen our viability by further developing our own resources. The pathways are a blueprint to invest in ITC so that unique facilities like our geo labs and long-term monitoring/field sites, and our in-house research support services all contribute to our strategic goals in conducting excellent and relevant research with a broad set of societal partners.

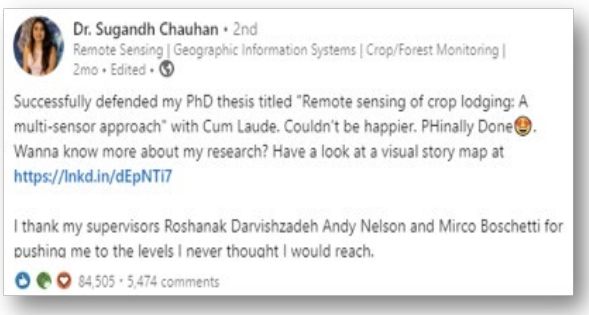
Ensuring viability means making clear choices on how we are organized, how we maximize our impact and visibility, how we allocate resources for research and support facilities, and how we nurture partnerships and invest in talent in line with our values. All these choices consider university, national, and international contexts. Here we detail ten of those choices and how they contribute to our future viability.

1 The structure of ITC in terms of research groups and researchers. We will retain the administrative structure of our six academic departments supported by service departments. While each department has its own domain focus and specialized expertise, they all provide crucial contributions to the four profiling themes (Annex R). Cross-disciplinary research teams will continue to be formed from the department programs, to address the four main themes whilst leveraging connections with campus, national and international partners (Annex U). An example is the Expertise Centre on Disaster resilience which addresses urgent issues on disaster risk management. It is currently being shaped based upon ITC's expertise and connecting to UT's Resilience spearhead. The teams will make use of the Shaping dialogues format to annually reflect on ambitions, activities, and achievements. We will adopt best practices, i.e., lessons learned from Covid-19 way of working, for effective virtual team management for more inclusive and more regular exchanges.

2 Communicating our research and societal impact. Major channels for publication and exchange will continue to be OA scientific journals, proceedings of important international scientific conferences, and books. Academic datasets, workflows, protocols, code, and software will be recognized and published as open as possible, and at least published FAIRly, using state-of-the-art distribution channels (such as DANS). We will improve our research presence in management plans and reports, and improve our tracking of these, to get a more comprehensive assessment of the societal impact of our research. Our increased presence in international and national networks should lead to broader communication of our research in policy reports that feature our research outputs.

Communication choices relate to our commitment to OS and the dissemination of results both to other scientists and to the public by promoting participation and co-creation. We will continue to reinforce this commitment. Our staff, students, and alumni already feature in several national and international news items every year, on traditional and social media platforms. We recognize the need to do more to increase what is published on news channels about our research. An important starting point is to communicate with the help of fixed categories, such as a format called "Our research at ITC has impact", where we (1) communicate frequently, (2) within a specific set of textual and graphic layout rules, (3) in understandable language and (4) with attractive images and maps, how ITC's research makes the world around us a better place.

We note an important trend in the media landscape for the coming years[xxxiv]: private networks are becoming increasingly important with less emphasis on traditional media and corporate social media accounts. It is important for our researchers to share content on their own platforms, such as LinkedIn. As an example, a LinkedIn post of a recent *cum laude* graduate on her PhD topic of wheat lodging received enormous attention (85,000 likes and 5,500 comments).



The implications are promising; when researchers talk to the people in their own network more about their research and ensure a high degree of diversity within their own network, then a research project can reach many different people. We will continue to amplify these messages by publishing on the ITC and UT websites and using social media platforms at the faculty and university level. We will keep up with relevant developments in media, marketing, and communication so that we remain constantly connected to society.

For internal means of communication, the Campus magazine and press newsletter allow us to share our research with the UT community, who then amplifies the news through its networks. We will work closely with the Marketing Communication Department to encourage and guide our staff and students to disseminate scientific findings, through events like TEDxTwenteU and Campus Talks videos. Communication through video will become more important with the advent of 5G and beyond. We have seen this trend in e-learning, and the benefits for science communication are clear. We also see an increased use of web-based visualizations to convey the societal need for integrated, innovative, and inclusive geo solutions.

3 Enhancing our visibility in the Netherlands. We aim to increase our visibility in the Dutch research and policy landscape in diverse ways, from international representation to local engagement. *Internationally,* we will engage more actively with the Dutch representation in majority world countries, through our existing contacts and through expansion via academic and institutional partners. *Nationally,* benefiting from the sector plans for Earth and Environmental Sciences, we will increase the joint development of scientific research projects with Dutch universities by leveraging our four themes that align with important challenges in National Research Agenda (NWA) and strengthening our position in Dutch Artificial Intelligence consortia. This will reinforce existing contacts and increase our recognition by Dutch research and advisory organizations (NWO and KNAW), both as a national center of excellence in geospatial science and as a prominent research partner on big societal issues with a spatial component. Our partnerships are not purely academic, so we will actively involve national partners in private-public partnerships, either on a 1–1 basis, i.e., a direct service with a single industrial partner, or as consortia. The UT strategic business development unit (SBD) will be pivotal in this process. We will develop stronger links with Dutch industry, in particular with companies that strengthen or use geo-information science technology. This concerns both links with relevant industrial partners as well as supporting spin-off companies. *Regionally,* we see several opportunities to transfer knowledge achieved in our capacity development in the majority world to related problems in the Twente region, such as drought monitoring, livability of urban areas and cadastral planning. We will actively engage with industrial and governmental partners in the Twente Region to identify challenges and co-develop potential solutions for regional and local problems.

4 Diversity in our funding and support for grant development. Our continued success in attracting external funding during the last few years will allow us to grow. The approximate goal is a 10% increase in staff volume in five year's time. We will strive for a balance between scientific projects like those from NWO, international collaborations in Horizon Europe programs, and contract or industrial funding. We will further strengthen our (personal) grant support program where a small but diverse group of staff will screen, advise, and strengthen research proposals and help develop a community of practice around this. We will continue to work with the University's Strategic Business Development unit to better profile the unique skills within ITC and match these with opportunities. In each profiling theme, we aim for a long-term research project where ITC takes the lead as well as several smaller grants and contributions to projects consortia led by others. We work towards at least one personal grant a year on average from the NWO (Veni-Vidi-Vici) and ERC funding instruments.

5 Investments to support our research. We will continue to invest in our suite of state-of-the-art high-tech geo labs, including the GeoScience lab (GSL), the Remote Sensing and GIS lab (RSGIS lab), the group decision room (GDR) and the Visualization and usability lab. The Big Geospatial Data Analysis portal hosted by CRIB has already 300+ users and attracted great interest within the UT and beyond including FAO, while the (semi-) controlled outdoor Living Innovation Lab at the Campus was developed with other UT faculties. These facilities are developed in line with state-of-the-art technology, society and advice from the sounding boards and user groups (see Annex S). Our *Ingenuity*-2 specifically targets strengthening our main themes and collaborations (e.g., Expertise Centre on Disaster Resilience, Geo-Health), enhancing our geolabs (e.g., UAV centre) and innovating our research methodologies (geo-citizen scientist). Through these investments we aim to go beyond the state-of-the-art and further improve our research quality and visibility which, in return, will make us an interesting network partner and be considered for funding. We will actively map the use of our facilities through their mention in research outputs and our annual year plans.

6 Integrating Open Science in our research cycles. We have initially concentrated on opening our publications and data, i.e., the last phase of the research enterprise as detailed in section 2.3. We will investigate ways to design open workflows. Details on specific goals and strategies are in the OS Strategy Plan (Annex T). Our motivation to concentrate our efforts to also open activities in earlier phases of research is that expanding OS practices and embedding them in formal training of PhDs and early-career researchers will lead to higher employability: code and data management skills are highly valued by the private sector. We will identify synergies between CRIB and OS to increase the impact of our research activities. Societal and ethical implications will be critically studied to make our work open whenever possible and closed when necessary (geoprivacy). Despite the benefits of OS, we recognize legitimate reasons for not being entirely open. For example, not all data can be released due to privacy concerns, while disclosing the author's identity during peer review can influence a referee's decision resulting in bias based on gender, affiliation, and career stage[xxxv]. We will address these issues through *situated openness,* being a way of researching, that assumes knowledge production and dissemination is *situated* within historical, political, socio-cultural, and legal relations[xxxvi]. One way of realizing situated openness in the context of data sharing is following the CARE Principles, i.e., Collective Benefit, Authority of Control, Responsibility, Ethics[xxxvii]. Annual OS plans will be compiled by the OS Officer with feedback from relevant stakeholders in the scientific and support departments.

7 Our PhD Policy and Training. A diverse, strong, and active cohort of excellent PhD candidates remains essential. To ensure this, we will continue our efforts to acquire research grants from national and international funding sources for PhD research, such as Horizon Europe and NWO. We will maintain efforts to attract candidates with their own scholarship via the graduate admission procedure (see section 4.3). PhD candidates funded by grants will be selected according to our standard recruitment procedure. Institutionally, they will continue to be embedded in TGS who takes care of the registration, intake, generic training, documentation of the qualifier defense, progress monitoring through a TSP[xxxviii] and completion of the PhD trajectory, all supported by the current *Hora Finita* information system. The procedure is also documented in the Doctoral Education Guidelines[xxxix]. We will also carefully monitor delays and provide additional support where meaningful.

We will continue to be a member of National Research School SENSE as a network and discussion platform with related research institutes with overlapping interests and ambitions and benefit from the additional training opportunities offered by

SENSE members. Together with TGS and SENSE members we will further explore the collaborative development of methodological and thematic PhD training courses that align with current developments in our field such as OS, AI, big data analytics and geo-ethics as well as join efforts on career events and links to job markets. See Annex M for PhD training program details.

Next to formal training, PhD candidates will be carefully guided in their scientific domain by a suitable supervisory team (two or three supervisors). As research problems become increasingly complex, more cross-department or cross-faculty supervision will become the practice, requiring formalization at the start of the project. Socially and academically, PhD candidates will be stimulated to participate in the ITC PhD community pITCom that organizes events at least once per year for PhD candidates independently or together with our management. For the future, pITCom will be further involved in stimulating the exchange of knowledge, skills, experiences, and research activities, both within pITCom and between scientific staff and PhD candidates. We aim to align PhD intakes with our research profile and supervision capacity.

8 Our academic culture. Our workplace values set the tone for our work culture. We reflected on our three core values through an online survey conducted in late 2020[xl]: below we include some illustrative quotes from survey respondents.

1. Inclusiveness - We recognize the importance of diversity in talent, bringing together multiple ways of approaches and analysis, respecting others, and respecting differing opinions. This fosters a strong sense integration and a sense of social safety, among staff, students, and alumni from diverse cultures and countries. *The world of ITC is the world.*

"The community feeling and collaborative environment - I haven't seen this level ever before and think that this is what ITC can be most proud of."

2. Societal relevance – We have a broad vision of the role of "geo" in society. We are societally relevant, and our capacity development mandate makes us accountable. Our long-term partnerships in countries in the majority world strengthen the capacity of individuals, organizations, and institutions to address global challenges with local actions. Our work often takes place where these challenges are most urgent and where equitable access to technology is most needed. *What we do matters.*

3. Delivering quality/excellence in geospatial science – We are a global hub for geo expertise and talent based on a forward-looking culture of innovation and integrity. We have an excellent reputation for delivering quality research and education in the geo domain which is unique because of our international outlook, our focus on less developed regions, and commitment to making high-tech solutions available to all (see Annex Q). *Spatial is special.*

"ITC has a strong research base and a wide platform for creating great professional and social networks."

Values we can still aim to improve are *flexibility, integrating different approaches, better support for personal and professional growth, and transparency,* which deserve attention in our way of working to bridge the gap between aspirations and day to

day practice. In the end, viability is served by outputs within the profiling themes, products, use, marks of recognition by our peers and societal relevance.

9 Our research integrity. Creating an open, safe, and inclusive research culture will prevent misconduct or serious breaches of research integrity. All ITC researchers will endorse the Netherlands Code of Conduct for Research Integrity based upon the Singapore Statement on Research Integrity. Both statements are applicable to anyone who does research at our Faculty and to anybody that uses research results in decision-making. At ITC, we will continuously support and promote research integrity at the faculty level and cooperate with other faculties in establishing the UT House of Integrity[xli]. We regularly organize Research Integrity Masterclasses to create awareness on integrity issues. We provide adequate supervision and mentoring, in particular for junior colleagues. The IEC will keep on playing an important role as well as our data management policy: responsible managing and sharing of research data and findings will prevent data loss, while allowing reproducibility and verification of research findings.

We see research integrity as a precondition for being a trusted organization for funding and in research networks and in that sense strengthening our viability.

"ITC's ability to do research and education for an international development mission. Unlike any other university faculty (maybe in the world) it is in its core."

10 Our policy to guide and select talent for diverse research units. We aim to educate the research leaders of the future. Our research leaders act as figureheads, and although all are different, they contribute to the three pillars of academic integrity. We have a very strong *we-feeling* because we value team work over individual work. We already have a few formal instruments in place to steer this; for instance, we appointed a Horizon Europe proposal officer, but this will be the focus of the years to come.

We recognize and reward people formally by promotions through the UFO[xlii] or TT system[xliii] and informally by valuing their efforts. We offer excellent working conditions for researchers, including high quality labs and other research support facilities, and possibilities to travel and attend conferences. Through recognition and rewarding discussions we identify and implement diverse career paths. Future work is to modernize the UFO and TT system with inputs from the OS Strategy Plan to better facilitate their implementation, including personal development plans and mentoring schemes for coherent career paths for all. This should align with the changing academic culture and diverse career tracks. We will also develop instruments for developing and rewarding teams, aligned with our ambition to nurture collaborations within our profiling themes.

Diversity is a major part of our selection criteria for new staff, appraisals, and promotion. Our understanding of diversity goes beyond gender diversity and considers diversity in cultural backgrounds and domain expertise. Our goal of fostering diversity is well reflected in our PhD community and at the Assistant and Associate Professor level, but there is room for improvement at the professor and higher management levels. We will pay attention to this in future recruitment and changes in management positions. We see, however, a positive trend in our progress and we will develop strategies to stimulate diversity and inclusiveness in all research activities, thus also when forming research collaborations and consortia.

6 LIST OF ACRONYMS

4TU	4TU.Federation	MINERVA	Microwaves for a New Era of Remote Sensing of Vegetation for Agricultural Monitoring
AFRIGEO	The African Group on Earth Observations	MSc	Master of Science
AI	Artificial Intelligence	NASA	National Aeronautics and Space Administration
CAHMDA-VII	7th International Workshop on Catchment-scale Hydrological Modelling and Data Assimilation	NFP	European Environment Agency
CBD	UN Convention on Biological Diversity	NGO	Non-Governmental Organization
CRIB	Laboratory on Big Data/Big Geodata Service Portal	NRS	Natural Resource Sciences Dept.
CSC	Chinese Scholarship Council	NSO	Netherland's Space Office
CSSTEAP	Centre for Space Science and Technology Education in Asia and the Pacific	Nuffic	The Dutch Organization for Internationalization in Education
DANS	Data Archiving and Networked Services	NWA	Dutch Research Agenda
DMP	Data Management Plans	NWO	Dutch Research Council
DSI	Digital Society Institute	NWO-WOTRO	Cross-Domain Initiative, Science for Global Development
EC	European Commission	NWP	Netherlands Water Partnerships
ECTS	European Credit (Transfer System)	OA	Open Access
eDNA	Environmental DNA	OS	Open Science
EENSAT	Ethiopian Educational Network to Support Agricultural Transformation	PBL	Planbureau voor de Leefomgeving/Environmental Assessment Agency
ENS	NWO Domain Science	PGM	Urban and Regional Planning and Geo-Information Management Dept.
EO	Earth Observation	P-NUT	PhD Network at the University of Twente
EOS	Earth Observation Science Dept.	PPP	Public-Private Partners
ERC	European Research Council	RDM	Research Data Management
ERDT	Engineering Research and Development for Technology	RIVM	National Institute for Public Health and the Environment, Netherlands
ESA	Earth Systems Analysis Dept.	RMIT	Royal Melbourne Institute of Technology
ESA	European Space Agency	RS	Remote Sensing
ESD	Earth Science Division	RSGIS	Remote Sensing and GIS Lab
FAO	Food and Agriculture Organization of the United Nations	SACC	Student Affairs Coaching and Counselling Department
FIG	International Federation of Surveyors	SDGs	United Nations Sustainable Development Goals
FTE	Full-Time Equivalent	SDI	Strategic Defense Initiative
G4AW	Geodata for Agriculture and Water	SENSE	Research School for Socio-Economic and Natural Sciences of the Environment

GDR	Group Decision Room	SEP	Standard Evaluation Protocol
GEO	Group on Earth observations	STW	Stichting Technische Wetenschappen
GEO LDN	Group on Earth Observations Land Degradation Neutrality Initiative	SWOT	Strengths, Weaknesses, Opportunities and Threats
GeoAI	Geospatial Artificial Intelligence	TAS	Time Accounting System
GEOBON	Group on Earth Observations Biodiversity Observation Network	TGS	Twente Graduate School
GEOGLAM	Group on Earth Observations Global Agricultural Monitoring Initiative	TSP	Training and Supervision Plan
GeoNAREM	Geo-Information for Natural Resources and Environmental Management	TT	Tenure Track
GIP	Geo-Information Processing Dept.	TTW	Toegepaste en Technische Wetenschappen
GIS	Geographic Information System	UAV	Unmanned Aerial Vehicles
GLTN	Global Land Tool Network	UD	Universitair docent
GSL	Geoscience Lab	UFO	Universitair Functieordenen
H2020	Horizon 2020	UHD	Universitair hoofddocent
IBM	International Business Machines Corporation	UNFCCC	United Nations Framework Convention on Climate Change
ICA	International Cartographic Association	UN-GGIM	UN Statistics Division
IEC	ITC Ethics Committee	UN-Habitat	United Nations Human Settlements Program
INPE	National Institute for Space Research, Brazil	UN-IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	The Intergovernmental Panel on Climate Change	UNISDR	UN Office for Disaster Risk Reduction
ISPRS	International Society for Photogrammetry and Remote Sensing	UT	University of Twente
ITC	Faculty of Geo-Information Science and Earth Observation of the University of Twente	VSNU	Association of Universities in the Netherland
JRC	Joint Research Centre	WaPOR	FAO portal to monitor Water Productivity through Open Access of Remotely sensed derived data
KIC	Knowledge and Innovation Convenant	WFP	World Food Program
KNMI	Koninklijk Nederlands Meteorologisch Instituut/Royal Netherlands Meteorological Institute	WHO	World Health Organization
KNUST	Kwame Nkrumah University of Science and Technology	WHW	Wet op het hoger onderwijs en wetenschappelijk onderzoek
MESA+	Nanotechnology Research Institute	WRS	Water Resources Sciences Dept.
SENSE	Research School for Socio-Economic and Natural Sciences of the Environment	ZEF	Zentrum für Entwicklungsforschung, University of Bonn
		SDI	Strategic Defense Initiative

7 LIST OF ANNEXES

For access to these resources, contact the ITC research coordinator

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8 NOTES

[i] This is a more descriptive name for lower income countries, the global south, or developing countries. It recognises that these countries represent the majority of the world's population; this name recognizes the social and economic status of the countries.

[ii] An institution is a socio-technological system within which people and organizations function. Institutional strengthening therefore encompasses any process through which organizations and other societal actors increase their awareness of and their capacity to develop, access, or use geospatial tools, products, and services to meet "their needs" according to systems of rules that structure their behaviour and social interactions.

[iii] https://sdgs.un.org/goals

[iv] The Paris Agreement (2015) of the United Nations Framework Convention on Climate Change (UNFCCC)

[v] UN Habitat focusing on integrating sustainable development and environmental challenges in the urban agenda vision

[vi] The Sendai Framework for Disaster Risk Reduction

[vii] The European Commission's (EC) H2020 research program

[viii] The Netherlands Space Office's (NSO) Geodata for Agriculture and Water program (G4AW)

[ix] The European Space Agency's (ESA) Copernicus program

[x] National Aeronautics and Space Administration's (NASA) Earth Science Division (ESD)

[xi] https://www.utwente.nl/en/education/tgs/

[xii] SENSE: Research School for Socio-Economic and Natural Sciences of the Environment

[xiii] DANS: https://easy.dans.knaw.nl/ui/home

[xiv] We chose for DANS Easy because it is a national, long-term (>50 year) repository that allows research data to be archived either publicly or with restricted access (e.g., in case of licenses, or privacy reasons).

[xv] https://www.coalition-s.org/#:~:text=Plan%20S%20is%20an%20initiative%20for%20Open%20Access,international%20consortium%20of%20research%20funding%20and%20performing%20organisations.

[xvi] https://www.utwente.nl/en/organisation/about/integrity/news/2020/2/515102/house-of-integrity

[xviii] https://vsnu.nl/en_GB/job_classification_ufo.html

[xix] SOURCE: Pure all publications from 2014 till 2020, total amount: 3715 records.

[xx] Search term: "Remote sensing" (dimensions uses a fuzzy search) in 'Free text, full data'.

Filters: Publication year (2014-2020) and Research Organization (University of Twente).

[xxi] GEO (earthobservations.org)

[xxii] https://www.itc.nl/research/study-for-phd/

[xxiii] https://www.itc.nl/research/study-for-phd/documents/tsp-explanation.pdf

[xxiv] https://www.itc.nl/intranet/research/PhD%20dissertation%20requirements%20ITC.pdf

[xxv] On 17 October there was a special occasion at the Faculty Bureau: the data set of PhD candidate Irene Garcia-Martí was the 100,000th data set deposited in DANS EASY: https://www.itc.nl/news/2019/10/58210/100000th-data-set-deposited-in-dans-easy-by-irene-garcia-marti

[xxvi] https://www.utwente.nl/en/organisation/about/integrity/news/2020/2/515102/house-of-integrity

[xxvii] https://www.itc.nl/about-itc/organization/boards-councils/academic-board/

[xxviii] Mission and vision of ITC

[xxix] https://www.utwente.nl/en/research/vision/

[xxx] https://www.servirglobal.net

[xxxi] https://www.stars-project.org/en/; https://www.itc.nl/about-itc/organization/scientific-departments/water-resources/earth-observation-sites/naivasha-masaimara-kenya/

[xxxii] https://www.itc.nl/news/2021/6/1094358/ut-campus-will-have-a-living-innovation-lab

[xxxiii] https://innovationorigins.com/nl/onderzoek-naar-luchtwegklachten-eindhovense-kinderen/

[xxxiv] ANP, Het Communicatievak in 2025

[xxxv] Tennant, J.P. & Ross-Hellauer, T (2020). The limitations to our understanding of peer review. *Res Integr Peer Rev* 5, 6. DOI:https://doi.org/10.1186/s41073-020-00092-1

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[xxxviii] https://www.utwente.nl/en/education/tgs/currentcandidates/phd/downloads/tspform-horafinita.pdf

[xxxix] https://www.utwente.nl/en/education/tgs/currentcandidates/phd/downloads/doctoral-education-guidelines.pdf

[xl] 253 members of our community contributed: Academic staff (70); support staff (38); PhD candidates (31); MSc students (63); PhD alumni (36); MSc alumni (60). Respondents have been associated with ITC for different periods: < 6 years (144); 6-20 years (79); > 20 years (30).

[xli] https://www.utwente.nl/en/organisation/about/integrity/news/2020/2/515102/house-of-integrity

[xlii] https://www.utwente.nl/en/hr/terms-of-employment/ufo/

[xliii] https://www.itc.nl/tenuretrack/

[xliv] https://www.vsnu.nl/files/documenten/Nieuwsberichten/Een_gezonde_praktijk_in_het_Nederlandse_promotiestelsel.pdf

[xlv] https://www.itc.nl/research/evaluation/

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